IEA WIND ENERGY
Annual Report 2007

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

July 2008

ISBN 0-9786383-2-8

Front cover: A view of several wind farms located in the Sierra de Guerinda in Navarra, Spain. These wind farms are owned by Acciona Energia and most of the turbines are the model G-47 660 kW from Gamesa Eolica. Wind farms in such as these supplied nearly 10% of Spain's electrical demand in 2007. Photo courtesy of Gamesa Eolica.

Foreword

The thirtieth IEA Wind Energy Annual Report reviews the progress during 2007 of the activities in the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems under the auspices of the International Energy Agency (IEA)*. 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 2007, 26 countries participated in more than 40 implementing agreements of the IEA. OECD Member countries, non-Member countries, and international organisations may participate.

The IEA Wind implementing agreement and its program of work is a collaborative venture among 24 contracting parties from 20 Member Countries, the European Commission, and the European Wind Energy Association. This IEA Wind Energy Annual Report for 2007 is published by PWT Communications in Boulder, Colorado, United States, on behalf of the IEA Wind Executive Committee. It was edited by P. Weis-Taylor, with contributions from experts in IEA and in participating organizations from Australia, Austria, Canada, Denmark, the European Commission, the European Wind Energy Association, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, the Republic of Korea, Mexico, the Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

Ana ESTANQUEIRO
Chair of the Executive Committee
2006-2008

Patricia WEIS-TAYLOR
Secretary to the Executive Committee
1998-present

* 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.

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www.ieawind.org

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Ana Estanqueiro,
Chair of the Executive Committee, 2006 to 2008.

Welcome to the 2007 IEA Wind report! This year the IEA Wind agreement celebrated 30 years of international cooperation on research, development, and deployment of wind energy systems. We also celebrate what is happening in this remarkable energy sector; wind energy is the fastest-growing energy technology and it is being deployed all over the world, from the European Alps to South American Patagonia, and from China to the United States. Involvement includes the most developed countries in the world as well as countries for whom using wind energy makes the difference between having electricity, or not.

From many perspectives, 2007 was an uncommon year. The United States, which lead the first burst of wind energy deployment in the 1980s and then halted for two decades, has shown how fast a country can change direction and suddenly have the fastest growing wind capacity in the world. In other countries, such as China and India, wind power is joining more conventional forms of generating electricity to meet their needs for immense increases in energy. Countries such as Germany, the Netherlands, and Sweden began their move towards offshore wind and the world just surpassed 93 GW of wind capacity.

The IEA Wind activity was as intense as the deployment of this sector and is recorded in the chapters of this Annual Report. Task 11 organized five Experts Meetings and closed the year with a workshop to develop Long Term Research Needs. This meeting assembled the heads of the national wind programs and leading laboratories and institutes worldwide. New IEA Wind Tasks on the Cost of Wind Energy (Task 26), Safety Labeling of Small Wind Turbines (Task 27), and Social Acceptance of Wind Energy Projects (Task 28) began their activities. Two important IEA Wind Tasks completed their work: Task 20 on aerodynamics and Task 21 on dynamic models of wind farms for power systems. Other Tasks continued their contributions to wind energy by providing needed information and analysis tools. Task 19 (cold climate), Tasks 23 (offshore), Task 24 (wind/hydro integration), and Task 25 (wind and power system integration) produced important results that appeared in significant journals and conferences.

To promote cooperation with the G8 and the so called "plus five" countries, IEA Wind participated in the IEA-sponsored NEET (Network of Expertise on Energy Technologies) workshops held in Brazil, China, and South Africa. We hope to welcome these countries into the IEA Wind Agreement. IEA Wind also reinforced links, contacts, and cooperation with other IEA Implementing Agreements: DSM, ENARD, Hydrogen, RETD, and others.

To increase the visibility of IEA Wind and facilitate communication with wind energy actors, we developed a new corporate image, which is evident in this Annual Report and includes an updated logo for IEA Wind.

It was not an easy year for the wind energy community. The strong and steady deployment resulted from the dedicated efforts (and hard work!) of us all. At IEA Wind we smile and feel proud of our countries becoming greener. When we pass by a new wind power plant, we also feel very proud of the work we have done this year. I take this opportunity as Chair to thank all Executive Committee Members, Alternates, Operating Agents, and Collaborators for their commitment and effort toward IEA Wind and for the contribution we all gave for a safer and better future.

Ana Estanqueiro

Chair of the Executive Committee, 2006 to 2008

1.0 Introduction

In 2007, cumulative installed wind power capacity increased more than 26% worldwide and 21% in the member countries of the IEA Wind Implementing Agreement. In the IEA Wind member countries, more than 13,315 MW was added in 2007 for a total of close to 75 GW of generating capacity. Even more encouraging, electrical production from wind increased 31% in IEA Wind countries to about 155 TWh (Table 1). This electrical production from wind met 1.6% of the total electrical demand in the reporting IEA Wind member countries—up from 1.42% in 2006. The percentage contribution from wind is growing steadily even though electrical demand is also growing in many of the countries. Electrical output from wind in the IEA Wind member countries was more than enough to cover the total electricity consumption of Sweden.

At the close of 2007, 80% of the nearly 94 GW (Table 2) of worldwide wind generating capacity was operating in the IEA Wind member countries. Located in Europe, North America, Asia, and the Pacific Region (1), the member countries are sharing information and research efforts to increase the contribution of wind energy to their electrical generation mix. They are also reaching out to other countries to join this co-operation.

This Executive Summary of the *2007 IEA Wind Annual Report* synthesizes the information presented for 2007 by the IEA Wind member countries, the European Commission, and the European Wind Energy Association (Chapters 11 through 30) and in the reports of the Research Tasks (Chapters 2 through 10). As background for 2007, data from the past 12 years as reported in documents of IEA Wind (3, 4, and 5) are also included. In this 2007 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.

2.0 Progress Toward National Objectives

2.1 Wind generation capacity

The dramatic increase in electrical generation capacity and output from wind in the IEA Wind member countries can be seen in Figure 1. Capacity has increased from less than 5 GW in 1995 to nearly 75 GW in 2007. In 2007, the member countries added more than 13 GW of new wind generating capacity, and much more is being planned for 2008 and beyond. More than half of the countries added more than 100 MW of new capacity, and three countries for the second year in a row added more than a gigawatt each of new capacity: the United States (5,329 MW), Spain (3,522), and Germany (1,667 MW) (Table 3).

In addition, Canada, Italy, Portugal, and the United Kingdom added 300 MW or more. Total generating capacities of each country varied greatly, from Germany with 22,247 MW to Switzerland with about 12 MW. In the United States, wind energy capacity grew 46% in 2007 and accounted for more than one third of that nation's new electrical generation for the year. Looking regionally, in Europe wind power installations alone made up 40% of new power

Table 1 Key Statistics of IEA Wind Member Countries 2007		
	2006	2007
Total installed capacity	61.855 GW	74.844 GW
Total offshore wind capacity	891 MW	1,125 MW
Total new wind capacity installed	10,463 MW	13,315 MW
Annual increase in capacity from previous year	22%	21%
Total annual output from wind	118 TWh/yr	155 TWh/yr
Wind generation as % of national electric demand	1.42%	1.6%

Table 2 Worldwide Installed Capacity for 2007	
IEA Wind Members*	
Country	MW
Germany	22,247
United States	16,904
Spain	15,145
Denmark	3,124
Italy	2,726
United Kingdom	2,390
Portugal	2,125
Canada	1,845
Netherlands	1,745
Japan	1,538
Austria	982
Greece	873
Australia	824
Ireland	803
Sweden	788
Norway	385
Republic of Korea	193
Finland	110
Mexico	85
Switzerland	12
Total	74,844
Rest of World**	
Country	MW
India	7,844
China	5,906
France	2,370
New Zealand	322
Belgium	287
Poland	280
Brazil	247
Egypt	230
Taiwan	224
Turkey	192
Morocco	124
Ukraine	86
Costa Rica	74
Iran	67
Hungary	65
Bulgaria	62
Estonia	58
Caribbean	57
Czech Republic	56
Lithuania	52
Luxembourg	35
Argentina	30
Latvia	27
Philippines	25
Pacific Islands	24
Tunisia	20
Colombia	20
Chile	20
Croatia	17
Reunion (France)	10
Others (<10 MW)	52
Total	18,883
Grand Total	**93,710**

installations and grew more than any other power-generating technology there.

Growth in six other countries was also well above the 21% average for the IEA Wind group: Canada (26%), Finland (28%), Italy (28%), Portugal (24%), Spain (30%), and Sweden (38%) (Table 4).

Many countries report significant amounts of capacity in the planning stages including planning applications submitted, successful acquisition of land leases, projects under construction, and projects waiting final connection to the grid. For example, 47 new projects were approved through the planning system in the UK totaling over 1,888 MW. These projects brought the total UK capacity (approved but not yet under construction) to 5,322 MW.

Table 3 National Statistics of the IEA Wind Member Countries for 2007

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 (GWh/yr)	National electricity demand (TWh/yr)	% of national electricity demand from wind*
Australia	824	0	7	564	2,000	2,526	220.0	1.1%
Austria**	982		17					
Canada	1,845	0	386	1,400	1,320	4,340	***565.0***	0.8%
Denmark	3,124	423	-11.5	5,212	1,280	7,171	36.0	19.9%
Finland	110	14	24	107	2,160	188	90.0	0.2%
Germany	22,247	7	1,667	19,460	1,888	39,500	617.2	6.4%
Greece	873	0	125	1,118	1,850	2,328	51.0	4.6%
Ireland	803	25	59	686	1,900	1,785	26.0	6.9%
Italy	2,726	0	603	2,943	1,638	4,074	340.0	1.2%
Japan	1,538	11	229	1,331	1,156	2,207	889.4	0.2%
RP of Korea	193	0	18	127	1,417	399	403.1	0.1%
Mexico	85	0	0	0	NA	248	206.7	0.1%
Netherlands	1,745	108	209	1,847	1,787	3,400	115.6	2.9%
Norway	385	0	60	185	2,727	899	127.0	0.7%
Portugal	2,125	0	427	1,132	1,979	4,036	50.0	8.1%
Spain	15,145	0	3,522	>16,000	1,623	27,026	276.8	9.8%
Sweden	788	133	217	958	1,700	1,429	150.0	1.0%
Switzerland	12	0	0	34	NA	16	58.0	0.03%
United Kingdom	2,390	404	427	1,952	2,060	***5,381***	406.0	1.3%
United States	16,904	0	5,329		1,650	48,000	4,800.0	1.0%
Totals	74,844	1,125	13,315	55,056	1,773	154,953	9,428	1.64%

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

** Numbers from Wind Power Monthly

Bold italic= estimated vale

Offshore generating capacity also increased 26% in the IEA Wind countries reporting such installations. And much more offshore capacity is in the planning stages. In Sweden, the 110-MW Lillgrund wind farm was completed in 2007, and the 30-MW wind farm will be completed in lake Vänern in 2008. In other countries, a number of other offshore sites have already obtained permits or are in the permitting process (Denmark, Germany, Ireland, Japan, Korea, Netherlands, and the UK).

Another trend that affected electricity production is repowering—the replacement of older, smaller turbines with fewer, larger turbines representing the state of the art in power production. Repowering is expected to increase in years ahead. In the Netherlands, 17 turbines with a total capacity of 8.4 MW were replaced with 17 turbines with a total capacity of 24.5 MW. The net repowering effect was an increase of 16 MW. In Germany this year, 108 old turbines totaling 41 MW of capacity were replaced by 45 new turbines with 103 MW. This type of activity represented about 6% of new wind energy installations for the year. A large repowering project was started on Fehmarn Island in the Baltic Sea. In this project, 170 different turbine types with a total power of 45 MW were removed and will be replaced by 68 Enercon E 70 turbines adding up to 156.4 MW. In 2007, Denmark reduced its generation capacity for the first time, removing 14.1 MW and installing 2.6 MW of new wind generation.

Other countries with low increases in capacity in 2007 are poised for huge increases in the coming years. Australia's government plan, 20% by 2020, will increase the national Mandatory Renewable Energy Target 9,500 GWh to 45,000 GWh in 2020. This will require approximately 10,000 MW of renewables capacity.

Increased interest in small wind systems (less than 40 kW) was reported in several countries (Canada, Ireland, Italy, Portugal, Spain, the United Kingdom, and the United States). In the United States, the small wind turbine (defined as a wind turbine with a capacity rating of 100 kW or less) industry grew by almost 20% in 2007. The industry added 9.7 MW of new capacity, bringing the total small wind capacity to more than 55 MW. More than 9,000 units were sold for 42 million USD, and 98% of the units were produced in the United States. The phenomenon of many small wind turbines and small companies that make and market them presents challenges to policymakers that are being addressed through certification and testing programs. In response to member countries, IEA Wind approved a new research task in 2007 on quality labeling of small wind turbines.

2.2 Contribution to electrical demand

Total electrical production from wind energy in the IEA Wind member countries has increased from less than 10 TWh in 1995 to more than 155 TWh in 2007 (Figure 1 and Table 3). The contribution from wind energy to the combined electricity demand of the member countries has increased from under 0.2% overall in 1995 to 1.64% in 2007. Within the member countries, contribution to national electrical demand varied from under 1% in several countries to nearly 20% in Denmark. In five countries, the wind energy contribution to national electrical demand exceeded 5%, and twelve countries exceeded the 1% mark (Table 3). Greece is approaching 5%, with 4.6% of its electricity demand satisfied by wind energy in 2007. In the United States, as a result of record growth the past two years, wind energy for the first time supplied 1% of that country's electrical demand in 2007. And in the states of Minnesota and Iowa, nearly 7.5% of the electricity consumed was generated by wind power.

Wind energy is becoming a significant source of new generation to meet peak demand. For example, in Spain over the year, wind energy contributed 10% of the total electrical demand and was the fourth largest contributing technology in the system after coal power plants (25% of demand), natural gas (24%), and nuclear energy (20%). When hourly demand in Spain rose to 45 GW on December 18, 2007, wind energy generated 6 GW to help meet that demand. On several occasions in Spain, wind energy has covered 30% of the hourly demand, and for several days it supplied more than 20% of the daily demand for electricity. In the Netherlands, the contribution of wind electricity grew from 2.35% in 2006 to 2.94% of total electricity consumption, making wind the main source of renewable electricity in the Netherlands. Even though Denmark did not add wind power capacity in 2007, wind energy still met 19.9% of total electrical demand for the year.

Table 4 Increase in Wind Energy from End of 2006 to End of 2007		
Country	Capacity added in 2007	% Wind capacity increase
United States	5,329	46%
Spain	3,522	30%
Germany	1,667	8%
Italy	603	28%
Portugal	427	24%
United Kingdom	427	22%
Canada	385	26%
Japan	234	14.9%
Sweden	217	38%
Netherlands	209	12%
Greece	125	17%
Norway	60	18%
Ireland	59	8%
Finland	24	28%
Republic of Korea	18	10%
Austria	17	2%
Australia	7	1%
Mexico	0	0%
Switzerland	0	0%
Denmark	-12	-0.4%

In the United States, the wind capacity operating in 2007 generated 48 TWh/yr—enough to provide power for 4.3 million U.S. homes and displace approximately 30 million tons of CO_2 that would have been emitted by traditional resources.

In Europe overall, total wind power capacity operating by the end of 2007 will produce 119 TWh, or 3.7% of EU power demand in an average wind year, and will avoid emissions of about 90 million tons of CO_2 annually. In 2000, less than 0.9% of EU electricity demand was met by wind power.

Some countries track production in relation to the wind index, a local indicator of the energy in the wind for a year compared with the average year for that locality. Several countries mentioned that 2007 was a better wind year than 2006, leading to higher wind energy production (Denmark, Germany, and Italy).

2.3 National targets

All IEA Wind member countries recognize that renewable energy in general and wind and solar energy in particular offer great potential to reduce overall carbon emissions of the power industry. In addition, reducing the cost of electricity and decreasing reliance on imported fuels are justifications for several national targets. National objectives or targets are used to define goals, develop policies, measure progress, and revise policies and goals as needed along the way.

An important goal set for the European market for wind energy technology has been EU framework legislation combined with legislation at the national level aimed at reducing barriers to the development of wind energy and other renewables. The EU target is to have renewable energy sources (RES) provide 20% of EU electricity consumption by 2010. This target was established by the Renewable Electricity

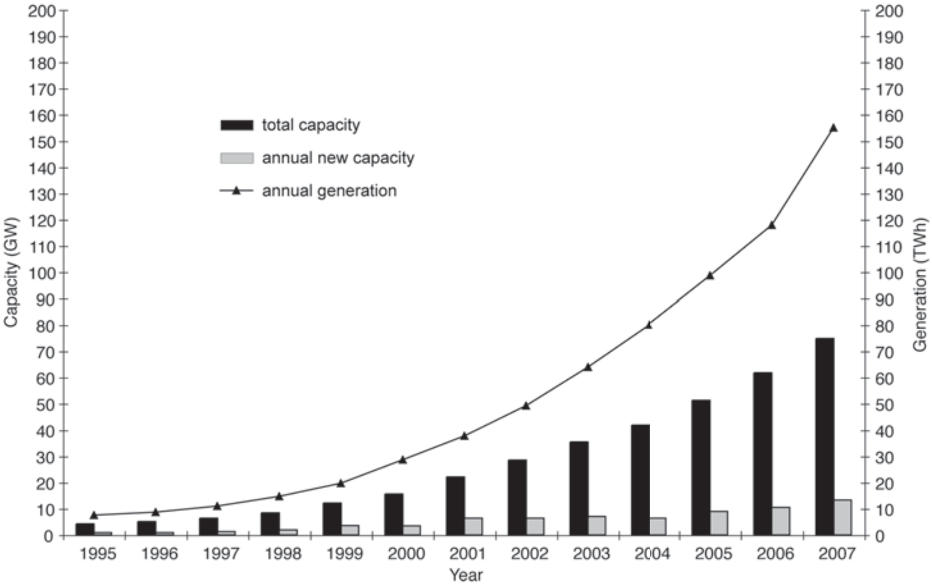

Figure 1 Annual installed capacity, cumulative installed capacity, and annual generation as reported by the IEA Wind member countries, 1995–2007.

Directive (77/2001/EC), which sets out differentiated national indicative targets for each member state.

Growth in 2007 has brought wind power capacity near or above national targets in several countries. In Italy, a new annual record for installed wind power capacity brought Italy's total online capacity to more than the 2,500-MW target established for wind power in the 1999 National White Paper for Exploitation of Renewable Energy Sources.

As targets are met, new targets are established to keep RES development moving forward. In 2007, Germany exceeded the EU target (12.5% contribution of all renewables by 2010) with a 14.2% contribution of renewables. New targets were therefore set in 2007. By 2020, the government aims to increase the proportion of primary energy consumption generated from renewables to 16%. Eventually, the proportion of electricity consumption from renewable sources will be increased to 25 to 30% and then continually expanded.

In Spain the national energy objective implies reaching a capacity of 20,155 MW of wind energy by the end of 2010. With the 3,522 MW installed in 2007, an important step was taken to achieve that objective. In fact, growth of only 1,700 MW/yr will meet the final objective. Now, the industry considers the 20,155-MW target well within reach, and there are discussions to raise the target to 40,000 MW by 2020.

Ambitious targets in turn have prompted new legislation to improve the chances of achieving them. In Germany, medium- and long-term targets for offshore expansion in the German seas were set in 2002: 1,500 MW by 2011 and up to 25,000 MW by 2030. The Infrastructure Acceleration Act took steps to achieving this by obliging transmission system operators to pay for and install the grid connection from the onshore grid access point to the offshore wind farm. In 2007, the draft bill of the revised Renewable Energy Sources Act was submitted by the government to the parliament with a considerable increased feed-in tariff for offshore wind energy.

Setting national capacity targets in response to EU directives or government plans allows evaluation of policies and industrial capacity necessary to achieve the goal. For example, in Italy to achieve the target of energy expected from wind in 2020, or 22.6 TWh, the wind sector must add at least 9,300 MW, of which 2,000 MW will likely be offshore, in 13 years. This translates to an average annual growth of something more than 700 MW. Based on the 603 MW Italy added in 2007, the 700 MW can now be anticipated for 2008 and beyond.

According to an initiative proposed by the U.S. president, areas with good wind resources have the potential to supply up to 20% of the total U.S. electricity demand. In response, a collaborative effort in 2007 by industry and government concluded that producing 20% of the nation's electricity from wind technology is technically feasible by 2030. It would require total wind generating capacity to increase from the current 16.9 GW to more than 300 GW. To achieve this target by 2030, capacity will need to increase by 16 GW/yr after an initial 10-year ramp-up period.

(See Table 1 of Chapters 10–29 for specific national targets.)

2.4 Issues affecting growth

IEA Wind member countries report several key issues affecting increased deployment of wind energy. Work within the countries and co-operative research tasks (Annexes) within the IEA Wind Implementing Agreement are under way to address some of these issues. (See also Section 5.0, R, D&D Activities of each country chapter.)

Countries experiencing rapid growth attributed it to favorable financial incentives and regulatory environments that allowed for efficient approval and construction of projects.

Slower growth was often attributed to uncertainty about the future of incentives, lack of sufficient incentives, or difficult regulatory issues that prevented timely approval of projects.

2.4.1 Grid capacity, integration, and transmission

Access to the grid is essential for increasing wind energy capacity. Today's grids are mostly the result of previous planning, and are adapted to the needs of an electricity system made up of centralized, large-scale power plants. The move toward smaller and more decentralized generation plants thus requires adaptation of the grid; also, the high growth rates of electricity demand in several IEA Wind member countries is challenging existing grid capacity.

In Portugal, the forecast of 20% wind energy penetration will require careful design of the Portuguese transmission system, which is less interconnected than systems in central European countries. Studies of the issue indicated that adding reversible (pumped) hydropower capacity would not only contribute to the national renewable energy goals, but would also enable easy wind power integration. In response, the Portuguese government defined ten new hydroelectric power plants for deployment, and seven of them with installed capacity of 807 MW will be reversible.

Integrating wind energy and hydropower renewable resources for the benefit of consumers and the electrical generation system is appealing, and its technical and economic issues have been explored in IEA Wind Task 24, Integration of wind and hydropower systems. Expected outcomes of this work to be completed in 2008 include the identification of practical wind/hydro system configurations and an understanding of the costs, benefits, barriers, and opportunities when integrating wind and hydropower systems.

The impact of wind energy on the power system is being addressed by work in IEA Wind Task 21, Dynamic models of wind farms for power systems studies. Participating countries have worked to develop and validate wind farm models that are suitable for evaluating power system dynamics and transient stability. The final report, released in 2007, provides an overview of the available wind farm models and presents a systematic approach for model benchmark testing. Additional modeling work will be carried out under IEA Wind Task 25, Design and operation of power systems with large amounts of wind power.

In Spain, grid management has been reformed and every wind farm is assigned to a control center, which makes the feed-in more transparent. With a joint effort between the system operators and the wind energy sector, wind parks will continue to increase their contribution to meeting electrical demand. The industrial sector and the system operators have implemented the new grid code (P.O.12.3), and the impact of wind energy on system operation has been smaller than expected. The regulation systems have been able to regulate and optimize system management with very low costs.

System operation impacts from wind power are a concern of transmission system operators. Responding to the need to explore this issue, IEA Wind Task 25 Design and operation of power systems with large amounts of wind power began work in 2005. In Finland, an analysis completed in 2007 in conjunction with IEA Wind Task 25 estimated the balance settlement costs for wind power in Finland. The estimated cost for the Finnish power system due to day-ahead forecast errors is less than 0.3 €/MWh for 500 MW wind power and rises to 1.5 €/MWh for 4,000 MW wind power (10% wind penetration). In a second analysis, grid reinforcement due to wind power in Finland was estimated to be around 50 €/kW for 5% to 10% wind penetration (2,000 to 4,000 MW wind).

Transmitting electricity from offshore wind farms has a special set of issues that are being explored in Task 23 Offshore wind technology development. Offshore cable connections, financing, and technical challenges of high seas and deep water are being addressed (as well as other issues with offshore deployment of wind turbines).

2.4.2 Planning issues and public resistance

Planning issues were mentioned as both benefiting wind development (when smooth) or obstructing projects. Wind development benefits when regional and state plans incorporate wind energy development (Australia, Canada, Finland, and the United States).

The Australian wind energy industry focused on managing and improving the community consultation processes in 2007 and launched Certified Wind Farms Australia (CW-FA), the world's first wind farm accreditation scheme. The aim of the scheme is to promote the sensitive and responsible uptake of wind energy in Australia by ensuring that the development and operation of wind farm projects is consistent with best practice standards.

Complex requirements in plans can obstruct wind development. In Sweden, for example, several permits are required for a single wind project application, according to the Environmental Code, the Planning and Building Act, the Electricity Act, and sometimes other regulations. This results in several different trials, even though it essentially is the same assessment that is made, with possible multiple appeals and long delays from first application until permits are obtained. The government has therefore appointed a review panel to look over the legislative process and make suggestions for changes. The panel will put forward its suggestions at the end of 2008.

In Italy, a theoretical potential for wind energy of 12 GW was determined by an assessment conducted in 2007. This growth from the current 2.7 GW is conditional on many issues. The most important is that all new plants are subject to political and administrative authorizations which are, in turn, often affected by problems of acceptance by local communities. Italy sees streamlining the authorization process, and, above all, improving its efficiency, as essential for increasing wind energy capacity in Italy.

It is recognised that wind turbines can adversely affect the aviation domain. The UK has hosted an IEA Wind Task 11 Experts Meeting on the subject and has set up the Wind Energy, Defence and Civil Aviation Interests Working Group to investigate the issue and improve understanding between the aviation and wind energy industries.

In response to growing concerns about public acceptance of wind energy development, IEA Wind Task 11 held a Topical Experts Meeting on the subject in 2007. The result was a new Task 28 Social acceptance of wind power projects with Switzerland as the Operating Agent. The work will collect case studies of successful community and market engagement and develop and publicize successful strategies for conducting wind power development.

2.4.3 Complex terrain and local environment

Complex terrain and special local conditions such as icing or severe lightning pose challenges for wind turbine design and installation of wind projects in some countries including Japan, and Korea. For example, participants in Task 19, Wind energy in cold climates, work to advance turbine designs that can withstand icing and loading due to increased air density. In Japan, standards are being developed for a J-class turbine that can withstand typhoon-force winds and high-energy lightning strikes that have damaged turbines there.

2.4.4 Other issues

The low cost of competing conventional energy, the lapsing of incentive schemes, and the shortage of wind turbine supply have been cited as obstacles to more rapid wind development.

3.0 Benefits to National Economy

In addition to saving costs of imported fuel and reducing CO_2 emissions, IEA Wind member countries recognize the benefits to their national economies from wind energy such as regional development activities, employment, exports, etc.

The Finnish manufacturing industry has a group to promote technology development and to export wind technology. This group estimated the benefit to the national economy in its roadmap for wind power technology. According to the calculations, investing a total of 220 million € for wind energy from 2006 to 2020 could raise annual wind technology exports from 200 million € to 1,400 million €/yr by 2020, create 18,000 new jobs, and result in a CO_2 reduction of 7 million tons during those years (10 TWh total).

In Spain, wind power has lowered CO_2 emissions by about 18 million tons just during 2007 and saved up to 50 million tons of conventional fuels. Over the 2005–2010 period, it is estimated that more than 127 million tons of CO_2 emissions will be avoided thanks to wind energy generation in Spain. The new National Plan of Assignations 2008–2012 will mean wind generation will save more than 400 million €, assuming an emission rights price of 20 € per ton.

3.1 Market characteristics

3.1.1 Economic contribution of the wind sector

The economic impact of wind energy development is reported in various ways by the IEA Wind member countries (Table 5). One measure, sometimes referred to as economic turnover or contribution to gross domestic product, is the value of all economic activity related to such development. It includes payments to labor, cost of materials for manufacture and installation, transportation, sales for export, and value of electricity generated. Other values reported include industrial activity, construction, and value of exports. Many countries are estimating the number of jobs created by wind energy manufacturing, development, and operation.

In Germany, harbor and shipyard sites such as Bremerhaven, Cuxhaven, and Emden have been suffering from a crisis in Europe's marine industry over the past decades but have benefited from the expansion of the wind industry and the beginning offshore wind business. Other industries such as the steel construction industry are preparing for the future offshore market with remarkable investments such as installation and transportation vessels and platforms at a cost of several hundred million euros.

Wind energy in Spain has also emerged as a driving force for industrial development. In 2007, investment was more than 5,000 million €, and around 50% of the Spanish production is dedicated to the export market. Jobs resulting from wind power reached 45,000 in 2007. Of this total, direct generation of jobs in operation and maintenance of wind farms, manufacturing, assembly, research, and development is estimated at more than 18,000, while indirect generation linked mainly to components is estimated to be more than 27,000.

3.2 Industrial development and operational experience

3.2.1 Turbines

The average rated capacity of new turbines installed in 2007 continued the trend toward larger machines. The average rating in 2007 rose to nearly 1.8 MW (Figure 2). The IEA Wind member countries contain turbine manufacturers that serve global as well as national markets. Countries reporting a national manufacturer of 1-MW or larger turbines include Denmark, Finland, Germany, Italy, Korea, the Netherlands, Norway, Portugal, Spain, and the United States.

Several countries that do not have local turbine manufacturing capabilities report the manufacture of supporting components (Australia, Canada, Greece, Ireland, Switzerland, and the United Kingdom). These include blades, control systems, power inverters, generators, nacelle assembly, or towers.

In addition to megawatt-scale wind turbines, intermediate-sized turbines of 660 to 850 kW are being manufactured in several countries for single turbine installations or small wind power plants (Germany, Italy, Korea, and the Netherlands).

A broad spectrum of R&D activities are financed by the industry or supported by state governments to develop larger and larger wind

Table 5 Wind Capacity, Jobs, and Economic Impact in 2007			
Country	"Capacity (MW)"	Estimated number of jobs	"Economic impact (Million EURO)"
Germany	22,247	84,300	11,729
United States	16,904	17,000	6,165
Spain	15,145	45,000	5,000
Denmark	3,124	28,000	4,690
Italy	2,726	10,600	1,000
United Kingdom	2,390	8,000	
Portugal	2,125		
Canada	1,845	3,340*	1,490*
Netherlands	1,745		230
Japan	1,538		
Austria**	982		
Greece	874		
Australia	824	978	180
Ireland	803		90
Sweden	788		
Norway	385		
Republic of Korea	193		
Finland	110		
Mexico	85		
Switzerland	12		100
* Numbers form 2006			
** Numbers from Wind Power Monthly			

turbines. In 2007, Enercon installed a first E 126/6 turbine with a rated power of 6 MW. At the same site near Emden, Germany, BARD Engineering, a new player among the turbine manufacturers, installed the first VM turbine—a 5-MW turbine for offshore purposes. In Italy, concrete towers were used for the first time to erect 13 Enercon 2-MW turbines near Alberona in autumn 2007.

Small wind turbine domestic manufacturing and encouragement of micro-generation is expanding the market for small wind turbines (Canada, Denmark, Italy, Japan, Portugal, Spain, and the United States).

3.2.2 Offshore installations

Interest in offshore wind development even in lakes is growing because it offers the possibility of huge increases in capacity with fewer public acceptance obstacles and fewer issues of complex terrain. By the close of 2007, more than 1,100 MW of capacity was located offshore in seven IEA Wind member countries, with 134 MW added for the year. Offshore wind is very productive. In Europe alone, at the end of 2006 (the latest year with information), offshore wind farm installations represented 1.8% of the total installed wind power capacity but generated 3.3% of the electricity from wind energy.

The potential from offshore wind is truly impressive. In Denmark in 2007, a Committee for Future Offshore Wind Turbine Locations under the Danish Energy Authority published the report *Future Offshore Wind Turbine Locations – 2025*. The report charts possible offshore areas where turbines could be built to an overall capacity of some 4,600 MW. Such a capacity could generate approximately 18 TWh—or just over 8% of total energy consumption in Denmark or approximately 50% of Danish electricity consumption. In Finland, nearly 10,000 MW of wind power potential has been identified in the process of renewing regional plans. Plans for two offshore projects totaling 100 MW were published, and building could start in 2012. The first semi-offshore projects were built in 2007 with six 2.3-MW turbines and five 3-MW turbines. A 45-MW demonstration project is in the planning phase as well. In Korea, recent government research has focused on developing 2-MW onshore and 3-MW offshore turbine models, as well as running a 4-MW offshore demonstration project that will be realized in 2009.

In the Netherlands, the country's second offshore wind farm Q7 in the North Sea began delivering electricity to the Dutch national utility grid at the end of 2007. The 120-MW farm has a surface area of 14 km². The turbines are positioned 550 m apart. In Canada, interest in offshore wind projects is growing, with the west coast and Great Lakes being considered as the first areas that will be developed.

The significant technical issues remaining for offshore wind development are the topic of research in many of the participating countries and within the IEA Wind agreement.

3.2.3 Operational experience

Turbine availability is high in all countries, ranging between 94% (Finland) and 99%, with most countries reporting 98% or higher. Productivity is also relatively high—the result of good siting of farms based on national wind atlas data. In Mexico during 2007, power plants La Venta I (1.3 MW) and La Venta II (83.3 MW) produced around 248 GWh. The facilities operated at an annual capacity factor of 33.4%, according to the manager of the wind power plants.

3.3 Economic details

3.3.1 Turbine and total installed project costs

Although many countries do not report cost information, several member countries reported increases in wind turbine costs ranging from 20% to 80% between 2006 and 2007. These cost increases are attributed to rising materials costs and varying exchange rates between the supplying and buying countries. Turbine costs reported by the IEA Wind member countries averaged from a low of 849 €/kW (U.S.) to a high of 1,300 €/kW (Italy) for 2007 (Figure 3 and Table

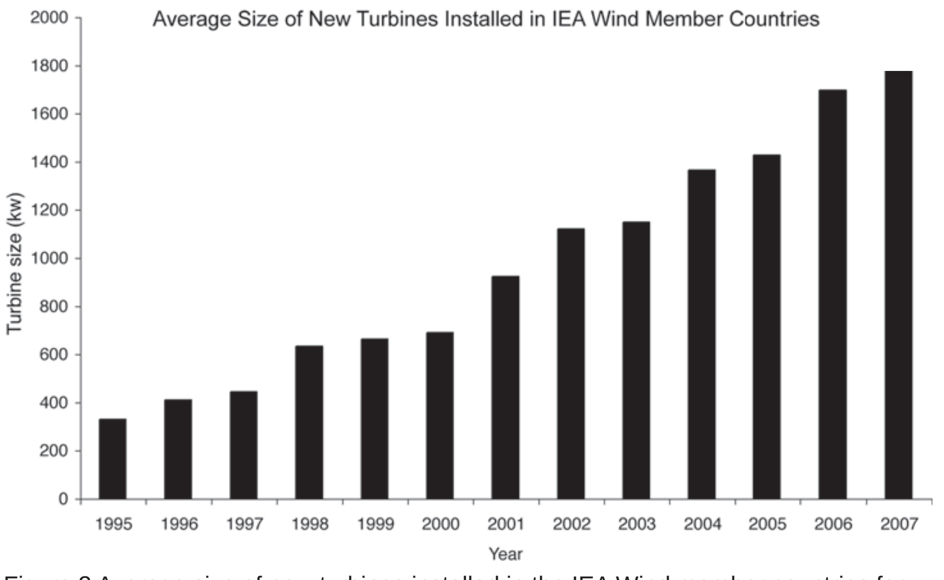

Figure 2 Average size of new turbines installed in the IEA Wind member countries for 1995–2007.

6). Total installed costs for 2007 in the reporting countries ranged from a low of 1,000 €/kW (onshore UK) to a high of 2,000 €/kW onshore (Ireland) or 2,174 €/kW offshore (UK). Most countries report the installed cost of wind projects rising in 2007 (Figure 3 and Table 6). Some member countries have reported how costs of wind projects are distributed. For example, Ireland estimates breakdown of costs for a typical onshore wind park to be 70% wind turbine, 11% foundation and civil works, 12% electrical connection, and less than 7% for development.

3.3.2 Operation and maintenance costs

Costs for service, consumables, repair, insurance, administration, lease of site, etc., for new large turbines ranged from 2% to 3.5% of capital cost per year or from 10 €/MWh to about 19 €/MWh. When O&M costs are mentioned by the member countries, they are reported as fairly constant over the years. O&M costs are higher for offshore turbines.

3.3.3 Tariffs and buyback rates

Key to the economic viability of a wind project is the balance of costs and revenue. Wind energy tariffs, feed-in tariffs, or buyback rates are the payments to the wind farm owner for electricity generated. In some countries, this is the market price of electricity. In others, the wind energy tariff includes environmental bonuses or other added incentives to encourage wind energy development. In many countries, the revenue of each wind farm is governed by the contract (power purchase agreement) negotiated with the power purchaser, so these numbers reported by the IEA Wind member countries are estimated averages or ranges. For explanations of revenue to wind park owners, including tariffs and buyback rates, refer to the country chapters of this report.

4.0 National Incentive Programs

As can be seen in Table 7, the four most often used incentives are direct capital investment as subsidies or grants for projects, providing a premium price for electricity generated by wind (tariffs or production subsidies), obliging utilities to purchase renewable energy, and providing a free market for green electricity.

In each country, the mix of incentive types and the level of government where they are applied is unique and changing. While individual nations are free to establish their own incentive systems, some countries discuss harmonized market–based incentives across the EU to simplify the process.

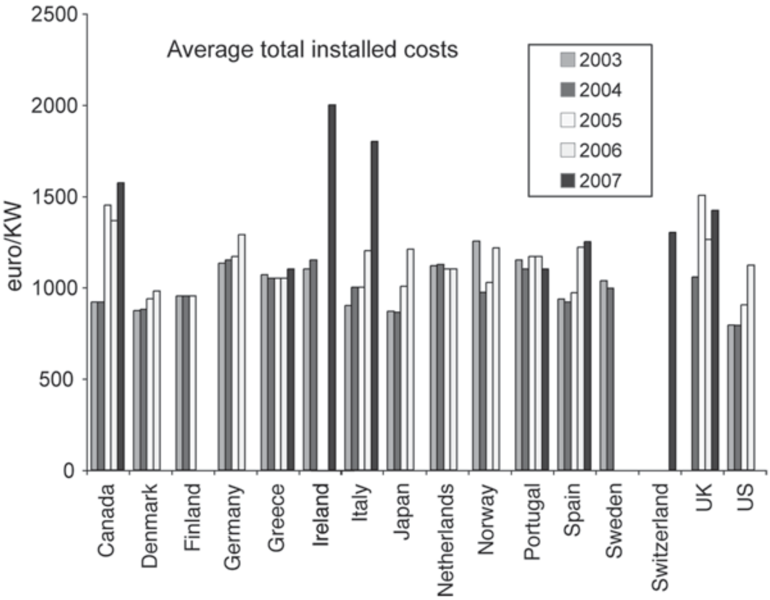

Figure 3 Average total installed costs of wind projects 2003–2007 as reported by IEA Wind member countries. These include costs for turbine, roads, electrical, installation, development, and grid connection.

Table 6 Estimated Average Turbine Cost and Total Project Cost for 2007 (where data are available)		
Country	Turbine cost	Total installed cost
	euro/kW	
Canada		1,573
Greece		1,100
Ireland	1,200	2,000
Italy	1,300	1,800
Japan	1,146	
Portugal	1,025	1,300
Spain		1,250
Switzerland		1,302
United Kingdom		"795-1,087 onshore 1,631-2,174 offshore"
United States	849	

Several assessments of existing programs and analyses of cost trends for generation sources were conducted in 2007. The results of these will be used to design incentive programs. For example, in Germany, the EEG incentive program was audited in 2007 to adapt prices for renewable energies to new market conditions and technological developments. A draft bill of the revised EEG was submitted in 2007 that proposes a considerably increased feed-in tariff (by more than 50%) for offshore wind energy and proposes to decrease the annual reduction (from 2% to 1%) of the feed-in tariff for onshore turbines, taking into account the growing world market prices for raw materials. In the Netherlands, the Ministry of Economic Affairs assessed the financial viability of the different renewable electricity production technologies. The Ministry intends to use this assessment to decide on the level of the tariffs required to bridge the difference between cost and market prices (unprofitable top) for each renewable electricity source and technology for 2008. For both wind on land and offshore, the assessment expects the electricity market price to rise from 37 €/MWh to 56 €/MWh, which leads to a base tariff of 71 €/MWh. At the end of 2007, the market was anxiously waiting for the publication of the final subsidy levels and other details of executive regulations.

At the EU level, the overall target of 20% of electricity production from renewable sources by 2010, the RES-E Directive, gives EU member states freedom of choice regarding support mechanisms. Thus, various schemes are operating in Europe, mainly feed-in tariffs, fixed premiums, green certificate systems, and tendering procedures. These schemes are generally complemented by tax incentives, environmental taxes, contribution programs, or voluntary agreements.

Incentive programs that help offset the capital cost of wind farm development to varying degrees have been successful in several countries. Price incentives (feed-in tariffs) are paid to operators according to the amount of electrical generation of the wind project, thus rewarding productivity. Tariffs can also be used to promote specific national goals and have stimulated wind farm development in several countries.

Some IEA Wind member countries have national and state governments that require utilities to purchase a percentage of their overall generating capacity from renewable resources. Often called Renewable Portfolio Standards (RPS) or Renewables Production Obligation (RPO), they allow utilities to select the most

Table 7 Incentive Programs in IEA Wind Member Countries for 2007

		Australia	Canada	Denmark	Finland	Germany	Greece	Ireland	Italy	Japan	Republic of Korea	Mexico	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	United Kingdom	United States	TOTALS 2006	TOTALS 2007
Investment Support	Direct capital investment subsides/ grants		X		X				X	X	X			X	X	X			X	X	11	10
	Capital investment write-offs		X									X	X								3	3
	Soft loans	X									X		X							X	3	4
	Others	X		X				X	X								X				1	5
Production Support	Premium price for generation		X			X	X	X	X		X		X		X	X		X	X		11	11
	Exemption from energy taxes				X												X		X		3	3
	Production tax credits	X																		X	1	2
	Others	X	X						X		X	X								X	5	6
Demand Creation	Obligation for production from renewables on suppliers	X	X						X	X						X			X	X	8	7
	Free market for green electricity	X			X				X				X		X	X	X	X		X	7	9
	Others					X	X	X			X										3	4

Note: see country chapters for more detail economical renewable technology. The preferred option by most utilities to satisfy this obligation is wind energy. In the United States, it is estimated that 46% of nationwide retail electricity is covered by RPS policies.

Wind energy qualifies as green electricity used to meet utility RPOs, to trade as certificates, or to meet consumer preferences. In Italy, an incentive program also encourages renewal of hardware by granting green certificates to turbines installed under older programs. During 2007, the Italian wind developer IVPC replaced the main components of 51 ten-year-old, 600-kW turbines totaling 30.6 MW with new gearboxes, generators, etc., in order to obtain the right to get green certificates according to the Italian law. Previously these turbines had been entitled to obtain the premium feed-in tariffs granted for a period of eight years under the former RES support scheme.

Other kinds of support have accelerated the development of wind energy in the IEA Wind member countries. For example, publishing wind energy atlases developed with public research money helps developers select productive sites. In 2007, Finland identified the uncertainty in the 1992 wind atlas as a bottleneck to planning for taller multi-megawatt machines along the coast and began work to be completed in 2008 and 2009 to update the atlas.

Clear, consistent programs give the industry a firm foundation.

5.0 R, D&D Activities

5.1 Setting priorities

An important activity of the wind energy research community is the setting of priorities for investment of precious research money. Canada is developing a wind energy technology roadmap to identify priority areas for investment in research and development to achieve cost reductions and maximize economic benefit. In 2008, the IEA Wind agreement will develop a new strategic plan in preparation for extending the agreement for another five years from 2008 through 2013. Key to that activity is setting R, D&D priorities. Several analyses in 2007 will contribute to such R, R&D planning. One of these is an IEA Wind Task 11 Topical Expert Meeting on long-term R&D needs held in December in Berlin. Representatives from 13 countries generated a list of importatnt R&D requirements.

In the European Union, the European Wind Energy Technology Platform (TPWind), launched in 2006, is an industry-led initiative to identify and prioritize areas for increased innovation, new and existing research, and development tasks. Historically, cost reductions for wind technology have come 40% from R, D&D and 60% from economies of scale. TPWind focuses not only on short- to long-term technological R&D but also on market deployment. The TPWind structure, as defined by the Steering Committee in 2007, is composed of four technical working groups responsible for building a Strategic Research Agenda, two working groups responsible for building a Market Deployment Strategy, and one Finance Group responsible for exploring and proposing funding mechanisms for implementing the strategy. In May 2008, TPWind will issue its Strategic Research Agenda and Market Deployment Strategy documents.

In 2007, IEA Wind launched a new research task—Task 26, Cost of wind energy. This task will assess methodologies for estimating COE and establish a method to calculate the impact of R&D on the cost of energy. The results of this task could help countries set research priorities, justify proposed research activities, and evaluate ongoing and completed research.

5.2 Research funding

Of the countries that mentioned research funding in their reports, Canada, Finland, Germany, Korea, Norway, Spain, and Switzerland reported increases in research budgets for 2007. In Germany, the budget for research and development of wind power reached a record amount of 34.7 million €, almost double the previous year's figure (2006: 16.1 million €). Plans for 2008 also include increased budgets for R&D. Many countries have identified research to improve energy technologies (including wind) as a priority beginning in 2007. Denmark will double its R,D&D spending on energy technology to 1 billion DKK from 2010 onward.

In 2007, more than 20 R&D projects were running with the support of the Fifth and Sixth Framework Programmes of the EU (the Framework Programmes are the main EU-wide tool to support strategic research areas). Many IEA Wind member countries participate, often in leadership roles, in these joint research projects.

5.3 Test site news

An important part of the national research programs are test sites for large and small wind turbines and for components.

Canada's Atlantic Wind Test Site has evolved into the National Wind Energy Institute of Canada (WEICan) and will be active in testing and certification, research and innovation, training and public education, and technical consultation and assistance. It has recently signed an exclusive framework agreement to provide the North American wind industry with type testing services. In a related effort, a collaborative of universities has set up the Corus Centre dedicated to research, development, and the transfer of wind technology. It is surrounded by two wind farms with a total capacity of 108 MW, making it a unique natural laboratory to study the impact of the cold environment on the extraction of wind energy.

In Denmark, Risø National Laboratory (now part of the Technical University of Denmark) owns and manages the test site for multi-megawatt wind turbines at Høvsøre, a site on the northwest coast of Jutland with high wind speeds (9–10 m/s at heights of 80–100 m). The test site consists of five test stands allowing turbines with heights up to 165-m tip heights (approximately 5 MW).

In Germany in June 2007, FINO 2 began operation as the first offshore research platform in the Baltic Sea. FINO 2 conducts analyses of wind and wave movements, marine ecology, and shipping traffic. FINO 3, in the North Sea, is scheduled for commissioning in June 2008. FINO 3 will repeat measurements based on the FINO 1 measuring regime and take measurements about foundations and lightning.

The first offshore wind farm in German waters will be the offshore test site "alpha ventus" (formerly known as "Test Site Borkum West"). In 2008, construction will begin for 12 wind turbines in the 5-MW class in a water depth of 30 m. In total, the government has earmarked some 50 million € for research at the test site over a five-year period. One aim of research at the alpha ventus offshore test site is to develop wind turbines in the multi-megawatt class for offshore conditions and to assure good reliability, high efficiency, and easy assembly and service. To this end, turbine manufacturers Multibrid GmbH and REpower Systems AG will test their large turbines primarily at alpha ventus. One turbine of each type is to be equipped especially for research purposes. The test site will provide data for studies of all aspects of offshore wind energy development, from foundation design to grid connection issues.

For aerodynamic research, a new wind tunnel that is acoustically optimized and has a 14-m working section is under construction in Bremerhaven, Germany. The wind tunnel will allow experiments on fairly large models and can test original segments of wind farms. The turbines in the wind tunnel allow the simulation of wind fields with wind speeds of up to 250 km/h. The wind tunnel is expected to begin operation in spring 2008.

In Mexico, construction of the basic infrastructure of the Regional Wind Technology Center was completed in 2007. It is the first project in Mexico to receive a permit to operate as a small power producer. Installation of wind turbines has been delayed because of the long delivery times for machines in the wind energy market worldwide. When completed, the Center will supply researchers with operational data on the interaction of specific types of wind turbines with the electrical system.

Norway has developed a test station for wind turbines on the midwestern coast of Norway. Activities at the test station include testing of new components for wind turbines. Another project in Switzerland, Alpine Test Site Guetsch: Meteorological measurements and wind turbine performance analysis, can expand knowledge of atmospheric icing—specifically in the Alps. It fits into an international comparison network (COST 727) and will allow for comprehensive testing and improvement of monitoring equipment.

5.4 Selected technology R&D news

The country chapters of the 2007 IEA Wind Annual Report contain much information and references to research planned, under way, and recently completed. A few highlights of R&D accomplishments for 2007 are presented here.

5.4.1 Offshore wind

Research emphasis on offshore technology is seen in several countries. For example, two-thirds of the new projects in Germany were in the offshore sector: logistics, foundations, grid aspects, ecology, test site platforms, and multi-MW turbines. Technological research priorities also included the optimization of supporting structures and rotor blades, the further development of open- and closed-loop control and monitoring technology, offshore assembly techniques and logistics, and the management of maintenance and repairs. In Denmark, large turbines for offshore—the O-series multi-megawatt 200-m-high turbines—are a main focus. The EU-funded UPWIND project is working on many issues contributing to development of 8- to 10-MW machines.

A new large Spanish R&D project has been started to develop technologies enabling deployment of offshore wind plants in deep waters (over 40 m). Eolia is a consortium of 16 companies that also includes 25 research centers and 7 private companies subcontracted by the consortium. The project's research activities integrate a series of technologies, including energy (wind power and other electricity technologies), aquaculture, desalination, construction, and naval technologies.

Several offshore research activities produced results in 2007. In Italy, Blue H launched a prototype floating foundation called SDP (Submerged Deepwater Platform) in December 2007 with an 80-kW turbine mounted on it. In 2008, the prototype will be anchored in 108-m-deep waters at a distance of 10.6 nautical miles from the coastline and experimental tests will begin. In Norway, two concepts for floating wind turbines are under development to operate in areas of deep water (200 m to 800 m). A prototype is expected to be in operation during 2009.

Studies completed in 2007 of the wind resource potential off the coast of Norway show a total theoretical potential annual wind resource of 14,000 TWh. Areas from the shoreline out to water depth less than 300 m are included in this potential. The studies document resource variation geographically along the coastline as well as seasonal variation of the wind speed over the year. In Portugal, an extensive measurement campaign is under way to produce an offshore wind atlas.

Within IEA Wind Task 23, Offshore wind technology development, participants formed a working group named Offshore Code Comparison Collaboration (OC^3) to focus on coupled turbine/substructure dynamic modeling. The OC^3 baseline turbine model has been adopted by two major UpWind Work Package teams as their aerodynamics and foundation modeling research work. Also, the code comparison work to date has established a procedure and database that could be used for future code verification exercises such as the one outlined in UpWind Work Package WP 1A1, Integrated Design Approach and Standards. This WP calls for the development of a reference turbine as well as procedures for verifying models and codes. OC^3 has provided a basis for both of these goals.

5.4.2 Large turbine development

Larger turbines are being designed for both onshore and offshore applications, and several new designs and approaches appeared in 2007. In Spain, Windlider 2015, an industrial research project led by Gamesa and Ecotecnia, received a 13-million-€ grant, almost half of the 28.5 million € estimated total investment required for the large wind turbine project. The project's objectives are to improve the design process of future turbines, boost Spanish-owned enabling technologies, create a simulation model to determine the effect of new configurations on turbine performance, and deploy experiments in scales up to 5 MW with complete turbine prototypes and critical components (generators, gearboxes, converter, chassis yaw, etc.).

Research has been under way to address key barriers to wind energy development in Japan—the threat of typhoons and very-high-energy lightning strikes. The Japan Steel Works Co. Ltd. (JSW) has developed a new 2-MW, 82.6-m gearless wind turbine with a permanent-magnet synchronous generator which began operation in September 2007. The first 2-MW, 70.6-m wind turbine with same design has operated since June 2006. JSW plans to install more than 100 units by 2009. Komai Tekko, Inc., developed the KWT300 wind turbine with design turbulence intensity of 0.20, which is better than the IEC class I value of 0.18. The survival wind speed is 70 m/s. The prototype KWT300 has been operated and monitored more than one year at the Futtu site facing Tokyo Bay.

To further assure that Japan has appropriate turbines, the J-Class Wind Turbine Guideline is being developed by taking actual measurements of wind characteristics and mechanical loads of turbines at several wind plant sites over Japan and conducting combined computational fluid dynamics work. The final report including these guidelines will be published in March 2008. These guidelines will be proposed for incorporation into the IEC 61400-1 standards within IEC S-wind turbine class. This will make the results of the research available to regions worldwide where meteorological and topographical conditions are similar to those in Japan.

In Norway, ScanWind Group AS is manufacturing a 3.5-MW, directly-driven, variable-speed turbine with a permanent-magnet generator for use in Class 1 wind areas for the coastal onshore and the offshore market. Another initiative has begun to develop a new weight-reduced generator for wind power applications. The main objective of this project is to develop a new permanent-magnet generation system that reduces the generator mass by at least 25%.

In Germany, multi-megawatt turbine development is very active in the industrial sector. The research program supports this activity by conducting technological research into components such as alternators, foundations, rotor blades, control systems, and offshore installation and logistics.

In Korea, the government's annual budget for wind R, D&D in 2007 has been aimed at localizing the manufacturing of MW-size wind turbine systems and their components. Recent government research has been carried out to develop 2-MW onshore and 3-MW offshore turbine models. The research program is also running a 4-MW offshore demonstration project that will be realized in 2009. To satisfy recent requests from the wind industry for increased research infrastructure and education programs, the government launched several sponsored programs. The Wind Turbine Technology Research Center aims to develop core technology and infrastructure with industries while training field engineers and technicians. The National Wind Research Laboratory and the Graduate School for Wind Energy are dedicated to research-oriented education programs for the next five years under an initial contract. In 2007, the first domestically produced 750-kW and 1.5-MW turbines were introduced to the Korean market, while the 2- to 3-MW turbines were still under development and scheduled for field testing over the next two years.

In the United States, work contributing to industrial development of cost-effective large wind turbines included development of a prototype 1.5-MW direct-drive generator using rare earth permanent magnets. Built and tested in 2007, it uses 56 poles and is 4 m in diameter, compared with 10 m for a typical wound rotor of the same capacity. Another approach to reducing size, weight, and cost was a prototype design that uses a single-stage planetary drive operating at a gearbox ratio of 9.16:1. The gearbox drives a 190-rpm, 72-pole, permanent-magnet generator. This approach reduces the diameter of a 1.5-MW generator to 2 m. The prototype was tested in 2007, and a second phase of testing is planned for 2008.

The largest ever EU-funded R&D project in the field of wind technology was well under way in 2007. The UPWIND project is an integrating initiative to look at the design of very large turbines expected for the future. Many IEA Wind member countries participate in elements of this research effort.

5.4.3 Materials

Research involving innovative materials or innovative uses of materials to improve wind technology was reported by the member countries. For example, the EU OPTIMAT BLADES research project was completed and provides design recommendations for the optimized use of materials for rotor blades. A wealth of experimental data was gathered within this project, including results of CRES research in Greece. In the Netherlands, a smart structures for rotor blades project aims to alleviate significant blade loads by applying spanwise-distributed load control devices without incurring lower reliability or higher maintenance. In 2007, Delft Technical University proved the concept in its wind tunnel. Researchers observed load reductions between 70% and 90% and concluded that up to 60% of fatigue blade load alleviation is possible. In 2008, the university will carry out a rotating experiment with a 2-m-diameter wind tunnel model in its new Open Jet Facility. Another research line at Delft is the development of sustainable vacuum-infused thermoplastic composites for MW-size wind turbine blades.

In Finland, work on the EU project UPWIND resulted in technologies to control the shape of composite structures at laboratory scale. In 2007, a one-m-chord blade section with controllable trailing edge was manufactured using shape memory alloys integrated into the composite and tested in a wind tunnel.

5.4.4 Small wind turbines

Increased interest in small wind turbine technology was mentioned by several countries. In Spain, work is under way to support the small wind turbine sector through promotion, dissemination, sensitization, and information collection. In line with this work, CIEMAT will serve as OA for the new IEA Wind Task 27, Safety labeling of small wind turbines.

In Portugal, the T-URBan project, a prototype small (2.5-kW) wind turbine with horizontal axis, is in the test phase. This turbine has a 2.3-m rotor diameter and is designed for a 10- to 15-m-high tower. This project, designed and constructed using Portuguese technology, will be completed and operational by mid-2008.

In the United States, the Skystream 1.8-kW turbine with integrated inverter and controls and low-noise, swept fiberglass began commercial production in 2007. The manufacturer applied for certification from Germanischer Lloyd WindEnergie GmbH (GL) after tests at government laboratories for blade fatigue, IEC duration, and IEC power performance.

In Norway, a wind/hydrogen demonstration project at Utsira has now been in operation for two years. The purpose of the project is to demonstrate how renewable energy can provide safe and efficient energy supply to isolated areas. The system is based on wind energy as the only energy source. Excess power is used to produce hydrogen, which is to be used later in a fuel cell.

5.4.5 Costs

The members of IEA Wind have agreed that a clear, impartial voice regarding the costs of wind systems is needed to avoid the publication of erroneous costs of wind systems. Task 26, Cost of wind energy will provide the tools to compare the costs of wind energy with other electricity-generating technologies. It will modify the underlying assumptions that are applied to the different technologies. Finally, this task aims to form the basis for a more comprehensive analysis of the value of wind energy. The Netherlands, for example, participates in Task 26 because it will give insight into international cost data for offshore wind energy that can be used for policy decisions.

5.4.6 Grid integration

Transmission system effects are an important part of the Danish research program with a study looking at the ability of wind power plants to contribute to regulation and stability of the grid. Integration of offshore wind farms has special issues, so Task 23 held a workshop in 2007 that laid the foundation for future sharing of research on this topic.

In the United States, several studies in 2007 looked at the operational impact of high contributions of wind energy in specific utilities. For penetrations of wind up to 25% in Minnesota and up to 33% (wind and other renewables) in California, the ancillary costs were below 0.005 USD/kWh, indicating that significant wind energy generation can be integrated into the electricity grid with minimal costs in large transmission systems.

5.4.7 Environmental impact assessment

In Denmark, four surveys in 2007 of water bird distribution in the Horns Rev 1 wind farm confirmed reports from maintenance personnel that common scoters had returned to the area. Initial surveys right after construction in 1999 concluded that the once-plentiful birds had abandoned the area of the wind farm.

In Germany, a standard has been developed for analyzing the effects of offshore wind turbines on the marine environment. The "standard analysis concept" (StUK 3) prescribes binding ecological investigations, e.g., on marine mammals, birds, and fish, for applicants and licenseholders. In another study, sound emissions of wind turbines during the operation are being investigated using underwater sound and vibration measurements for two selected plants. A number of projects are devoted to the development and testing of optimized techniques for accompanying ecological research at sea. In August 2007, an automatic camera system was installed on the research platform FINO 2 that detects bird movements near the mast and documents any collisions. Another effort to record the movements of birds is testing a horizontal radar system offshore in 2007. It has already been successfully tested on land.

5.4.8 Innovative applications

In Greece, CRES participates in the Floating, Autonomous, Ecological, and Effective Desalination Unit project to design and develop a wind-powered reverse-osmosis (RO) unit for seawater desalination. The system includes a 30-kW wind generator, an RO unit of 80 m3/

day potable water capacity, a battery bank, and control system.

6.0 Next Term

Continued growth in deployment is expected in most IEA Wind member countries. To support the increasing need for durable, cost-effective machinery, larger technology research budgets will be provided by growing national and industrial research programs.

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1) EWEA, www.ewea.org.

2) The Windicator, *Windpower Monthly*, April 2008, Denmark: Wind Power Monthly News Magazine.

3) IEA Wind Annual Reports 1995–2006, www.ieawind.org.

4) IEA R&D Wind Annex XV reports 1995, 1997.

5) IEA Wind, 2003, *Strategic Plan*, 1 November 2003 to 31 October 2008, www.ieawind.org.

Author: Patricia Weis-Taylor, Secretary, IEA Wind

Chapter 1 Implementing Agreement

1.0 Introduction

The IEA's wind Implementing Agreement began in 1977, when that is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind) was initiated. The the development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems. The Tasks are listed as numbered Annexes to the Implementing Agreement.

At present, 24 contracting parties from 20 countries, the European Commission, and the European Wind Energy Association (EWEA) participate in IEA Wind. Australia, Austria, Canada, Denmark, the European Commission, EWEA, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, the Republic of Korea, Mexico, the Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States are now members (Table 1).

Recently, there has been increasing interest in IEA Wind participation from both the Organization for Economic Cooperation and Development (OECD) and non-OECD countries. This interest is being encouraged, and prospective members attend IEA Wind Executive Committee (ExCo) meetings to observe first-hand the benefits of participation.

2.0 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 presented in the Executive Summary of this Annual Report. Individual county activities are presented in Chapters 11 through 30.

3.0 Collaborative Research

In 2007, participants in the IEA Wind Agreement worked on seven cooperative research tasks, which have been approved by the ExCo as Annexes to the original Implementing Agreement text. Progress in cooperative research is described in chapters 2 through 8. In 2007, three new annex proposals were considered by the ExCo for approval as research tasks. These new efforts are described in Chapter 9. Tasks are referred to by their annex number. Some annexes have been completed and so do not appear as active projects in this report. This is why the numbers of active annexes may not be sequential.

Each member country must participate in at least one cooperative research task. Countries choose to participate in tasks that are most relevant to their current national research and development programs. Additional tasks are planned when new areas for cooperative research are identified by Members (Table 2).

The level of effort on a task is typically the equivalent of several people working for a period of three years. Some tasks have been extended to continue the work. The projects are either cost-shared and carried out in a lead country, or task-shared, when the participants contribute in-kind effort, usually in their home organizations, to a joint research program coordinated by an Operating Agent. By the close of 2007, 14 tasks had been successfully completed and two tasks had been deferred indefinitely. (Table 3)

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 under the tab for cooperative research or follow the links to individual Task Web Sites.

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 contracting party that has

Table 1 Contracting Parties in 2007 to the International Energy Agency Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind)	
Country/Organization	Contracting Party to Agreement
Australia	Australian Wind Energy Association
Austria	The Republic of Austria
Canada	Natural Resources Canada
Denmark	Danish Energy Authority
European Commission	The Commission of the European Communities
European Wind Energy Association	European Wind Energy Association
Finland	The National Technology Agency of Finland (TEKES)
Germany	The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Greece	Center of Renewable Energy Resources (CRES)
Ireland	Sustainable Energy Ireland
Italy	CESI S.p.A. and ENEA Cassaccia
Japan	National Institute of Advanced Industrial Science and Technology (AIST)
Korea	The Government of Korea
Mexico	Instituto de Investigaciones Electricas (IIE)
Netherlands	The Netherlands Agency for Energy and the Environment (SenterNovem)
Norway	The Norwegian Water Resources and Energy Directorate (NVE) and Enova SF
Portugal	National Institute for Engineering and Industrial Technology (INETI)
Spain	Instituto de Energias Renovables (IER) of the Centro de Investigación; Energetica Medioambiental y Tecnologica (CIEMAT)
Sweden	The Swedish Energy Agency
Switzerland	The Swiss Federal Office of Energy
United Kingdom	Department of Trade and Industry
United States	The U.S. Department of Energy

signed the IEA Wind Implementing Agreement. Most countries are represented by one contracting party that is usually 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 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 by unanimity when financial matters are decided. Members share the cost of administration for the ExCo through annual contributions to the Common Fund. The Common Fund supports the efforts of the Secretariat and other expenditures approved by the ExCo in the annual budget.

Table 2 Active Cooperative Research Tasks Defined in Annexes to the IEA Wind Implementing Agreement (OA indicates operating agent that manages the task)	
Task 11	Base technology information exchange OA: Vattenfall, Sweden (1987 to present)
Task 19	Wind energy in cold climates OA: Technical Research Centre of Finland - VTT. (2001 to 2008)
Task 20	HAWT Aerodynamics and models from wind tunnel tests and measurements OA: NREL, the United States (2003 to 2007)
Task 21	Dynamic models of wind farms for power system studies OA: Sintef Energy Research, Norway (2003 to 2007)
Task 23	Offshore wind energy technology development OA: Risø National Laboratory, Denmark and the National Renewable Energy Laboratory (NREL), United States (2004 to 2008)
Task 24	Integration of wind and hydropower systems, OA: NREL, United States (2004 to 2008)
Task 25	Design and operation of power systems with large amounts of wind power. OA: Technical Research Centre of Finland – VTT, (2005-2008)

Officers

In 2007, Ana Estanqueiro (Portugal) served as Chair. Morel Oprisan (Canada) and Brian Smith (United States) served as vice chairs. All of the officers were re-elected for the calendar year 2008.

Participants

In 2007, there were no changes in IEA Wind country participation. (See Appendix B for an updated list of Members, Alternate Members, and Operating Agent representatives.) During the year, the ExCo invited representatives from several countries to attend as observers.

Meetings

The ExCo normally meets twice a year for Members to review ongoing tasks; plan and manage cooperative actions under the Agreement; and report on national wind energy research, development, and deployment activities (RD&D). The first meeting of the year is devoted to reports on R&D activities in the member countries, and the second meeting is devoted to reports about deployment activities.

The 59th ExCo meeting was hosted by the Republic of Korea, on Jeju Island, 17, 18, and 19 April 2007. There were 27 participants from 14 of the contracting parties. Attendees included seven operating agent representatives of the tasks and a representative of the World Wind Energy Association. The ExCo reviewed and approved technical progress reports of ongoing tasks 11, 19, 20, 21, 23, 24, and 25; approved Task 26 to develop a work plan. The audit report of 2006 accounts of the Common Fund was approved. On 19 April 2007, the ExCo visited KIER's Jeju Test Site for New and Renewable Energy sources and the Haengwon Wind Farm. On 20 April nine ExCo members gave presentations at the International Workshop for Wind Energy sponsored by the Korean Wind Energy Association.

The 29th issue of the IEA Wind Energy Annual Report was published in July 2007.

The 60th ExCo meeting was hosted by the Spanish government, the government of Aragon, the foundation Hidrogeno, and CIEMAT in Zaragoza, Spain 25, 26, and 27 September 2007. There were 33 participants from 17 contracting parties, seven operating agent representatives of tasks, and observers. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2008. The ExCo also approved plans and budget for developing a new corporate image for IEA Wind. On 27 September 2007, the ExCo visted the municipality of La Muela, Spains first wind farm, the Vestas Mediterranean Surveillance Center, and the Museum of the Wind.

5.0 Planning Committee

A planning committee consisting of the Chair, Vice Chairs, the Secretary, the former Chair, and the Operating Agent Representative for Task 11 perform communication and

Table 3 Completed or Inactive Cooperative Research Tasks Defined in Annexes to the IEA Wind Implementing Agreement (OA indicates operating agent that manages the task)	
Task 1	Environmental and meteorological aspects of wind energy conversion systems OA: The National Swedish Board for Energy Source Development. (1978 to 1981)
Task 2	Evaluation of wind models for wind energy siting OA: U.S. Department of Energy - Battelle Pacific Northwest Laboratories. (1978 to 1983)
Task 3	Integration of wind power into national electricity supply systems OA: Kernforschungsanlage Jülich GmbH, Germany. (1978 to 1983)
Task 4	Investigation of rotor stressing and smoothness of operation of large-scale wind energy conversion systems OA: Kernforschungsanlage Jülich GmbH, Germany. (1978 to 1980)
Task 5	Study of wake effects behind single turbines and in wind turbine parks OA: Netherlands Energy Research Foundation. (1980 to 1984)
Task 6	Study of local flow at potential WECS hill sites OA: National Research Council of Canada. (1982 to 1985)
Task 7	Study of offshore WECS OA: UK Central Electricity Generating Board. (1982 to 1988)
Task 8	Study of decentralized applications for wind energy OA: UK National Engineering Laboratory. (1984 to 1994)
Task 9	Intensified study of wind turbine wake effects OA: UK National Power plc. (1984 to 1992)
Task 10	Systems interaction. Deferred indefinitely.
Task 12	Universal wind turbine for experiments (UNIWEX) OA: Institute for Computer Applications, University of Stuttgart, Germany. (1988 to 1995)
Task 13	Cooperation in the development of large-scale wind systems OA: National Renewable Energy Laboratory (NREL), USA. (1990 to 1995)
Task 14	Field rotor aerodynamics OA: Stichting Energieonderzoek Centrum Nederland (ECN), the Netherlands. (1992 to 1997)
Task 15	Annual review of progress in the implementation of wind energy by the member countries of the IEA OA: ETSU, the United Kingdom. (1994 to 2001)
Task 16	Wind turbine round robin test program OA: the National Renewable Energy Laboratory (NREL), the United States. (1995 to 2003)
Task 17	Database on wind characteristics OA: RISØ National Laboratory, Denmark. (1999 to 2003)
Task 18	Enhanced field rotor aerodynamics database OA: Netherlands Energy Research Foundation - ECN, the Netherlands Extend the database developed in Task XIV and disseminate the results. (1998 to 2001)
Task 22	Market development for wind turbines. On hold.

Table 4 Participation of Member Countries in Annexes During 2007. (OA indicates operating agent that manages the task)

	11	19	20	21	23	24	25
Country	Base Technology Information Exchange	Wind Energy in Cold Climates	HAWT Aero-dynamics and Models from Wind Tunnel Tests	Dymanic Models of Wind Farm for Power Systems Studies	Offshore Wind Energy Technology and Deployment	Integration of Wind Hydropower Systems	Power Systems with Large Amounts of Wind Power
Australia						x	
Austria							
Canada	x	x	x			x	
Denmark	x		x	x	OA		x
European Commission	x						
European Wind Energy Association							x
Finland	x	OA		x		x	OA
Germany	x	x			x		x
Greece			x				
Ireland	x			x			x
Italy	x	x					
Japan	x						
Republic of Korea	x				x		
Mexico	x						
Netherlands	x		x	x	x		x
Norway	x	x	x	OA	x	x	x
Portugal				x			x
Spain	x		x				x
Sweden	OA		x	x	x	x	x
Switzerland	x	x				x	
United Kingdom	x			x	x		x
United States	x	x	OA	x	OA	OA	x
Start Date	1987	2001	2003	2003	2004	2004	2005
End Date	Ongoing	2008	2007	2007	2008	2008	2008

cooperation activities between ExCo meetings. Support for IEA Paris initiatives has been provided by the Planning Committee. This support included attending NEET meetings in Brazil, China, and South Africa (excellent potential participants in the IEA Wind Agreement), attending 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.

Chapter 2 Task 11

Base Technology Information Exchange

1.0 Introduction

The objective of this research task is to promote wind turbine technology by co-operative activities and information exchange on RD&D topics of common interest. These particular activities have been part of the IEA Wind Implementing Agreement since 1978. Most of the IEA Wind member countries participate in this task so that researchers in their countries can benefit from this information exchange.

2.0 Objectives and Strategy

The task includes activities in two sub-tasks. The first is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. In the series of Recommended Practices, 11 documents have been published. Five of these have appeared in revised editions (Table 1). Many of the documents have served as the basis for both international and national standards.

During 2007, preparations began for development of a new Recommended Practice on using sodar technology for measurement of wind speeds.

The second sub-task is to conduct two types of meetings of experts on topics designated by the IEA Wind ExCo. The first type of meeting is Joint Action Symposia in specific research areas. Once a Joint Action is established, experts meet on a regular basis to share progress on the issue. So far, Joint Actions have been initiated in aerodynamics of wind turbines, wind turbine fatigue, wind characteristics, offshore wind systems, and wind forecasting techniques. The second type of meeting, Topical Expert Meetings, is arranged on topics decided by the IEA Wind ExCo. Proceedings are distributed to attendees and to the countries that pay fees to participate in Task 11. Sometimes Topical Expert Meetings result in a recommendation for a Joint Action, so participants can continue to share information on a regular basis.

Topical Expert Meetings can also begin the process of organizing new research tasks as additional Annexes to the Implementing Agreement. For example, in 2007 the meeting on social acceptance issues of wind energy projects brought together the interested experts who wrote a proposal for a new task, Social Acceptance of Wind Power Projects. This proposal will be discussed during 2008.

During these 27 years of activity to promote wind turbine technology through information exchange, 55 volumes of proceedings from Expert Meetings (Table 2) and 26 volumes of proceedings from Joint Action Symposia (Table 3) have been published.

3.0 Progress in 2007

Completing the work plan approved by the ExCo, the following activities were planned and accomplished during 2007:

- 51st Topical Expert Meeting on State of the Art of Remote Wind Speed Sensing Techniques Using Sodar, Lidar, and Satellites;
- 52nd Topical Expert Meeting on Wind and Wave Measurements at Offshore Locations;
- 53rd Topical Expert Meeting on Radar, Radio, and Wind Turbines;
- 54th Topical Expert Meeting on Social Acceptance of Wind Energy Projects;
- 55th Long Term Research Needs – In the Frame of the IEA Wind Co-operative Agreement.

The Joint Action Symposium on Aerodynamics was this year arranged as a part of the Task 20 work. (See Chapter 4 HAWT Aerodynamics and Models from Wind Tunnel Measurements, Task 20.).

3.1 Remote wind speed sensing techniques using sodar, lidar, and satellites

3.1.1 Background

Wind power projects now frequently installed in complex terrain, offshore, in forests, and on taller towers at high levels in the atmosphere. The turbines installed in these locations are increasingly, large multi-megawatt wind turbines. However, our basic knowledge of winds in these challenging environments is inadequate.

Traditionally, to make accredited measurements for wind energy purposes, cup anemometers are mounted on meteorological masts. As turbines are designed with taller towers, mast instrumentation, erection, and maintenance have

Table 1 List of Recommended Practices Developed by IEA Wind						
No	Area	Edition	Year	First Ed.	Valid	Status
1	Power Performance Testing	2	1990	1982	no	Superceeded by IEC 61400-12, Wind power performance testing
2	Estimation of Cost of Energy from WECS	2	1994	1983	yes	
3	Fatigue Loads	2	1990	1984	yes	Part of IEC 61400-13 TS, Measurement of mechanical loads
4	Acoustics Measurement of Noise Emission From Wind Turbines	3	1994		no	Superceded by IEC 61400-11, Acoustic noise measurement techniques
5	Electromagnetic Interference	1	1986		yes	
6	Structural Safety	1	1988		no	See also IEC 61400-1
7	Quality of Power Single Grid-Connected WECS	1	1984			See also IEC 61400-21
8	Glossary of Terms	2	1993	1987		See also IEC 60030-413 International Electrotechnical vocabulary: Wind turbine generator systems
9	Lightning Protection	1	1997		yes	See also IEC 61400 PT24, Lightning protection for turbines
10	Measurement of Noise Immission from Wind Turbines at Receptor Locations	1	1997		yes	
11	Wind Speed Measurement and Use of Cup Anemometry	1	1999		yes	Document will be used by IEC 61400 MT 13, updating power performance measurement standard

become expensive; prices increase with height and obtaining building permits can be time-consuming. At the same time, using measured wind speed at the rotor center results in discrepancies between predicted output and actual turbine performance. This fact has increased the need for determining the wind over the whole turbine rotor.

Successful development of wind power should be based on sound information on winds in each location. To achieve this, it is important to apply new observation methods and strategies. Most promising are the new (for wind energy purposes) remote sensing techniques: sodar, lidar, and satellite. Sodar is based on sound propagation, lidar on laser Doppler, and satellite on microwave scatterometry and Synthetic Aperture Radar (SAR) methods. At the Experts Meeting the advantages and limitations of the various techniques were described and discussed.

3.1.2 Summary

Participants agreed that more experience is needed with remote sensing for wind energy purposes to increase the accuracy and the repeatability of measurements. It is especially

Table 2 Topical Expert Meetings Held Since 1995*			
55	Long-Term Research Needs – In the Frame of the IEA Wind Co-operative Agreement	Berlin, Germany	2007
54	Social Acceptance of Wind Energy Projects	Luzerne, Switzerland	2007
53	Radar, Radio, and Wind Turbines	Oxford, United Kingdom	2007
52	Wind and Wave Measurements at Offshore Locations	Berlin, Germany	2007
51	State of the Art of Remote Wind Speed Sensing Techniques Using Sodar, Lidar and Satellites	Risoe, Denmark	2007
50	The Application of Smart Structures for Large Wind Turbine Rotor Blades	Roskilde, Denmark	2006
49	Challenges of Introducing Reliable Small Wind Turbines	Stockholm, Sweden	2006
48	Operation and Maintenance of Wind Power Stations	Madrid, Spain	2006
47	Methodologies for Estimation of Cost of Wind Energy and the Methodologies to Estimate the Impact of Research on the Cost	Paris, France	2005
46	Obstacle Marking of Wind Turbines	Stockholm, Sweden	2005
45	Radar, Radio, Radio Links, and Wind Turbines	London, UK	2005
44	System Integration of Wind Turbines	Dublin, Ireland	2004
43	Critcal Issues Regarding Offshore Technology and Deployment	Skærbæk, Denmark	2004
42	Acceptability of Wind Turbines in Social Landscapes	Stockholm, Sweden	2004
41	Integration of wind and hydropower systems	Portland, OR, USA	2003
40	Environmental issues of offshore wind farms	Husum, Germany	2002
39	Power performance of small wind turbines not connected to the grid	CEDER, Soria, Spain	2002
38	Material recycling and life cycle analysis (LCA)	Risø, Denmark	2002
37	Structural reliability of wind turbines	Risø, Denmark	2001
36	Large scale integration into the grid	Hexham, UK	2001
35	Long term research needs - for the time frame 2000 – 2020	Petten, The Netherlands	2001
34	Noise immission	Stockholm, Sweden	2000
33	Wind forecasting techniques	Boulder, Colorado	2000
32	Wind energy under cold climate conditions	Helsinki, Finland	1999
31	State of the art on wind resource estimation	Lyngby, Denmark	1998
30	Power performance assessments	Athens, Greece	1997
29	Aero-acoustic noise of wind turbines	Milano, Italy	1997
28	State of the art of aeroelastic codes for wind turbines	Lyngby, Denmark	1996
27	Current R&D needs in wind energy technology	Utrecht, Netherlands	1995
*For meetings prior to 1995, see www.ieawind.org			

Table 3 Joint Action Symposia Since 1994				
No.	Year	Host	Place	Country
Aerodynamics of wind turbines				
16	2003	NREL	Boulder, CO	USA
15	2001	NTUA	Athens	Greece
14	2000	NREL	Boulder	USA
13	1999	FFA	Stockholm	Sweden
12	1998	DTU	Lyngby	Denmark
11	1997	ECN	Petten	Holland
10	1996		Edinburgh	United Kingdom
9*	1995	FFA	Stockholm	Sweden
Fatigue of wind turbine blades				
5	1999	Uni. Delft	Delft	Holland
4	1996	DLR	Stuttgart	Germany
3*	1994	ECN	Petten	Holland
Wind				
3	2003	Risø	Roskilde	Denmark
2	1999	Risø	Roskilde	Denmark
1	1994	GL	Hamburg	Germany
Wind forecasting techniques				
2	2004	DTU	Lyngby	Denmark
1	2002	SMHI	Norrköping	Sweden
* For symposia prior to 1994 see www.ieawind.org under Task 11				

important to compare the performance of lidar and sodar with anemometers. The IEA-developed Recommended Practices for anemometry are available and could be used as a reference for developing similar documents for lidar and sodar. Participants pointed out that such documents are needed in a near-future.

As a first step to develop a Recommended Practice, participants agreed to form two Ad-Hoc groups to put together proposals for the proper operation of a sodar/lidar for measuring wind data. The ad-hoc groups will make to-do lists for improvements of the instruments.

General statements raised during the discussion were:

• There is a need for more experience from remote sensing, especially comparing the performances of lidar and sodar with anemometers;
• Lidar and sodar will complement each other for a while. Both instruments will have a future in atmospheric science;
• Both sodar and lidar have room for improvements;
• For some time to come, remote sensing will be used in conjunction with conventional anemometry, but, it is important to understand all the sources of errors before replacing conventional methods.

3.2 Wind and wave measurements at offshore locations

3.2.1 Background

Electricity from renewable energy sources will make an important contribution to tomorrow's energy policy. Of these sources, offshore wind has an enormous potential to contribute substantially to global climate protection.

According to estimations of the European Wind Energy Association (EWEA) 10,000 MW of offshore wind power will be installed within this decade, and by 2020 it will be 75,000 MW. In 2007, more than 300 wind turbines with a total of 600 MW are installed off the coasts of Denmark, Ireland, Sweden, and the UK.

Several measuring stations are either planned or already operating in the North and Baltic Seas. They deliver technical and environmental data required for the planning and approval of offshore wind farms. For manufacturers of wind turbines and foundations, the findings from these measuring stations will lead to designs that are better adapted to the offshore conditions. On the basis of measured wind data, banks and investors will make their economic assessments. Institutes, standardization bodies and certification organizations will use the results to cross-check and validate the requirements derived from other fields (onshore wind energy and offshore technology). Increasing knowledge will advance the development of wind energy at sea.

One of these measuring stations is the German research platform, FINO 1, in the North Sea. It was installed in 2003 and has delivered comprehensive series of data since then. One of the main objectives of the FINO project is to improve understanding of the meteorological and oceanographic conditions at sea. Results were presented and discussed at this Topical Expert Meeting.

3.2.2 Summary

At the concluding discussion, a general attitude was that better knowledge of wind and wave climates offshore may result in more effective ways of designing wind turbines and foundations. This may, in the end result, in lower cost per produced kilowatt-hour.

The opening discussion concerned the future needs in wind and wave data availability. The view among most of the participants was that there is a lack of good wind data. The existing sources provide data of inferior quality; such as, reanalysis data with spatial resolution that is too coarse, model data that is insufficiently validated, observational time series that are too short, data with restrictions or data that is too costly. A lack of recommended practices and standards for wind data analysis was also reported by some participants.

Whether existing databases, such as, "winddata.com", which was originally an IEA initiative, are updated any longer or not, was subject to some discussion. Several model wave databases exist, but more measured time series are needed. The participants reached the consensus that simultaneous measurements of waves and wind are needed. To perform and compile these data, a recommendation on how these should be performed and documented would be needed.

The meeting discussed how the needs for standards and recommendations could be met. A joint effort is needed with support coming from the parties in such an effort. IEA can aid efforts in this direction, but it can not finance them.

3.3 Radar, radio and wind turbines

3.3.1 Background

The objective of the workshop was to create a forum for discussion of a topic of great importance to stakeholders in the wind power business and was a follow up of the meeting held in the UK in 2005.

3.3.2 Summary

The discussion centered on the future exchange of knowledge within this area. Most participants were in favor of establishing a new subtask within IEA Wind Task 11. Interest was expressed in increasing the dissemination of information by way of an open access website where reports and test results could be shared. Other recommendations to improve communication channels and future TEM meetings included:

- Arrange future TEM meetings to include a session for 'break-out' workshops to enable technical subgroups to discuss specific topics. Recommendations from each subgroup can then be reported back to the task group.
- Put forward a proposal to set up a 'new' task area, which specifically addresses radar, radio, and wind turbines topics and issues.
- Increase awareness of existing working groups.
- Create a central holding for IEA projects papers, etc.
- Involve wind energy associations such as EWEA.

To initiate these recommendations the UK representative for the DTI agreed to liaise with relevant participants and then circulate a note to the IEA Wind operating agent indicating preferred forum for continued discussion on the radar/turbine issue. The IEA operating agent offered assistance to provide documentation and facilitate these recommendations.

3.4 Social acceptance of wind energy projects

3.4.1 Background

Increasing the share of renewable energy is high on the policy agenda in countries around the world. Several governments have set ambitious targets and have started to implement support schemes aimed at facilitating market implementation. The degree to which these policies have been successful varies between countries, but wind energy stands out with the most impressive growth rates in some countries.

As wind turbines are spreading, however, it has been increasingly recognized that there is one factor that can potentially be a powerful barrier to the achievement of renewable energy targets: social acceptance. Germany, as the country with the largest number of installed wind turbines worldwide, has seen the media picking up on the theme of local resistance to new wind energy projects. Countries that are only at the beginning of the diffusion curve, such as the Netherlands, Switzerland, and the UK, are also facing vivid debates on local and sometimes national levels.

While debates of social acceptance are not totally new to the energy sector - just think of contested siting decisions for nuclear power plants, nuclear waste storage facilities, or large hydropower dams - this issue needs to be urgently addressed if policies are to be implemented successfully.

3.4.2 Summary

The participants in the meeting concluded that there are a number of things which can be done on an R&D level to support the deployment of wind energy. The areas of interest covered the following:

- Socio-political acceptance: top-down vs. bottom-up initiatives, communication, feedback loops between socio-political acceptance and market acceptance;
- Community acceptance: international learning processes between opponents (or proponents) of windpower, what are the most effective ways for planners to create a "sense of ownership" among local stakeholders? Objective measures for landscape perception;
- Market acceptance: business models for wind energy developers, customer segmentation: What is it that really makes consumers buy renewable energy, and how does this key motivation differ between customer segments? In-depth case study of the internal diffusion process of pro-wind energy attitudes within (large) energy companies.

3.5 Long-term research needs

3.5.1 Aim and objectives

The aim of the Topical Expert Meeting was to discuss long-term research needs for the timeframe 2020. The objective to identify needed future results from R&D in different time frames. The strategic goal of the TEM was to give recommendations to the IEA Wind ExCo and to the governments involved which are at the latest international wind technological stage. The outcome of the meeting will be used to develop a new strategic R&D plan for IEA Wind.

The objectives were to review the latest wind energy technology and to draw conclusions for further successful development to expand the place of wind energy in the world's energy mix by means of R&D.

3.5.2 Summary

The chair made a comparison of between the outcomes of today's meeting and a similar meeting held in 2001. It was noted that there are new initiatives coming from other organisations that look into R&D needs. It is obvious that there are a number of new players in the R&D arena today. Ongoing activities which aim at identifying R&D topics include structured initiatives for identifying R&D such as the EU/EWEA TPWind, REOLTEC, and MEGAWIND. Windpower with its application in a broader sense was discussed such as wind – hydro – pump storage and plug-in hybrids, and vehicles to grid. Education and knowledge transfer networks are considered to be a crucial topic for the industry and utilities. In some areas it is difficult to recruit persons with adequate skills. Reliability and operation & maintenance is becoming more and more important. Especially considering the number of failures that occur in wind turbines.

The meeting summarized the list of R&D topics as follows:

- Wind field and sea state knowledge and models
- Turbine development, concept, blades, drive trains, and smart structures
- Internal grids and grid connection
- Components and reliability issues
- Tower development, everything that minimises loads on the towers
- Offshore foundations, fixed and floating, and deeper water solutions
- O&M and reliability
- Environmental impact and recycling
- Education.

These results will serve as input for updating the IEA Wind Strategy on Long-Term Research Needs.

4.0 Plans for 2007 and beyond

Task 11 has been extended through 2008 and a new work plan was approved to continue coordinating Topical Experts Meetings and Joint Action Symposia. Four meetings of this type will be arranged during 2008. Examples of meetings include, but will not be limited to the following.

- Smart structures
- Gear boxes and drive train dynamics
- Noise and noise propagation models
- Forecasting.

Work related to the development of a Recommended Practice on the use of sodar for measuring wind speeds will continue.

All documents produced under Task 11 are available to organizations within the countries that participate in the Task: Canada, Denmark, European Commission, Finland, Germany, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Organizations within these countries can receive the newest documents from the Operating Agents representative. All documents more than one-year old can be accessed on the public Web pages for Task 11 at www.ieawind.org.

Author: Sven-Erik Thor, Vattenfall, Sweden.

Chapter 3 Task 19

Wind Energy In Cold Climates

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.

In order 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. The resulting research Task 19 began in May 2001 and continued for three years. At the end of the first three-year period, the participants decided to extend the cooperation. The main driver was the need to better understand wind turbine operation in the cold climates and also to gain benefit from the results of the national projects that were launched during the first three years. Continuation of Task 19 through 2008 was approved by the ExCo. Table 1 lists the participating countries in 2007.

The expression "cold climate" was defined to mean sites where turbines are exposed to low temperatures outside the standard operational limit and to sites where turbines face icing. These conditions retard energy production during the winter. Typically such sites are often elevated from the surrounding landscape or located in high northern latitudes (1) (Figure 1).

2.0 Objectives and Strategy

The objectives of Task 19 are to:

• 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 to estimate the effects of ice on production. A better method would reduce incorrect estimates and therefore the economic risks that are involved in cold climate wind energy projects currently. Verify the method on the basis of data from national projects as possible;
• 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 applying wind energy in cold climates to guidelines.

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

Table 1 Countries Participating in Task 19 During 2006	
Country	Institution
Canada	Natural Resources Canada
Finland	VTT Technical Research Centre of Finland (Operating Agent)
Germany	ISET
Italy	University of Trento
Norway	Kjeller Vindteknikk
Sweden	WindREN AB
Switzerland	ENCO (for Swiss Federal Office of Energy)
USA	NREL

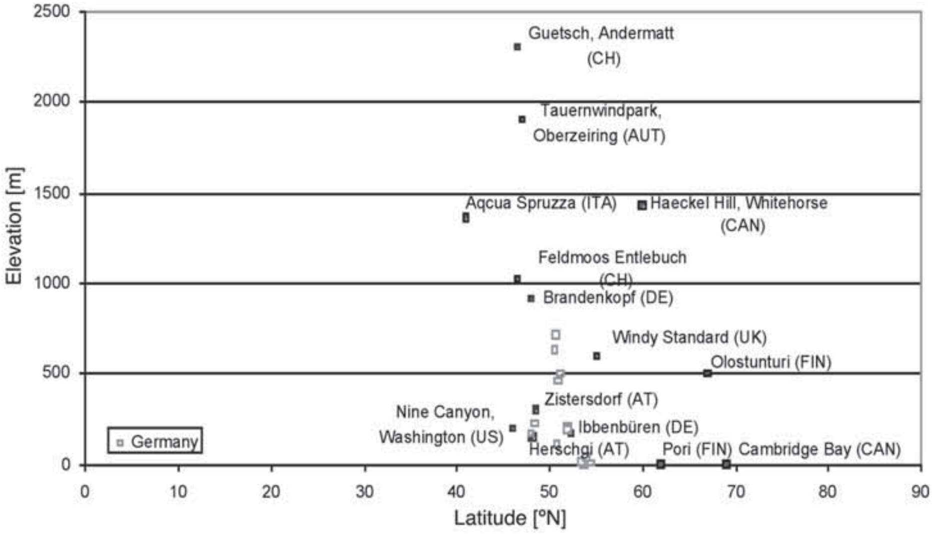


Figure 1 Location of selected sites that experience cold climate conditions annually.

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-operations. Some take part to the European Union funded COST727 action, which aims at improving the European-wide ice measurement network and forecasting atmospheric icing. This information benefits directly the work of the Task 19.

The co-operation will continue to disseminate actively the results through the Internet page of the Task 19 (http://arcticwind .vtt.fi) and in conferences and seminars (2–6). At the end of the current task period (2008), a final report will be published that contains updated state-of-the-art of technology and updated recommendations regarding the use of wind turbines at sites where winter conditions prevail significant amount of a 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 2007

During the year, one meeting was held in September in Kassel, Germany, hosted by Institutt fur Solaren Energieteknologien (ISET). Two invited presentaions were given: A GL-Technical Note for Cold Climate – An Overview, Mike Wöbbeking, Germanischer Lloyd Industrial Services GmbH and Antifreeze Coatings for Rotor Blades from Wind Turbines, Dr. Konstantin Siegmann, Institute of Materials and Process Engineering, Zürcher Hochschule Winterthur. As a result of the meeting, Germanischer Lloyd was engaged to review the Recommendations reports (5, 6).

At the meeting, participants discussed the need to continue activities in the wind energy in cold climates. The need for continuation in one way or another was expressed. The issue of low temperatures is mentioned in standards and recommendations; however, icing 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 the present Task. There may be a need to continue this work beyond the present term of the Task but it was considered too early to take a position on the issue.

The project website at http://arcticwind.vtt.fi has been updated and serves as an extranet among the participants of Task 19.

4.0 Plans for 2008

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

- publish updated state-of-the-art-report;
- publish updated recommendations report;
- complete database of wind turbines in cold climates;
- complete database of relevant reports.

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

References:

(1) *State of the art of wind energy in cold climate*, T. Laakso, H. Holttinen, G. Ronsten, L. Tallhaug, R.Horbaty, I. Baring-Gould, A. Lacroix, E. Peltola, B. Tammelin, IEA Wind Annex XIX, 53 p., 2003, http:\arcticwind.vtt.fi, date of access 31.1.2006.

(2) *Cold climate wind energy co-operation under the IEA*, Jonas Wolff, Per Lundsager, Lars Tallhaug, Göran Ronsten, Ian Baring-Gould, Proceedings of Boreas V, Levi, Finland, 2000.

(3) *The state of the art of wind energy in cold climates*, H. Holttinen, G. Ronsten, L. Tallhaug, P. Lundsager, R. Horbaty, I. Baring-Gould, A. Lacroix, E. Peltola, T. Laakso, Proceedings of GWPC, Paris, France 2002.

(4) *IEA co-operation on wind turbines in icing and cold climates*, E. Peltola, T. Laakso, G. Ronsten, L. Tallhaug, R. Horbaty, I. Baring-Gould, A. Lacroix, Proceedings of Boreas VI, Pyhätunturi, Finland, 2003.

(5) *Specific recommendations for the development of wind energy projects in cold climate*, T. Laakso, E. Peltola, G. Ronsten, L. Tallhaug, R. Horbaty, I. Baring-Gould, A. Lacroix, Proceedings of EWEC, London, UK, 2004.

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

Authors: Esa Peltola, VTT Processes, Finland and Timo Laakso, Pöyry Energy, Finland.

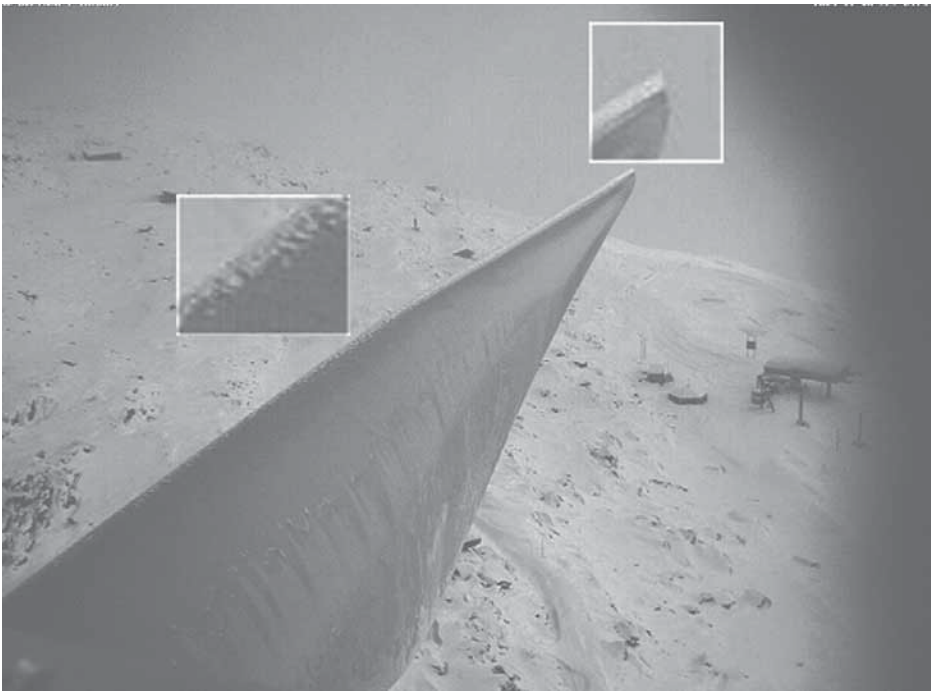


Figure 2 Wind turbine within walking distance from a ski lift in Gütsch. Turbine is equipped with a de-icing system. Photo: ENCO AG, Switzerland.

Chapter 4 Task 20

HAWT Aerodynamics And Models From Wind Tunnel Measurements

1.0 Introduction

As wind energy deployment advances worldwide and wind turbines continue to grow larger, improving wind energy performance will require more accurate and reliable aerodynamics models. Attainment of this goal demands that theoretical and computational modeling develop in concert with experimental measurements of comparable accuracy and reliability. Over the past decade, turbine aerodynamics measurement instrumentation and data quality have improved substantially as a result of efforts like IEA Wind Task 14 Field Rotor Aerodynamics and Task 18 Enhanced Field Rotor Aerodynamics Database.

During Tasks 14 and 18, turbine sizes and configurations were comparable to state-of-the-art turbines and aerodynamic measurements were representative of operational machines. Although of high quality, these measurements contained atmospheric inflow fluctuations and anomalies, which precluded clear discernment of complex turbine aerodynamics. Alternatively, wind tunnel experiments offered steady, uniform inflows capable of revealing turbine aerodynamic structures and interactions. However, wind tunnel dimensions generally restricted turbine size and left doubt as to whether data thus acquired were typical of full-scale turbine aerodynamics.

In order to acquire turbine aerodynamics measurements typical of full-scale turbines under conditions of steady uniform inflow, the National Renewable Energy Laboratory (NREL) UAE (Unsteady Aerodynamics Experiment) wind turbine was tested in the NASA Ames 80-ft by 120-ft (24.4-m by 36.6-m) wind tunnel. This test was designed to provide accurate and reliable experimental measurements having high spatial and temporal resolution, for a realistic rotating blade geometry, under closely matched Reynolds number conditions, and in the presence of strictly controlled inflows. Completed in 2000, the test included 22 turbine configurations and produced nearly 2,200 data files containing approximately 100 GB of high-quality data.

Within months of test completion, select data were used as reference standards in a blind code comparison intended to evaluate wind turbine aerodynamics code fidelity and robustness. In this exercise, participants were given detailed UAE geometry and structural properties, and then they attempted to predict aerodynamic response for a modest number of test cases representing varied aerodynamic regimes. Code comparison participants did not have access to the experimental aerodynamics data until well after their model predictions were completed and submitted to NREL. Model types included blade element momentum models, prescribed wake models, free wake models, and Navier-Stokes codes. Results showed unexpectedly large disagreements between predicted and measured data. It should be noted that no consistent trends were apparent regarding the magnitudes or the directions of these deviations. The need for improved wind turbine aerodynamics models is clear, and the potential benefits are readily apparent. This IEA Wind research Task 20 was established to capitalize on high quality experimental aerodynamics data from the NREL UAE wind tunnel test, as well as comparable data from other sources. Appropriately analyzed, these data will yield unique and unprecedented findings regarding turbine aerodynamics. This information can be exploited to formulate and validate improved wind turbine aerodynamics models. More accurate, reliable models will improve wind energy machine design and continue the trend toward lower cost wind energy.

2.0 Objectives and Strategy

Task 20 research objectives and work areas are mutually consistent and structured to transition aerodynamics data to accurate, robust wind turbine aerodynamics models for machine design and analysis.

- Acquire accurate, reliable, high-resolution experimental aerodynamic and structural loads data for horizontal axis wind turbines representative of full-scale machines.
- Analyze these data using methodologies designed to reveal the flow physics responsible for phenomena observed on horizontal axis turbines.

Figure 1 NREL Unsteady Aerodynamics Experiment wind turbine in NASA Ames 80 foot by 120 foot wind tunnel.

• Formalize this understanding in hierarchically structured, physics-based model subcomponents, with appropriate consideration for computational efficiency.
• Integrate model subcomponents into comprehensive models in incremental fashion, as a basis for accurate, robust prediction of horizontal axis wind turbine aerodynamics and structural loads.

During 2007, Task 20 included the eight original member countries of Canada, Denmark, Greece, the Netherlands, Norway, Spain, Sweden, and the United States. In addition, two other IEA Wind member countries, Germany and the United Kingdom, participated through Task 11 collaborations (See Chapter 2). The organizations within these countries that contributed include the following:

• Center for Renewable Energy Systems (CRES), Greece
• Centro Nacional de Energias Renovables (CENER), Spain
• Denmark Technical University, Denmark
• École de Technologie Supérieure, Canada
• Energieonderzoek Centrum Nederland (ECN), the Netherlands
• Garrad Hassan & Partners, the United Kingdom
• Gotland University, Sweden

- Institutt for Energiteknikk, Norway
- Kiel University of Applied Science, Germany
- LM Glasfiber, Denmark
- National Renewable Energy Laboratory (NREL), the United States
- Risø National Laboratory, Denmark
- Royal Institute of Technology, Sweden
- Technical University of Delft, the Netherlands
- University of Liverpool, the United Kingdom
- Vestas, Denmark.

In the initial stages of Task 20, data acquired during the UAE wind tunnel test were hosted on the UAE Database website (http://www.nrel.gov/uaewtdata/), which was established and continues to be maintained by NREL. Website access can be obtained by requesting a user account through the Task 20 Operating Agent Representative (Scott Schreck, scott_schreck@nrel.gov). Currently, approximately 30 user accounts have been set up, and nearly 70 users have acquired data for diverse applications. If unique UAE data not available on the website are needed, special arrangements can be made with the Operating Agent Representative. At present, all Task 20 participants have acquired aerodynamic or structural loads data from the Unsteady Aerodynamics Experiment Database website. They also have carried out any data verifications or uncertainty analyses considered necessary in view of the manner in which they intend to use the data.

3.0 Progress in 2007

In 2007, most participants continued research activities previously proposed and initiated under Task 20. In addition, some new activities were initiated as new researchers joined the task. Research results were presented and discussed at the Task 20 Annual Progress Meeting, which was hosted at Risø National Laboratory, June 14–15, 2007. As with the previous four Task 20 meetings held in 2003 through 2006, the 2007 Task 20 meeting was conducted in collaboration with the Task 11 Aerodynamics of Wind Turbines Joint Action Symposium meeting.

At the June 2007 Task 20 annual meeting, researchers representing their respective countries reported on work carried out during the preceding year. The speaking program for the 2007 meeting is shown below, as it was organized and conducted during the meeting.

- Rotor Aerodynamics and Power Extraction
  Analysis of the Optimum Rotor of Betz, J. Sørensen, Technical University of Denmark; Energy Extraction Limits, P. Jamieson, Garrad Hassan & Partners; A Verification Study of the BEM Model and a Proposal for Two Modifications, H. A. Madsen, Risø National Laboratory; Can Winglets Increase Cp ... and How Much?, M. Gaunaa, Risø National Laboratory; Airfoil Design for Wind Turbines Considering Structural and Aerodynamic Characteristics, C. Bak, Risø National Laboratory.
- Analysis of Measurements
  Unsteady Aero for Annex 20 and MEXICO, H. Snel, ECN; Experimental Analysis of 3D Dynamic Stall on the NREL Phase VI Parked Bladed, X. Munduate and A. Gonzalez, CENER; LM Wind Tunnel Aerodynamics Commissioning, P. Fuglsang, LM Glasfiber; Rotationally Augmented Flow Structures and Time Varying Loads on Turbine Blades, S. Schreck, NREL.
- Wake Computations and Analyses
  Numerical Stability Analysis at a Wind Turbine Wake, S. Ivanell, Gotland University; Simulation of Wake of Wind Turbine Operation in Various Inflow Conditions, N. Troldborg, Technical University of Denmark; 3D Actuator Disc Modelling of Wind Farms with Navier-Stokes, R. Mikkelsen, Technical University of Denmark; On the Influence of Wake Resolution in Wind Turbine Flow Simulations, F. Zahle, Risø National Laboratory.
- Rotor Aerodynamics CFD and Design I
  Engineering Models vs. CFD Models with Respect to Augmented Lift Caused by Rotation, R. van Rooij, Delft University of Technology; Simulation and Control of Wind Turbine Flows Using Vortex Generators, C. Velte, Technical University of Denmark; Stochastic Modeling of Blade in Stall, F. Bertagnolio, Risø National Laboratory; Development of CFD Method for Aerodynamic Analysis of Large Diameter HAWT, G. Barakos, Liverpool University; Initial Investigation of Offshore Wind

Turbine Concept, A. Knauer, Institutt for Energiteknikk.

• Rotor Aerodynamics CFD and Design II 3D Transition Prediction of Wind Turbine Blades, P. Schaffarczyk, Kiel University of Applied Science; Rotational Effects on Wind Turbine Blades for Transition Prediction, G. Hernandez, Technical University of Denmark; A Comparison of Fatigue Loads of Wind Turbine Resulting for a Non-Gaussian Turbulence Model vs. Standard, H. Gontier, Kiel University of Applied Science; Rotor Aerodynamics in Wind Shear, N. Sørensen.

4.0 Plans for 2008

The June 2007 meeting was the final technical progress meeting for Task 20. Subsequently, participants documented their Task 20 research and submitted their summaries to the Operating Agent Representative to be integrated with the Task 20 final report. The Task 20 final report will be published by NREL and will be available on the IEA Wind Web site www.ieawind.org in 2008.

Author: Scott Schreck, NREL's National Wind Technology Center, United States.

Chapter 5 Task 21

Dynamic Models of Wind Farms for Power Systems Studies

1.0 Introduction

Large wind power installations may have a significant impact on power system stability that must be assessed prior to installation. To do this, accurate dynamic wind generation models are critical. Hence, model validation is a key issue and taken up by IEA Wind Task 21. The task began in 2002 and has developed a systematic approach for benchmark testing of models. The rationale for the proposed benchmark testing is that dynamic wind generation models are being applied for assessing grid connection of large wind farms, even though model accuracy is not always known. This, at best, leads to uncertainty in the market, and, at worst, to an erroneous design jeopardising power system stability. The challenge is twofold. First, the technology in modern wind farms is fairly complex, and their dynamic behavior may differ significantly depending on the wind turbine type and manufacturer's specific technical solutions. Thus, it is not trivial to develop accurate wind generation models. Second, model validation must be transparent and adequate for providing confidence. In this respect, Task 21 has contributed by describing a benchmark procedure and applying this procedure for testing numerical wind generation models.

2.0 Means and Objectives

Task 21 is carried out on a cost- and task-shared basis. The participants contribute with financial support to the Operating Agent and carry out activities, supply information, and join meetings as required to meet the task objectives.

The overall objective is to assist in the planning and design of wind farms by facilitating a coordinated effort to develop wind farm models suitable for use in combination with software packages for simulation and analysis of power system stability. The effort comprises the following immediate objectives and activities:

- Establish an international forum for exchanging knowledge and experience within the field of wind farm modelling for power system studies.
- Develop, describe, and validate wind farm models. (The wind farm models are developed by the individual participants of the task, whereas the description and validation are coordinated by the task, which helps provide state-of-the-art models and pinpoint key issues for further development.)
- Set-up and operate a common database for benchmark testing of wind turbine and wind farm models as an aid for securing good-quality models.

3.0 Status

The Task has participants from nine countries (Denmark, Finland, Ireland, the Netherlands, Norway, Portugal, Sweden, the United Kingdom, and the United States). Research institutes and universities carry out work to develop and test wind farm models, as well as completing grid studies in cooperation with wind turbine manufacturers and electric utilities. In total, participants of the Task have contributed with more than 20 labor-years of work effort. Cooperation within the task is through sharing measurement data, sharing model descriptions, and discussing work at meetings. A total of eight task meetings have been arranged.

Model developments are ongoing among participants, including both fixed- and variable-speed technologies and by using various software tools (Matlab/Simulink, PSS/E, SIMPOW, DIgSILENT, and EMTDC).

An internet "e-room" has been established for sharing documents and measurement data among the participants of the task. The database part of the e-room contains measurements from fixed and variable speed wind turbines.

A method for benchmark testing of models has been established by the Task, and selected models developed by the Task participants have been tested. The tests include both validation against measurements and model-to-model comparisons, and they consider dynamic operation during normal, fault-free conditions and response to voltage dips. See Figures 1 and 2 for examples of measurements and simulations of response to voltage dips. In total, some 14 models have been tested, including models of both fixed speed and variable speed wind turbines.

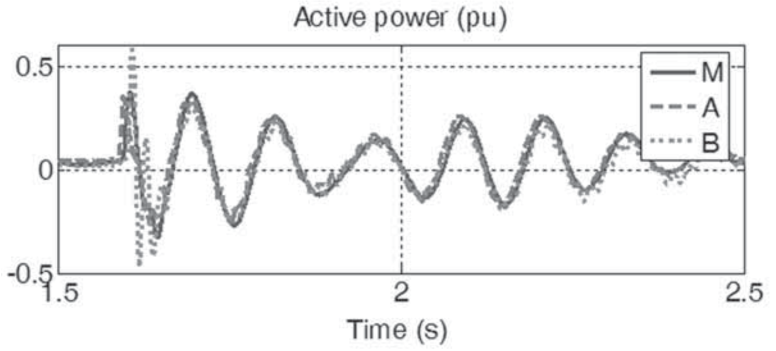


Figure 1 Time-series plot of measured and simulated active power output from a fixed-speed, stall-controlled wind turbine with squirrel-cage induction generator during a voltage dip on the grid. M is measurement; A and B are simulations.

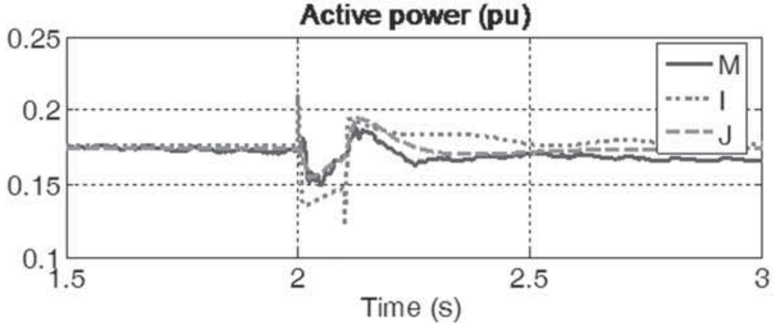


Figure 2 Time-series plot of measured and simulated active power output from a variable-speed wind turbine with doubly-fed induction generator during a voltage dip on the grid. M is measurement; I and J are simulations.

A topic of high interest is the ability of wind turbines to ride through temporary grid faults, hence, contributing to grid stability. Detailed numerical models may be used to assess such abilities, but these models must be validated against measurements to provide confidence. A proposal emerging as a spin-off from Task 21 is to update IEC 61400-21 (Measurements and assessment of power quality characteristics of grid connected wind turbines, ed. 1, 2001) to specify requirements for such testing. This work is now about to conclude with the circulation of IEC 61400-21, ed. 2 as a Final International Draft Standard by spring 2008. Hence, in the future, wind turbine manufacturers may refer to standard test certificates for demonstrating performance under grid transients, and also these same test certificates may be used for validating dynamic models of wind farms for power system studies.

The work of Task 21 including description of the benchmark test procedure and presentation of test results provide for a significant technical contribution. The Task is the first to present a systematic comparison of wind generation models against measurements. The test results give a clear indication of accuracy and usability of the models tested, and pin-point the need for both model development and testing.

The final report and parts of the measurement data will be available for download by mid 2008. Additional information about Task 21 can be found on the Internet at http://www.energy.sintef.no/wind/IEA.asp.

Author: John Olav Tande, SINTEF Energy Research, Norway.

Chapter 6 Task 23

Offshore Wind Energy Technology and Deployment

1.0 Introduction

Installing wind turbines offshore has a number of advantages compared to onshore development. Onshore, difficulties in transporting large components and opposition due to various siting issues, such as visual and noise impacts, can limit the number of acceptable locations for wind parks. Offshore locations can take advantage of the high capacity of marine shipping and handling equipment, which far exceeds the lifting requirements for multi-megawatt wind turbines. In addition, the winds blow faster and smoother at sea than on land yielding more electricity generation per square meter of swept rotor area. In addition, larger onshore wind farms tend to be in somewhat remote areas, so electricity must be transmitted over long power lines to cities. Offshore wind farms can be closer to coastal cities with relatively shorter transmission lines, yet far enough away to reduce visual and noise impacts.

Good wind resource, proximity to load centers, and expansion of development areas are some of the reasons why development of offshore wind energy is moving forward. By the close of 2007, there were 1,125 MW of offshore wind power operating in Denmark, Finland, Germany, Ireland, Japan, the Netherlands, Sweden, and the United Kingdom. During 2007, 234 MW of offshore wind energy was installed, 100 MW in Sweden alone and 90 MW in the UK. China, Germany, Norway, Spain, and the United States all have plans to install their first offshore wind farms within this decade. Figure 1 shows how the current offshore capacity is distributed among countries.

Challenges for offshore development include higher initial investment costs resulting from purchase of large machines and sub-sea cables to shore and more difficult access to the turbines, resulting in higher maintenance costs. Also, the environmental conditions due to salt water and additional loads from waves and ice are more severe at sea and nature protection issues are different.

Despite the difficulties of development, offshore turbines hold great promise for expanding wind generation capacity. For many countries in Europe, the space available for wind turbines offshore is larger than for onshore. For example, in the Netherlands roughly 3 GW of wind power could be installed in areas available outside the 12-mile zone (about 22 km) with a water depth of less than 20 m. The Netherlands shares this advantage of shallow water with countries such as Belgium, Denmark, Germany, and the United Kingdom.

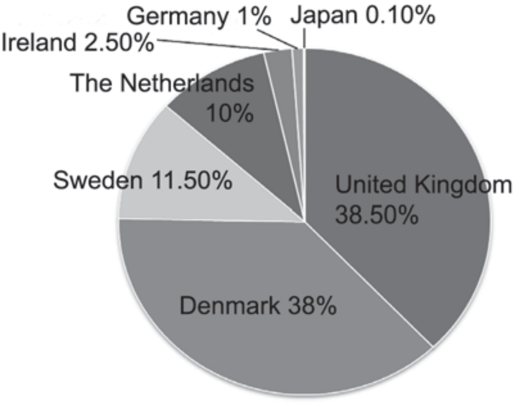


Figure 1 Offshore wind projects installed by the end of 2007, based on a total of 1,125 MW.

Recognizing the interest and challenges of offshore development of wind energy, IEA Wind Task 11 sponsored a Topical Experts Meeting (TEM #43) on Critical Issues Regarding Offshore Technology and Deployment in early 2004 in Denmark. The meeting gathered 18 participants, representing Denmark, Finland, the Netherlands, Sweden, the United Kingdom, and the United States. Presentations covered both detailed research topics and more general descriptions of current situations in the countries. After the meeting, the IEA Wind ExCo approved Annex 23 (Task 23) to the Implementing Agreement, as a framework for holding additional focused workshops and developing research projects. The work would increase understanding of issues and develop technologies to advance the development of wind energy systems offshore. In 2007, 10 countries have chosen to participate in this IEA Wind task, and many research organizations within these countries are sharing their experiences and conducting the work.

2.0 Objectives and Strategy

The overall objectives of Task 23 include:

- Organize workshops on critical research areas for offshore wind deployment. The goal of the workshops is to identify R&D needs of interest to participating countries, publish proceedings, and conduct joint research activities for the Annex participants.
- Identify joint research tasks among interested countries based on the issues identified at the Topical Expert Meeting #43.
- Conduct R&D activities of common interest to participants to reduce costs and uncertainties.

This task has been organized as two subtasks. Subtask One, Experience with Critical Deployment Issues, is lead by Risø National Laboratory (Risø) in Denmark; and Subtask Two, Research for Deeper Water, is led by the National Renewable Energy Laboratory (NREL) in the United States. The Task 23 structure is shown in Figure 2.

3.0 Progress in 2007

3.1 Subtask One: Experience with critical deployment issues

Statistics show a global wind energy capacity in 2007 approaching 1% of the global electricity capacity. Estimates made by international organizations and experts all predict a huge increase in wind energy development over the next 20 years and also on a longer term. Much of this development will be offshore wind energy. This implies that billions of euros will be invested in offshore wind farms over the next decades.

The aim of Subtask 1 therefore is to support this development by maintaining an overview of research activities with relevance to offshore wind energy within the scope of IEA Wind Task 23; arranging workshops where participants will inspire each other and test research results in order to improve results; and making research results available to decision makers in order to pave the way for new capacity.

The work in Subtask One has been divided into the following three research areas.

Research Area 1: Ecological Issues and Regulations. A first workshop for Research Area 1, Ecological Issues and Regulations, was planned to take place in Petten, Netherlands, in February 2008. The workshop had a registration of about 20 scientists and the introductory note included the following objectives.

- Provide a state-of-the-art overview of the knowledge of impacts of offshore wind turbine systems on the marine environment.
- Assess the consequences of regulatory frameworks, such as requirements for Environmental Impact Assessments (EIA's) and protection measures for nature reserve areas.
- Generate ideas for frameworks on how results of nature research can be used to (re) formulate regulations and legislation.
- The conclusions and recommendations, to be published in 2008, may stimulate

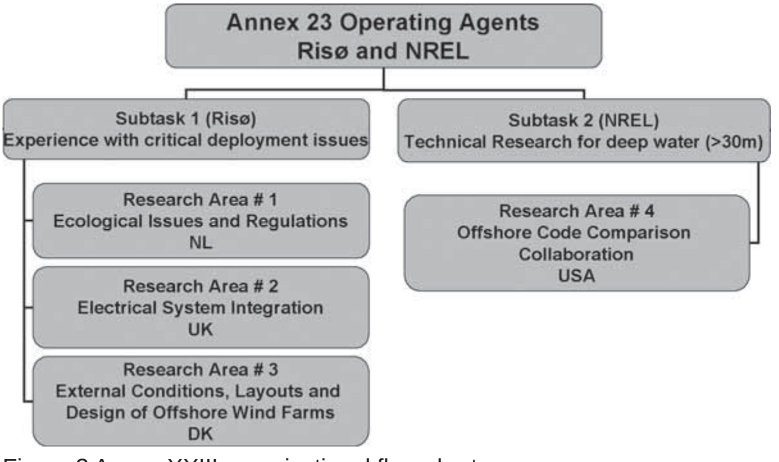


Figure 2 Annex XXIII organizational flow chart

both national research and policy developments and future IEA Wind activities.

Research Area 2: Grid Connection. In September 2005, at the first workshop at Manchester University, the United Kingdom, it was decided to focus the work program on five issues covering the subjects related to connection of Offshore Wind Farms to Onshore Grids. These are: Offshore wind meteorology and impact on power fluctuations and wind forecasting; behavior and modeling of high-voltage cable systems; grid code and security standards for offshore versus onshore; control and communication systems of large offshore wind farms; technical architecture of offshore grid systems and enabling technologies.

In 2006, a planning meeting was held at Risø and it was decided to two meetings in 2007, and one meeting in 2008. The five issues originally decided for this collaboration were maintained as work items for the three meetings. These meetings may identify the need for additional workshops and meetings. Also, participants agreed to supply information about projects in the member countries that will contribute to the IEA Wind collaboration, i.e. projects where it is agreed to supply detailed project information, including results for the benefit of coordinating the activities under this IEA Wind task.

A workshop on Grid Integration of Offshore Wind was conducted in June 2007, in London, the United Kingdom. The main issues included sharing of experience and knowledge specific to the grid connections for offshore wind generation plant and discussions on appropriate regulatory frameworks for connecting offshore wind farms.

An important part of the meeting was a brief overview of the situation in the UK. In that country, a number of early (Round 1) offshore wind farms are already connected to the onshore grid via low voltage connections (33kV). Larger Round 2 projects will be connected via offshore transmission systems (132kV +). Significant work has been undertaken by the Department for Trade and Industry and the industry regulator, OFGEM, to develop an appropriate regulatory framework for offshore transmission. The UK government announced the appropriate model to follow for offshore, tenders will be held for regulated licenses to connect specific offshore projects, and minimum security standards which should apply to offshore have been consulted on.

Research Area 3: External Conditions, Layouts and Design of Offshore Wind Farms. The first workshop was held in December 2005 at Risø, Denmark. At the workshop, wake modeling and benchmarking of models, marine boundary layer characteristics, and met-ocean data and loads were identified to be included in the future work program. As a result, a workshop on wake modeling and benchmarking of models was held at the Danish Test Station for large Wind Turbines, Høvsøre and Billund in Jutland, Denmark. The presentations and the discussions at that workshop indicated a great need for further collaboration and exchange of data in order to develop and verify computational models and to understand the physics of wakes and meteorological backgrounds.

In addition to the work of IEA Wind Task 23, the EU R&D project UPWIND includes similar activities. To multiply the benefits from both activities, coordination will take place between the members of IEA Wind Task 23 and partners of UPWIND. During 2008, the benchmarking experience and the results obtained from the continued collaboration, also with UPWIND, will be analysed and discussed.

For the identified research areas, marine boundary layer characteristics and met-ocean data and loads, a collaboration between two IEA Wind Tasks (11 and 23) resulted in a topical expert meeting (TEM) under Task 11 in January 2007. The meeting was titled the State of the Art of Remote Wind Speed Sensing Techniques Using Sodar, Lidar, and Satellites. These are very important techniques to explore boundary layer characteristics and offshore loads to wind turbines. These issues will be considered in an offshore context and separate arrangements will be offered if relevant. Additional collaboration took place when an IEA Wind Task 23 meeting was held in February 2007 in conjunction with a German Offshore Conference and the EU policy seminar on offshore wind.

A workshop with focus on the continued preparations for benchmarking is scheduled to take place in Denmark during the second half of 2008. This event will be coordinated with a workshop in Germany on Wakes Measurements and Modeling within and downwind of wind farms, current features and future trends in June or July 2008.

3.2 Subtask Two: Technical research for deeper water

Subtask Two focuses on technical issues associated with deeper water implementation of offshore wind energy. In practice it has included modeling of shallow water and deep water since many of the modeling issues are similar and it is important to benchmark the codes for shallow water where there is some experience. The official name of this working group is the Offshore Code Comparison Collaborative (OC^3).

The group has focused on benchmarking structural dynamics models used for estimating offshore dynamic loads. Since this effort requires intense collaboration, periodic meetings over the Internet have been established as the main form of collaboration with several physical meetings scheduled at key points in the project. To help with exchanging information, an IEA Wind web site has been set up for the subtask (access from www.ieawind.org Task Web Sites). A complete project plan can be found on the public sections of this web site, other sections are only available to Task 23 participants.

Currently, conservative offshore design practices adopted from marine industries are enabling offshore development to proceed. However, if offshore wind energy is to be economical, design reserve margins must be quantified and uncertainties in the design process must be reduced so that appropriate margins can be applied. Uncertainties associated with load prediction are usually the largest source and hence the largest risk. Model comparisons are the first step in quantifying and reducing load prediction uncertainties. Comparisons with test data would be the next step.

The objectives of this group include: identify and verify model capabilities and limitations; establish confidence in predictive capabilities; establish analysis methodologies; and identify areas needing further research and testing.

This project is designed to address near-term needs of the industry as well as future needs. Currently, the industry is focused on bottom-fixed shallow-water applications, especially in Europe where shallow water sites are plentiful. Deeper water sites are more common in Greece, Republic of Korea, Japan, Norway, Spain, the United States, and many other countries. This project should include support structures that are likely to become solutions for these markets also. The scope of this collaboration includes technologies ranging from the current shallow-bottom monopiles to deep-water floating platforms.

- Water Depth: 5 m – greater than 200 meters
- Support structures: monopiles to floating
- Wave loading models: linear and non-linear (breaking)
- Uncoupled and coupled dynamic models: FAST, ADAMS, BLADED, HAWC, HAWC2, BHAWC and FLEX5 (as modified by Vestas, Elsam & Stuttgart)
- Not included: aerodynamic models, turbulence models, various turbine types, controls.

This work has been approached as a multiphase project outlined in a project work plan. Phase I was strictly analytical with the goal of verifying the analytical capabilities and differences of the codes of the participants. Phases II, III, and IV will compare codes with various support structures and foundation models as follows.

- Phase I: Baseline turbine model development and comparisons
- Phase II: foundation model development and comparisons
- Phase III: full dynamic modeling of tripod support structure
- Phase IV: Floating system modeling and comparisons.

So far eight physical meetings have been held, and most coincided with other key international forums: United States 1/05; Denmark 1/05; Germany 6/05; Denmark 10/05; United States 6/06; Germany 1/07; Germany 9/07; Germany 12/07. Net meetings are held approximately every two months and continue to be productive. They significantly reduce the need for physical meetings and travel. Reports from Phase I Baseline model, wave models and II Foundation modeling on monopole have been published. The final report will be compiled from all the previous reports with an executive summary written by all participants. This will be written by spring 2009.

Early benefits have already been realized from the cooperation. The baseline turbine model used by OC^3 has been adopted by two major EU UpWind Work Package teams in their aerodynamics and foundation modeling research work. Also the code comparison work to date has established a procedure and database that could be used for future code verification exercises such as the one outlined in EU UpWind Work Package WP 1A1, Integrated Design Approach and Standards. This WP calls for the development of a reference turbine as well as procedures for verifying models and codes. OC^3 has provided a basis for both of these goals.

Active OC^3 participants include commercial enterprises, universities, and research institutes: Acciona Energia (Spain), CarlBro (Denmark), CENER (Spain), DNV (Denmark), Eslam (Denmark), Fraunhofer Institute (Germany), Garrad Hassan (UK), GL Windenergie (Germany), KWEDO (Republic of Korea), Norske Hydro (Norway), NREL (US), NTNU (Norway), Ramboll (Denmark), RePower (Germany), Risø/DTU (Denmark), Siemens (Denmark), Stuttgart (Germany), University of Massachusetts (US), and Vestas (Denmark.)

The natural next step for the OC^3 project is to compare the analytical models to real test data. This is a significant increase in complexity. Usually it is difficult for a public project to gain access to the needed data. Obtaining the model properties is difficult, and they are usually proprietary. The data sets are rarely complete enough for a good comparison with analytical models. Wind inflow data is usually from a single anemometer. Wave data is usually from a single point source. Currents might not be available. So comparisons are usually made on a statistical basis. However, even comparisons relying on statistical data are better than no comparisons at all. The value of such comparisons is that they give analysts and designers a measure of confidence that the loads they are predicting are representative of the conditions the turbines are actually operating in. Therefore, even though such a project is bound to be imperfect, it is essential.

4.0 The Next Term

In 2008, Denmark, Germany, Republic of Korea, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States will continue work in both subtasks. The workshop on offshore wind energy ecology and regulation will generate results. Benchmarking of wake models will continue as well as work on power variability, meteorology, spacing, and control.

Authors: Jørgen Lemming, Risø National Laboratory, Denmark, and Walt Musial and Sandy Butterfield, National Renewable Energy Laboratory, the United States.

Chapter 7 Task 24

Integration of Wind and Hydropower Systems

1.0 Introduction

Within IEA Wind member countries there is over 400 GW of hydropower capacity and in excess of 70 GW of wind power capacity. In many of regions of these countries, wind is being integrated into the electricity supply system in large amounts. Because of the natural variability of wind power production and the inherent uncertainty in its prediction, the impact of integrating wind power into utility operations typically increases the amount of generation reserves required as well as the need for flexible, rapidly responding generation resources. Since hydropower is generally quite flexible and able to provide reserves, many utilities are making use of these characteristics to help meet these increased balancing needs due to wind power. In doing so, many questions arise concerning economics, overall benefit to the electrical system, impacts on hydropower operations, and more.

Because of these questions, attendees at an IEA Wind Topical Experts Meeting in 2003 developed a proposal for IEA Wind Task 24 Integration of Wind and Hydropower Systems. This cooperative research effort, approved by the ExCo in May 2004, offers participants a way to multiply the experience and knowledge gained from individual efforts. This is particularly important since there are many different hydro system configurations in many different electricity markets. In addition, IEA Wind Task 24 cooperates with the IEA Hydropower Implementing Agreement, which is investigating integration of hydropower and wind through a complementary set of investigations. Task 24 is also working with IEA Wind Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power.

Task 24 has two primary purposes:

1) To conduct cooperative research concerning the generation, transmission, and economics of integrating wind and hydropower systems, and

2) To provide a forum for information exchange.

The specific objectives of the Task are:

- To establish an international forum for exchange of knowledge, ideas, and experiences related to the integration of wind and hydropower technologies within electricity supply systems;
- To share information among participating members concerning grid integration, transmission issues, hydrological and hydropower impacts, markets and economics, and simplified modeling techniques;
- To identify technically and economically feasible system configurations for integrating wind and hydropower, including the effects of market structure on wind-hydro system economics with the intention of identifying the most effective market structures; and
- To document experience with case studies pertaining to wind and hydropower integration, and create an Internet report library.

Expected outcomes of the work conducted under Task 24 include:

- The identification of practical wind/hydro system configurations;
- Documentation of the technical and economic feasibility of integrating wind and hydropower systems in specific case studies;
- A consistent method of studying the technical and economic feasibility of integrating wind and hydropower systems;
- Determination of the ancillary services required by wind energy and the electric system reliability impacts of incorporating various levels of wind energy into utility grids that include hydro generation;
- An understanding of the costs and benefits of and the barriers and opportunities to integrating wind and hydropower systems;
- A database of reports describing case studies and wind-hydro system analyses conducted through cooperative research of the Task.

2.0 Research Activities

Member countries and participants in Task 24 are listed in Table 1. The objectives and outcomes of the Task will be achieved through four types of case studies conducted by the participants: grid integration, hydrologic impact, market and economics, and simplified modeling of wind-hydro integration potential. While many case studies may involve all four of these

Table 1 IEA Wind Task 24 Member Countries, Contracting Parties, and Participants		
Country	Contracting Party	Participant
Australia	Australian Wind Energy Association	Hydro Tasmania
Canada	Natural Resources Canada	Natural Resources Canada; Manitoba Hydro; Hydro Quebec
Finland	TEKES National Technology Agency in Finland	VTT
Norway	Norwegian Water Resources and Energy Directorate	Sintef Energy Research; Statkraft Energy
Sweden	Swedish Energy Agency	KTH Swedish Institute of Technology
Switzerland	Swiss Federal Office of Energy	EW Ursern
United States	U.S. Department of Energy	National Renewable Energy Laboratory;
Arizona Power Authority; Bonneville Power Administration; Grant County Public Utility District; Sacramento Municipal Utility District		

topics, some studies may only address and share information related to one or two. Each case study will address problem formulation and assumptions, analysis techniques, and results. The general nature of each type of case study, including the countries that intend to participate is described below.

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) provide many possible combinations of wind, hydropower, balancing areas, and markets, and thus many possible solutions to issues that arise. Hydro generators typically have very quick start-up and response times and may have flexibility in water-release timing. Therefore, hydro generators could be ideal for balancing wind energy fluctuations or for energy storage and redelivery. Studying grid integration of wind energy, particularly on grids with hydropower resources, will help system operators understand the potential for integrating wind and hydropower resources. Each of the seven countries participating in the Task are planning to contribute at least one case study covering a wide variety of system configurations, with some representing 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 Quebec, in Canada. Hydropower facilities vary from run-of-the-river systems with little storage capacity (a day or two), to very large hydro plants with multi-year storage capability. This diversity should allow for a comprehensive look at the grid integration scenarios.

2.2 Hydropower system impact case studies

Depending on the relative capacities of the wind and hydropower facilities, integration may necessitate changes in the way hydropower facilities operate in order to provide balancing or energy storage. These changes may affect operation, maintenance, revenue, water storage, and the ability of the hydro facility to meet its primary purposes. Beyond these potential changes, integration with wind may provide benefits to the hydro system related to water storage or compliance with environmental regulations (e.g., fish passage) and create new economic opportunities. Without a proper understanding of the impacts and benefits, it is unlikely that many hydro facility operators will be interested in utilizing their resources to enable integration of wind power into their respective balancing areas. Thus, study of the impacts of wind integration on hydropower operations to determine the benefits and costs could help pave the way for implementation of wind-hydro projects. Four of the seven countries participating expect to contribute to these studies (Australia, Canada, Norway, and the United States). Examples of hydropower system impacts include the effects on meeting fish flow requirements, reservoir levels for recreation, irrigation deliveries of water, or other priorities in running a hydro facility that may supersede power production. Some of the hydropower facilities being considered have these constraints, while others do not.

2.3 Market and economic case studies

While grid integration and hydropower impact studies may demonstrate the technical feasibility of integrating wind and hydropower systems, implementation will often depend on the economic feasibility of a given project, which in turn depends on the type of electricity market in which the wind and hydro projects are considered. Addressing economic feasibility in the electricity market will provide insight into which market types are practical for wind-hydro integration, as well as identify key factors driving economics. This understanding may provide opportunities to devise new methods of scheduling and pricing that are advantageous to wind-hydro integration and permit better utilization of system resources. These market and economic case studies will address the effects of today's market structures on wind-hydro system economics with the intention of identifying the most-effective market structures. Economic studies that consider the value of wind energy generation and hydropower to the electricity customer are of greatest interest. Because economic feasibility is germane to integrating wind and hydropower, each participating country will contribute to these studies. Initial results of the case studies are consistent with other wind integration studies in that the efficiency and liquidity of the electricity market has a large influence on the economics, frequently dominating all other factors. Further, an important factor in interpreting the economic consequences of integrating wind with hydro is the perspective taken by the study: for the overall benefit of the electric customer vs. a single actor in the market (e.g. a utility, a wind developer, etc.).

2.4 Simplified modeling of wind-hydro integration potential

Of keen interest are methods for estimating the amount of wind power that can be physically or economically integrated into a balancing area with existing hydropower generation based upon the characteristics of the balancing area loads, hydropower facilities, and the wind power resource. Such methods will be considered as the case studies of the participants come to a close, and a search for basic indicators for such methods will be sought. The analysis methods should include only the most influential operational constraints for hydro and electric reliability concerns.

The goal is to develop a technique to approximate the potential for integrating wind and hydropower without the need to conduct an in-depth study. However, any simplified method must still take a "system-wide" perspective, with the understanding that wind and hydropower interact within a larger grid that includes other generation resources. Because of this, it may be more fruitful for some investigators to consider simplified methods that study how much wind can be integrated in a large interconnected grid that includes significant hydropower resources but not to consider specific hydropower resources. Three of the participating countries expect to contribute to the simplified modeling (Australia, Norway, and the United States).

As the breadth of these case studies indicate, integrating wind and hydropower can be quite complex. Figure 1 provides a conceptual view of the relationships between wind, hydropower, and the transmission balancing area along with "surrounding" issues.

3.0 Status and Plans

By the end of 2007, a kick-off meeting, a Web meeting, and four R&D meetings of the Task participants had been held. The kickoff meeting, in February 2005, at Hoover Dam near Boulder City, Nevada, United States defined the general work plan for participating countries. The first R&D Meeting was held in conjunction with the IEA Wind ExCo 56 meeting in Lucerne, Switzerland, in September 2005, and several participants reported on their case studies.

In defining how to best collaborate, it was recognized early that due to the differences in terminology and techniques inherent in an international collaboration, it would be necessary to create a consistent framework for formulating problems and presenting results (a "matrix"). Participants also decided that the work of the task should be completed in close association with a similar task forming as part of the IEA

Hydropower Implementing Agreement. Thus a joint Task or "Annex" was created, with formal ExCo approval in 2006.

During 2006, two more meetings of the task participants were held. The first was held on-line using a web meeting tool (Webex), made available through the U.S. Department of Energy. Through this tool, meeting participants called into a central voice conference, while at the same time being able to view and manipulate a common presentation accessed and displayed via the World Wide Web. Participants discussed the matrix and details of the next R&D meeting to be hosted by Hydro Tasmania. A final "working" version of the matrix was adopted at the end of 2006.

At R&D meeting #2, September 2006, in Launceston, Tasmania, progress was reported on all case studies. It has become clear that in addressing the expected results defined in the task work plan that care will need to be taken in distilling information from the case studies and in describing the results in the final report. At the meeting, additional outcomes were added as a result of collaborating with participants from the IEA Hydropower Implementing Agreement. Beyond case study reports, a path toward completing the final report of the task was defined.

During 2007, in addition to working on their case studies, participants attended two more R&D meetings held in collaboration with the participants of IEA Wind Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power. The idea behind a joint meeting arose from the subset of similar goals from Tasks 24 and 25. The first joint meeting was hosted by EWEA in conjunction with the European Wind Energy Conference 2007 in Milan, Italy. Twenty people from 11 countries attended the meeting. Task 24 participants discussed and debated methods to determine the what impacts wind energy has on power systems and how they are modeled and predicted. The second joint meeting, hosted by Statkraft Energy in Oslo, Norway in September, was attended by 21 people from 12 countries (Figure 2). Task 24 participants presented updates on their case studies and addressed the primary hydropower impacts of integrating wind power.

Each participant has completed a version of the matrix to describe its case studies. This allows comparison and reporting the results from the various case studies. With the exception of

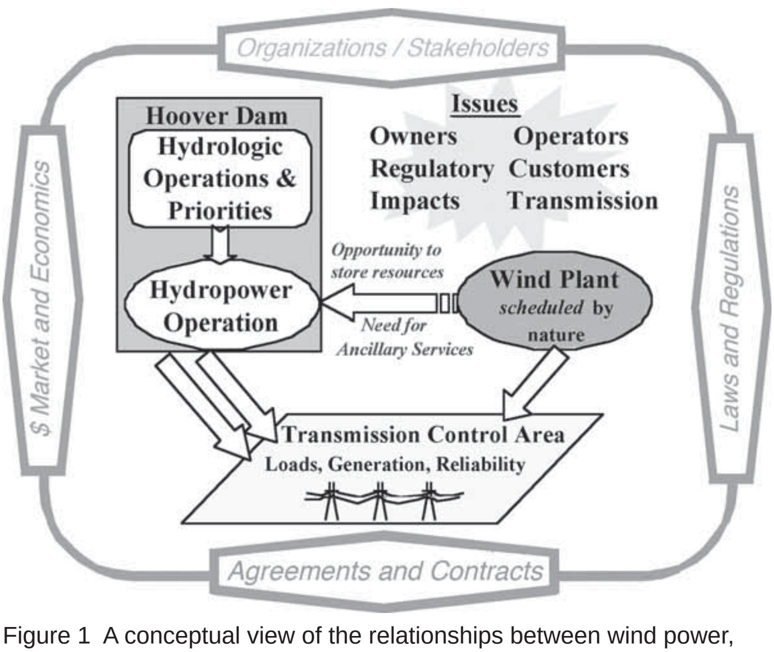


Figure 1 A conceptual view of the relationships between wind power, hydropower, and the transmission control area, and the issues surrounding their integration

the United States, all member countries identified the most significant (indeed only) impact on their hydropower utilities from wind power as the optimal economic use of the hydro resource. It appears that the United States is the only member country where specific flow constraints due to non-power requirements are important, where they typically supersede power production in priority.

It was also generally agreed that when considering energy storage, including that in hydro impoundment, no backup and/or storage is needed for wind integration. Storage is a system integration issue and no local dedicated storage is needed for wind energy. Storage may make sense when considered in the context of the efficiency of the entire system, but not necessarily when dedicated to any single generator in the system.

Other important issues were discussed including how to properly define the wind penetration level, creating a "flexibility index," and the required success factors for wind integration studies. It was also acknowledged that wind integration studies should take a "cost-benefit" perspective toward wind in the grid, instead of a more limited "integration cost" due to the variability and uncertainty of wind energy.

Finally, an outline of the final report for Task 24 has been created, and a draft of the final report will be discussed at the last R&D meeting, to be held in Quebec City, Canada, in June 2008. It is expected that the final report will be completed in 2008 and that the Task will be concluded.

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

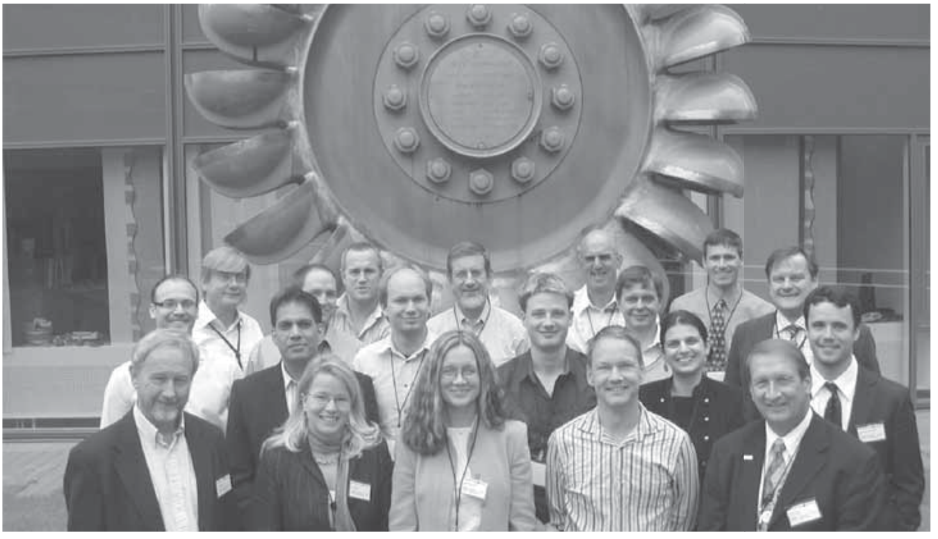


Figure 2 Meeting attendees at the Joint Task 24/25 R&D Meeting in Oslo, Norway, September 2007.

Chapter 8 Task 25

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

The existing targets for wind power anticipate a quite high penetration in many countries. It is technically possible to integrate very large amounts of wind capacity in power systems, the limits arising from how much can be integrated at socially and economically acceptable costs. So far, the integration of wind power into regional power systems has mainly been studied on a theoretical basis, as wind power penetration is still rather limited in most countries and power systems. However, already some regions (e.g. West Denmark, North of Germany, and Galicia in Spain) show a high penetration and have significant practical experience with wind integration.

In recent years, several reports have been published investigating the power system impacts of wind power. However, 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. The cost of impacts can be over estimated if conservative assumptions are used, for example, due to lack of sufficient data. An in-depth review of the studies is needed to draw any conclusions on the range of integration costs for wind power. This requires international collaboration. Because system impact studies are often the first steps taken towards defining wind penetration targets within each country, it is important that commonly accepted standard methodologies are applied in system impact studies.

2.0 Objectives and Strategy

The ultimate objective of IEA Wind Task 25 is to provide information to facilitate the highest economically feasible wind energy

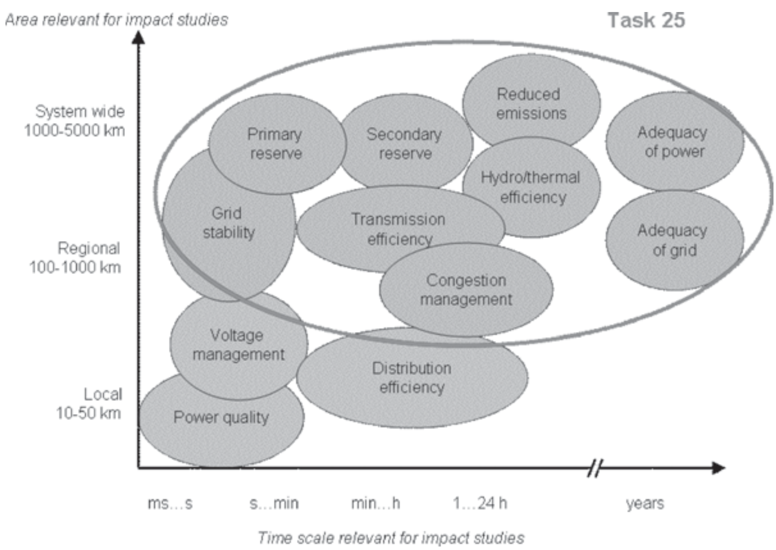


Figure 1 Impacts of wind power on power systems, divided into different time scales and size of area relevant for the studies. Primary reserve is denoted for reserves activated in seconds (frequency activated reserve; regulation) and secondary reserve for reserves activated in 5–15 minutes (minute reserve;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

penetration within electricity power systems worldwide. This task supports this goal by analysing and further developing the methodology to assess the impact of wind power on power systems. Task 25 will establish 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 and other R&D Task work.

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

The task work began with a state-of-the-art report collecting the knowledge and results so far. 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.

Annex 25 to the IEA Wind Implementing Agreement was approved at ExCo 56 in September 2005 and will run for three years, 2006–2008. Table 1 shows the participants in the task.

3.0 Progress in 2007

The meetings organised by Task 25 have established an international forum for exchange of knowledge and experiences. The spring Task meeting in 2007 was organised in conjunction with the European Wind Energy Conference, EWEC 2007, hosted by EWEA in Milan, where Task 25 organised a workshop session. In the autumn meeting, hosted by Statkraft in Oslo, participating countries presented the national results so far and the work on-going.

Table 1 Countries Participating in IEA Wind Task 25

Country	Institutions coordinating work in countries*
Denmark	Risø-DTU National laboratory of sustainable energy, Technical university of Denmark; (Energinet.dk)
EWEA	European Wind Energy Associations
Finland	VTT Technical Research Centre of Finland
Germany	ISET; (RWE and E.ON Netz)
Ireland	ECAR; (Eirgrid)
Netherlands	ECN
Norway	SINTEF Energy Research; Statkraft
Portugal	INETI Instituto Nacional de Engenharia, Tecnologia e Inovacao; (REN Rede Electrica Nacional)
Spain	Universidad de Castilla-La Mancha
Sweden	KTH Kungliga Tekniska Högskolan
UK	Centre for Distributed Generation & Sustainable Electrical Energy
United States	NREL National Renewable Energy Laboratory; UWIG Utility Wind Integration Group

*TSO participants in parenthesis. In some countries like Finland and Sweden, the TSO follows the national advisory group.

Coordination with other relevant activities is an important part of the Task 25 effort. The meetings in 2007 were organised together with Task 24 Integration of Wind and Hydropower Systems.

The system operators of Denmark, Germany, Ireland, and Portugal have joined the meetings organised so far. Links between TSO organisation working groups at CIGRE and ETSO European Wind Integration Study (EWIS project) have been formed.

Publication of the work is a key goal of Task 25 cooperative research. The highlights of 2007 were the publishing of state-of-the-art report and the session organised in EWEC 2007 presenting the results of national case studies and a summary. Work has begun on a simplified assessment of wind integration effort and power system flexibility, drawing on the work done by the operating agent for the IEA secretariat study on integrating renewable energy sources for the G8. A paper collecting experience on wind integration from Denmark, Germany, Ireland, Sweden, and the United States (New Mexico) was published in IEEE Transactions on Energy Conversion. Task 25 results were also presented at the Nordic Wind Power Conference NWPC 2007 and at national wind energy conferences in Austria and Finland. Task 25 work has also been presented in related IEA activities: workshop organized by the Implementing Agreement Renewable Energy Technology Deployment (RETD) and Electricity Networks Analysis, Research and Development (ENARD), and the kick-off meeting of the Demand Side Management related Task. Presentation in the workshop organized by IEA Secretariat relating to G8 study on integrating RES was made in May, 2007.

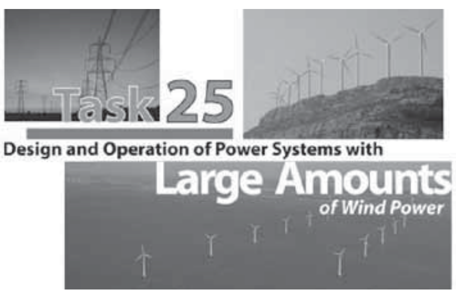


Figure 2 The Task 25 Web site is accessed from www.ieawind.org under Task Web Sites.

The Task 25 web site has been established at http://www.ieawind.org under Task Web Sites. The public portion of the site contains the Task 25 publications as well as literature related to system integration. The members-only section details the meeting presentations and information relevant to task participants.

3.1 Results of the state-of-the art report

The results of the state-of-the art report can be used by the participating countries to show that claims are not correct that wind power requires large amounts of reserve power and integration costs erode away the benefits of wind power. The report finds that a substantial tolerance to variations is already built in to our power network, and the impacts of wind power fluctuations can be further balanced through a variety of relatively easy, and for reasonably large penetrations (10-20%), inexpensive measures. 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 in reducing 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 the utilisation of 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 10–20% 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 1–4 € /MWh. 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 5–10% of the wind power capacity.

Figures 3 and 4 summarize the results from case studies reviewed in state-of-the-art report. 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 2008

The last year of the Task 25 work plan, 2008, will draw conclusions from the national case studies. Simple rules of thumb stating the probable impacts and cost ranges with different levels of wind penetration will be sought. Guidelines and best practices will be formulated. The library in the web pages of Task 25 will be complemented and updated together with Task 24 Integration of Wind and Hydropower Systems. Journal articles will be written about some of the issues in the state-of-the-art report.

The spring meeting will take place in March, hosted by the Danish TSO Energinet.dk. The autumn meeting is planned to be in Ireland. Task 25 will organize a session in EWEC 2008, to be held in Brussels in April 2008. Task 25 work and results will be presented at several other key meetings in 2008: the CIGRE C6-08 meeting in Berlin in February; the Irish Wind Energy Association meeting in April; a wind integration workshop in Madrid in May; the Windpower 2008 conference in Houston in June; and the IEEE Power Engineering Society Meeting in Pittsburg in July.

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 and it is therefore planned to propose an extension of an additional three years. During this extension, particpants will build on

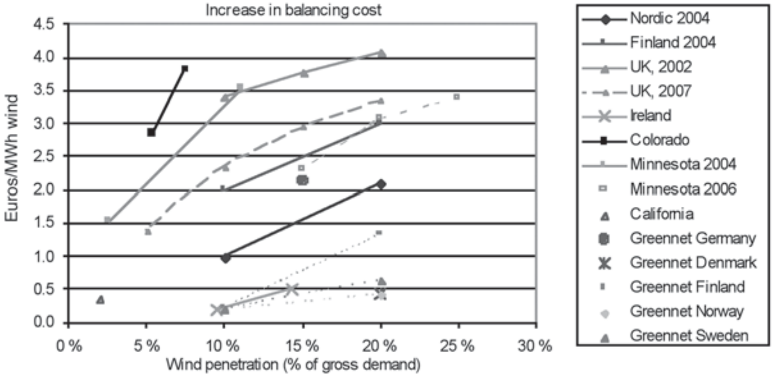


Figure 3 Results from estimates for the increase in balancing and operating costs due to wind power. The currency conversion used here is 1 € = 0.7 £ and 1 € = 1.3 USD.

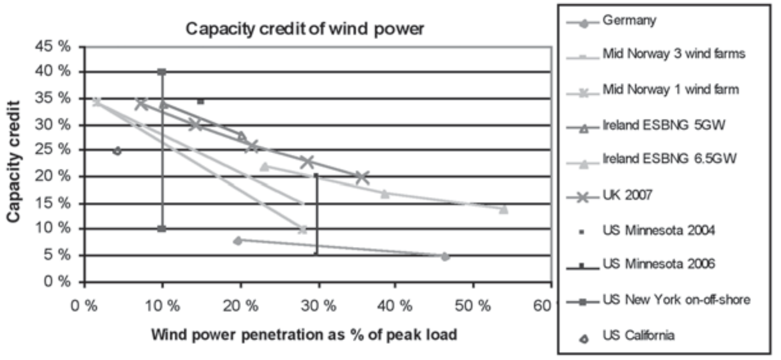


Figure 4 Results from studies on the capacity value (capacity credit) of wind power.

successes to date and expand into areas that are currently outside the original scope, in particular the important topic of cost/benefit analysis of high penetrations of wind power.

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

1.0 Introduction

In 2007, three new research tasks were proposed to the IEA Wind ExCo and approved to move forward to the work plan definition stage. The activity during 2007 varied, but all of these tasks are expected to move to final approval and accomplishment of work in 2008. These progress reports were submitted by the task organizers.

2.0 Task 26 Cost of Wind Energy

2.1 Background

Wind power generation has come to a "historical" point where, installed costs that were becoming competitive with other conventional technologies are now 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 is also a reason. Signals in the U.S. market indicate a 50% increase in the investment cost of wind systems, up to approximately 1,800 $/kW. 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, impartial voice regarding the costs of wind systems, organizations 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.

In addition to providing sound methodology and an impartial estimation of the costs of wind energy, the work undertaken in this cost annex is expected to allow better comparison of the costs of wind energy with other electricity-generating technologies, by modifying, when necessary, the underlying assumptions that are applied to the different technologies. Finally, this task aims to form the basis for a more comprehensive analysis of the value of wind energy.

2.2 Task 26 Objectives

The objectives of the proposed work are:

- To agree upon and develop an understanding of the cost components of onshore and offshore wind electricity generation, specifically quantifying and documenting expenses such as operation, maintenance, and replacement costs; projecting turbine cost trajectories; and assessing the impacts of specific performance parameters on overall plant production.
- To develop and propose an internationally accepted method for calculating the cost of energy for wind systems and the resulting cost of energy from wind energy projects that can be used by the IEA, internally and externally, and other organizations.
- To derive, if possible, the learning curve for wind energy, which allows governments and the research community to anticipate the future trends of wind generation costs.
- To design a methodology that helps identify the major cost drivers of wind energy. The analysis of such drivers is also useful for selecting which are the areas in which R,D&D activities can have a larger impact on cost reduction.
- In a later stage, the outcomes will be used to compare the cost of wind energy with those of other electricity-generation technologies, making sure that the underlying assumptions used are compatible and not biased against a particular source.
- The cost of wind energy will also be used to calculate the value of wind energy. At this point in time, it is difficult to list the factors that will be taken into account as some of them may be difficult to quantify. However, a tentative list could include: contribution of wind generated electricity to reduce greenhouse gas emissions, impact of wind in decreasing electricity prices, and contribution of wind in decreasing the overall risk of the energy system.

2.3 Task 26 Means to achieve objectives

The Task will draw upon current efforts within member countries relating to the cost of wind energy. Based on kick-off meetings, a framework for the specific issues to be addressed by the Task will be agreed to. The following activities have been proposed.

Identify and assess methodologies to estimate the cost of wind energy

Many approaches are used to calculate the cost of wind energy. As a consequence, their estimated values are not always comparable and create confusion for policy makers and other interested stakeholders. The first activity thus consists of the identification, analysis, and discussion of the different approaches.

It is understood that every country will have diverse economic and policy-driven elements that will impact cost-of-energy calculations such as production incentives or carbon credits. An attempt will be made to describe and quantify the different approaches used in different countries, allowing for a clearer cross-border assessment of wind project costs in addition to understanding the impact of a specific policy or other incentives on the cost of wind.

Develop a draft methodology for IEA Wind use

The final goal of the assessment process is to adopt a uniform calculation approach for use by IEA and other interested organizations. This activity should be completed in consultation with non-research based stakeholders, such as wind turbine manufacturers, project developers, and operators.

Identify learning curves for the cost of wind energy

Learning curves are an ad-hoc tool that allows the prediction –on the basis of past performance- of future cost trends of a certain activity. The task members will critically review the existing learning curves for wind energy and, if appropriate, recommend a standard one for general use.

Compare the cost of wind energy with that of other electricity-generating technologies

In the second to third year, task members will compare the cost of wind energy with the generation cost of other technologies. For reasons of homogeneity, the IEA generation cost estimates of the main electricity generation technologies will be used as a basis. Task members will analyze the assumptions applied to other technologies to determine if they are consistent with the ones agreed for the wind energy sector, and can propose amendments if necessary. The objective of this activity is to help governments and other interested stakeholders make informed comparison between the options that they have.

Develop a draft methodology to assess the value of wind energy

Apart from the private cost of wind energy, the task will also consider the financial cost of wind energy (first stage of the task) and the economic cost of wind energy (value of the energy technology due to reasons of security of supply, avoided CO2 emissions etc.), which includes variables that are not in the minds or in the hands of a private investor. Still, they influence the decisions of governments and other stakeholders at the time of planning their energy policies. This activity will thus consist on the design of a methodology that can be applied to assess the value of wind energy from the society's viewpoint by taking into account factors such as its contribution to reducing greenhouse gases, decreasing electricity prices, or improving the security/certainty of the energy systems. Task members will not undertake basic research through this activity, given the cost and difficulty it would imply, but a revision and assessment of the evidence that exists, in the form of studies and publications, when it has sufficient prestige. This proposed task will be re-discussed once the others have been completed as it constitutes a logical continuation of the work done previously.

Communication, outreach, and informational exchange

The Task will work to bring together experts to exchange information and experience. The wind research community has always had difficulties incorporating project developers and operators into the research discussion, even though project developers and operators have the most to lose from projects in which the costs are found to be in excess of projections. Including project developers, operators, and equipment suppliers will thus be critical to the long-term success of this Task. The team will propose concrete communication tools, such as thematic workshops, peer review processes, conferences calls, etc. to make sure that the necessary exchange takes place. The need for documentation requires the publication of Task results to allow their use as reference documents:

1. Guidelines will be developed and published via a project website, as appropriate;

2. Reports will be published as formal documents by one or more of the participating agencies as formal peer reviewed technical reports;

3. Results will be presented at international conferences and/or meetings.

It is expected that the Task would continue for a period of three years beginning at the time of specific approval by the ExCo. The official kick-off meeting of the Task will occur in 2008, and it is anticipated that there will be Annual Research Meetings of the participants thereafter.

2.4 Task 26 Results

Upon completion of the work undertaken by this Task the following will have been established:

1. An understanding of the wind energy cost system;

2. A methodology that can be applied by the IEA and other international and national organizations to assess the cost of wind energy;

3. A more appropriate comparative analysis of the cost of wind energy in comparison with those of other technologies;

4. A first approach to the social value of wind energy.

3.0 Task 27 Quality Labeling of Small Wind Turbines

This task, approved in April 2008, will develop a system of quality labelling for consumers of small wind turbines (SWT). Potential participants include: Germany: Institut für Solare Energieversorgungstechnik (ISET), Ireland: Association of Irish Energy Agencies, Italy, Japan: Japan Electrical Manufactures' Association (JEMA), Portugal: INETI, Spain: Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) (OA), and Switzerland.

The task will produce an IEA Wind Recommended Practice for Quality Labeling of Small Wind Turbines. It will also provide information for anyone interested in buying an SWT, such as recommended methodologies and independent test reports on power performance curves, acoustic noise emissions, strength and safety, and duration tests. Reliable third-party testers already exist, such as national laboratories, universities, and certification entities. The operating agent of this task will direct SWT manufacturers seeking to label their products to these groups. It should be noted that the actual testing of the wind turbines is out of the scope of this Task. The primary goals are to build bridges between SWT manufacturers and third-party testers and to provide private companies with a commonly-accepted testing methodology. This task will complete its work in three years.

4.0 Task 28 Social Acceptance of Wind Energy Projects

4.1 Background

The mission of IEA Wind is to stimulate co-operation on wind energy research and development and to provide high quality information and analysis to member governments and commercial sector leaders by addressing technology development and deployment and its bene¬fits, markets, and policy instruments.

Sometimes referred to as 'soft issues' to differentiate them from technology aspects, environmental and societal issues have become pivotal to the deployment of wind energy in many countries. Even where the economics of wind energy are favorable, deployment can only occur when the public and the planning authorities accept the technology. This requires an appreciation of the benefits of wind energy that weigh against any local visual and environmental effects. The evaluation of this balance is often complicated by its subjective nature and by the circulation of misinformation. Task 28 will take steps to assess the value of ongoing collaborative activities against strong national variations in policies and processes.

The Strategic Plan of IEA Wind summarizes the issues of social acceptance as follows:

- Key Issues: Environmental and societal issues: effects on flora and fauna, visual influence;
- Forward Plan: Evaluate collaboration on societal issues;
- Action Path: Develop initiatives to address societal issues and to determine the level of commonality and value of a collaborative program.

Social acceptance is an often-used term in the practical policy literature, but clear definitions are rarely given. We intend to contribute to the clarity of understanding by distinguishing three dimensions of social acceptance, namely socio-political acceptance, community acceptance, and market acceptance.

4.2 Task 28 Objectives and strategy

Specific or partial objectives of this new task include:

- Establish an international forum for exchange of knowledge and experiences related to social acceptance and other societal issues;
- Produce a state-of-the-art report on the knowledge and results so far on social acceptance of wind power installations, including a list of studies and online library of reports/articles;
- Establish "Best Practices" and tools for policy makers and planners to reduce project risks, accelerate time of realization of projects, and accelerate the exploitation of the full potential of wind energy in the concerned countries;
- Establish strategies and communication activities to improve or to maintain the image of wind power.

4.3 Task 28 Progress in 2007

The social acceptance issue has been addressed at the following meetings:

- Acceptability in Implementation of Wind Turbines in Social Landscapes, 42nd IEA Wind Topical Expert Meeting, Stockholm, Sweden, March 2004, Organized by: FOI.
- Social Acceptance of Renewable Energy Innovation, Latest Research Results and Implications for Social Science Research, Tramelan, Switzerland, February 17-18, 2006.
- Emerging Energies, Emerging Landscapes: Revisioning the Past, Constructing the Future, ESF Exploratory Workshop, Paris, France, 5 - 8 June 2007.
- Social Acceptance of Wind Energy Projects, 54th IEA Wind Topical Expert Meeting, Lucerne, Switzerland, 24-25 May 2007.

Based on these activities and results, the Swiss delegation to IEA Wind, began discussions to begin a new Task. This new task was presented at the IEA Wind ExCo in September, 2007 in Zaragossa, Spain. It was decided, that the planning for this new task should continue and that at the next ExCo meeting – based on firm commitments of other participating countries

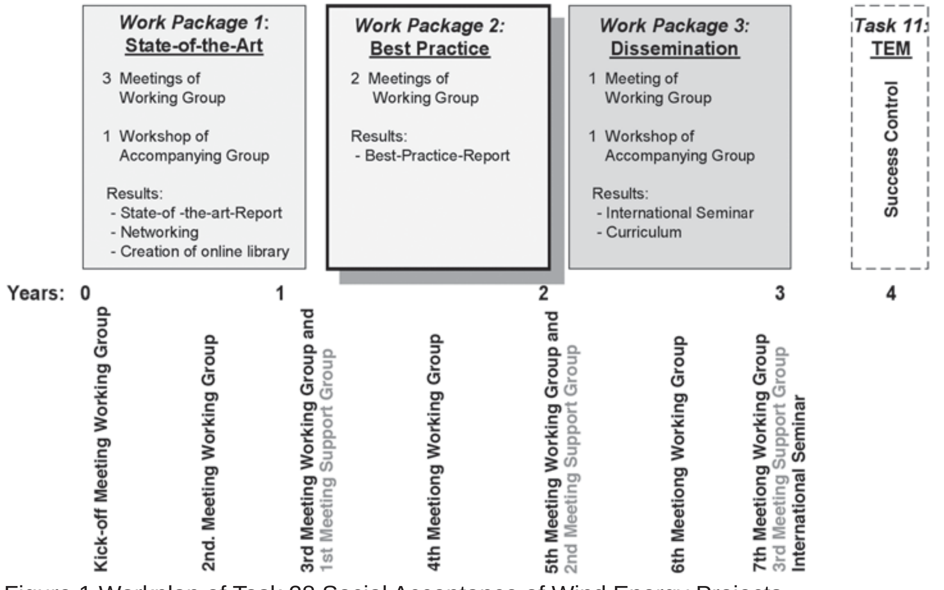


Figure 1 Workplan of Task 28 Social Acceptance of Wind Energy Projects.

– a final decision to start this task in 2008 should be taken. A detailed questionnaire for interested partners was developed and forwarded to all member countries of the IEA Wind.

4.4 Task 28 Plans for 2008 and beyond

The Task will be approved as an Annex to the Implementing Agreement at the IEA Wind ExCo in April 2008. It will run for a period of three years beginning in mid 2008 and be concluded at the end of 2011. The Task may be extended for such additional periods as may be determined by two or more participants, acting in the ExCo and taking into account any recommendation of the IEA Committee on Energy Research and Technology (CERT) concerning the term of the Task.

Research activities within this new task will lead to the following results:

- State-of-the-art report;
- Guidelines with list of best practices (methodology, input data, especially how social competence is to be used in project development);
- Translation of the existing knowledge of social scientists into the language of planners and engineers to improve and speed up wind energy planning processes, e.g. how to do the participation process, how to turn affected people into involved parties;
- Description of successful participation models;
- Curricula on social acceptance issues for seminars, training courses, and teaching units for wind power professionals;
- Conference on social acceptance (in 2-3 years) with developers and politicians, perhaps scheduled around an EWEA conference;
- Publish the results of the Task in reports and make them available on a server;
- Proceedings from workshops (presentations given at research meetings plus notes of the summary discussions);
- Creation of an online library composed of case study reports generated by the research participants;
- Due to the expected relevance of the outcomes of this Task to the policy makers of the different countries, results on guidelines, new methodologies, strategies, and best practices will be available to all participating countries, when not directly represented in the task.

5.0 Conclusion

These new tasks, as well as additional tasks proposed as a result of IEA Wind Topical Expert Meetings and discussions among IEA Wind ExCo members will be approved and carried out in the years ahead. Their progress will be reported in future IEA Wind Annual Reports.

1.0 Renewable Energy Markets and Policies

The IEA's Global Renewable Energy Markets and Policies Programme (GREMPP) encompasses two things. First, it is a compilation of national and international policies and measures relating to renewables in IEA, the Johannesburg Renewable Energy Coalition (JREC), and in other countries in the Global Renewable Energy Policies and Measures Database. Second, it conducts policy analysis.

In support of GREMPP, the IEA Secretariat organised an expert meeting on global best practices in renewable energy policy-making on 29 June 2007. The objectives included discussion of preliminary findings with regards to the effectiveness of renewable energy policies and measures; the application of identified best practice in the Plus Five (Brazil, China, India, Mexico, South Africa) and in developing countries; and the identification and assessment of possible renewable energy future pathways. The meeting conclusions in terms of policy experiences and a recommended 'policy toolbox' informed the analysis.

The IEA Secretariat has compiled data on renewable energy markets and policies in all IEA countries. To support the data collection on renewable energy markets and policies in the Plus Five countries, the IEA has hired consultant experts in each of these countries to collect policy and market data to feed into the GREMPP policy analysis.

The addition of verified data on national policies and measures in the IEA Global Renewable Energy Policies and Measures Database is ongoing. The new interface has recently been launched and an update was completed in February 2008. The database includes policy and statistical information on approximately 80 countries. It is accessible online at http://renewables.iea.org (Figure 1). Visitors can search for information by country, type of policy instrument, and technology, as well as by other criteria. The objective of the database is to provide a platform for enhancing awareness and knowledge of renewable energy policies and measures; to provide basic statistical information on countries' progress to date; and to strengthen the capacity of policy makers and other renewable energy stakeholders to develop new policies according to their strategic energy objectives.

Based on the collected data and with the assistance of expert consultants at the Fraunhofer Institute for Systems and Innovation Research in Germany, the Energy Economics Group at the Vienna University of Technology, and the Lawrence Berkeley National Laboratory in the United States, the IEA Secretariat has evaluated the calculated indicators of effectiveness and efficiency of deployment policies. The analysis of policy effectiveness and remuneration level

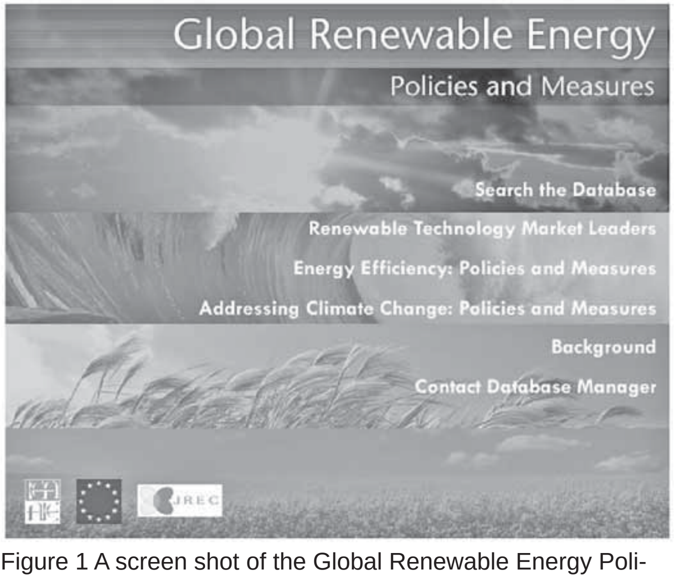


Figure 1 A screen shot of the Global Renewable Energy Policies and Measures Database homepage.

efficiency is based on a comprehensive examination of data and information on renewable energy markets and policies over the period 2000–2005. The study discusses the following renewable energy technologies in the electricity sector: wind, biomass, biogas, geothermal, solar PV, and hydro power. In the heating sector, it discusses biomass heat, geothermal, and solar thermal. In the transport sector, it discusses ethanol and biodiesel. Illustrative case studies of good (and bad) practice will complement the indicator analysis.

This analysis of policy effectiveness and support level efficiency constitutes the analytical core of a major publication entitled Deploying Renewables: Principles for Effective Policies, which incorporates the GREMPP findings. This book highlights key policy tools to fast-track renewables into the mainstream. It illustrates good practice by applying the combined metrics of effectiveness and efficiency to renewable energy policies in the electricity, heating, and transport sectors. It also highlights significant barriers to accelerating renewables penetration, and shows that the great potential for renewables can be exploited much more rapidly and to a much larger extent if good practices are adopted. Carefully designed policy frameworks, customised to support technologies at differing stages of maturity, will deliver a strong portfolio of renewable energy technologies. This study provides recommendations on key principles for policy design as a template for decision makers. The publication is scheduled to be launched in June 2008.

In a planned Phase Two of GREMPP, IEA will deepen the existing analysis of policy effectiveness, both by region and by sector. Regional foci will include Africa, Latin America, Russia and the Commonwealth of Independent States, and the Association of Southeast Asian Nations (ASEAN) countries. The Programme will also feature an expanded analysis of policy impact indicators and non-economic barriers. The analysis will estimate the external benefits of renewables—including reduction of greenhouse gas emissions and of regional air pollution, and employment creation—as well as of the possible environmental costs of the large-scale diffusion of renewables in the electricity, transport, and heating sectors.

2.0 Grid Integration of Renewables

This study is being carried out as part of the Gleneagles Plan of Action. It will produce recommendations to the July 2008 Hokkaido G8 Summit. These recommendations, based on a complete literature and research review, will relate to market design and rules, transmission and distribution system operation and management, newly emerging technologies, and the maximisation of system flexibility to enable significant quantities of variable output electricity.

On 29 May 2007, a workshop on technology issues relating to the grid integration of renewable energy, was held at which challenges were identified and concerns raised by a wide cross-section of stakeholders. The principal message coming out of the meeting is that, while technical challenges remain to the integration of renewable energy sources, in particular variable output technologies, it is not an absence of technological know-how that may limit market share. The principal challenges instead relate to market development, further cost reductions, advance planning, and good governance.

A second meeting, Trading and Transmission: a Roundtable, was held on 10 October. This meeting explored issues relating to market design and rules, and transmission and distribution system development and access.

In the renewables integration field, VTT, the Technical Research Centre of Finland, has been subcontracted to draw together the key findings of the wide range of research initiatives ongoing and completed in recent years. With the funding of the German government, Ecofys has also contributed with a study of technological solutions for increased renewables share. Possible key findings include:

- Renewable electricity technologies include both ‘firm’ and ‘variable’ types. Variability can be ‘smoothed’ to an extent by aggregating the output of many, dispersed producers, utilising resources that fluctuate over different timescales (wind, PV, marine, others).
- There is no intrinsic ceiling to variable renewables’ potential. Potential is governed by system flexibility: of network operation, dispatchability of generation, market operation, and by the size of the supply-and-demand balancing-area.

• Variability costs are nominal at low share, increasing with penetration, particularly in isolated markets (developing world or islands) and with distance from load.
• Supranational balancing-areas reduce variability costs, while international trade of electricity also benefits the electricity market as a whole.
• Transmission systems are inadequate and aging fast. Weaker grids need reinforcement. State-of-the-art technologies are not adopted quickly enough—such as dynamic line rating with temperature monitoring, which alone can increase the capacity of existing lines by up to 50%.
• Advance, system-wide planning is crucial to identify synergies and avoid delays. New transmission can be delayed by as much as 10 years by public opposition.

Possible recommendations from the meeting include:
• Network and market flexibility should be increased. Measures include flexible international interconnection, additional dispatchable generation, larger balancing areas, intra-day trading with real-time data flow, demand-side measures, and storage. These would benefit the electricity market as a whole.
• State-of-the-art technologies should be adopted as much and as quickly as possible.
• Ownership of generation and transmission infrastructure should be separated to encourage international trade and to enable equal and open access to networks.

Reference:

IEA Global Renewable Energy Policies and Measures Database: http://renewables.iea.org

Author: Nobuyuki Hara, Analyst, Desk Officer for Renewable Energy Implementing Agreements, Renewable Energy Unit, International Energy Agency, France.

Chapter 11
Australia

1.0 Introduction

With a huge landmass and some of the strongest and most consistent winds in the world, Australia shows enormous wind energy potential. A change in government in late 2007 signaled a major shift for climate change policy – placing the Australian wind industry in a strong position for development, with a very positive outlook for growth in 2008 and beyond. A stable and growing economy, established finance sector, strong manufacturing sector, and increasing demand for energy and expertise both domestically and from neighbouring Asian economies including China, add to the attractiveness of Australia as a base for businesses related to wind energy.

With the change in government and community support for climate change initiatives, wind energy is becoming both more accepted and attractive to communities, governments, and investors. A range of policies to be introduced federally in Australia, including an economy-wide emissions trading scheme and expanding the renewable energy target, will ensure wind (a proven technology) will lead in meeting demand. In addition, 2007 saw the Australian Wind Energy Industry Association (Auswind) successfully merge with the Australian Business Council for Sustainable Energy (BCSE) to form the Clean Energy Council in order to capitalize on anticipated growth and present a united set of policies to government.

The Clean Energy Council launched the Certified Wind Farms Australia (CWFA) scheme in 2007 to help provide community and planning authorities with the confidence to pursue wind farm projects. The CWFA scheme is a world first – independently auditing and accrediting wind farm projects against ISO14001 and Australian best practice guidelines. The scheme recently won the Australian and Victorian prize from the Planning Institute of Australia.

2.0 Progress toward National Objectives

2.1 Industry growth in 2007

Australia's growth potential for wind power is enormous. The government's 20% by 2020 plan will see the national Mandatory Renewable Energy Target (MRET) increased from 9,500 GWh to 45,000 GWh in 2020. This will require approximately 10,000 MW of renewables capacity. The wind industry is best placed to quickly meet this demand.

At the end of 2007, the total installed capacity was 824 MW. While there were only three new project commitments

Table 1 Key Statistics 2007: Australia	
Total installed wind generation	824 MW
New wind generation installed	7 MW
Total electrical output from wind	2.526 TWh
Wind generation as % of national electric demand	1%
Target:	The Mandatory Renewable Energy Target, 9,500 GWh from renewables by 2010, has been met. The new government has promised a further Renewable Energy Target, 45,000 GWh from renewables by 2020, beginning in 2009 (combining and extending state targets). Legislated targets introduced by state governments: Victoria – 10% by 2016

Table 2 Installed Wind Capacity Australia 2007	
Sum of installed capacity MW	
Operating	823.68
Construction	867.50
Development	5,067.94
Evaluation	3390.30
Potential	552.09
Total	10,701.51

during 2007 - amounting to 440 million € of investment - the 2008 outlook is more positive, as a result of the growing political and public support. Significant wind capacity is moving through the project planning stage – with over 400 MW of projects receiving planning approval during 2007. Nine projects (over 860 MW) were financially committed, although not yet operating, as of December 2007; including three new projects totaling 290 MW of capacity. Table 3 shows the history of wind generation capacity in Australia since 2000.

To fulfill the demand created by the incoming government's renewable energy policies, around 10,000 MW of new renewable energy projects will be built over the next decade. The wind industry is poised to play a major role in meeting this demand.

Among the projects which are currently committed are: Snowtown (TrustPower; 88 MW), Hallett (AGL; 95 MW), Hallett Hill (AGL; 71 MW), Mt. Millar (Transfield Services Infrastructure Fund; 70 MW), and Lake Bonney Stage 2 (Babcock & Brown Wind Partners; 159 MW) projects in South Australia; Waubra (Acciona Energy; 192 MW) and Cape Bridgewater (Pacific Hydro; 71 MW) projects in Victoria; and Capital Wind Farm (Babcock & Brown Wind Partners; 132 MW) in New South Wales. Each of these is expected to be commissioned during 2008 except for Hallett Hill and Capital. Figures 1 and 2 show important wind farms contributing to Australian utilities.

2.2 Progress toward national global targets

A turning point for Australia's approach to climate change policy was reached in 2007; it was a year of changes that will result in positive, long-term impacts for the wind industry. In June, the Australian Wind Energy Association (Auswind) and the Australian Business Council for Sustainable Energy merged to form the Clean Energy Council – a single powerful industry voice for the nation's clean energy sector. The development of a national renewable energy industry body – The Clean Energy Council – kicked off a period of growth for climate change business opportunities in Australia.

Figure 1 Condrington wind farm courtesy Pacific Hydro.

Table 3 Total Installed Capacity Australia	
Sum of installed capacity	
Year	MW
2000	32
2001	73
2002	105
2003	198
2004	380
2005	708
2006	817
2007	824

Concurrently, Australia was in the midst of a federal election campaign. As part of their campaign, the Australian Labor Party announced a new commitment to a long-term emissions target of 60% reduction (compared with 2000 levels) by 2050. In announcing this target, the Australian Labor Party recognised the urgent need to reduce Australia's greenhouse gas emissions and was subsequently voted into power.

2.3 The Kyoto Protocol

Kevin Rudd commenced his role as the new Prime Minister of Australia by signing the UN's Kyoto Protocol for carbon emission reduction. This pledge set forth the Rudd government's election policy announcement and put Australian climate change policy alongside the European Union, China, California, and other economies at the forefront of action.

The Australian government then went one step further by committing to a 20% by 2020 national renewable energy target, in addition to a cap and trade market for emissions. These commitments will contribute to the realization of strong and consistent growth in Australia's renewable energy industry. Australia's stationary energy sector is responsible for 50% of the country's greenhouse gas emissions. Currently, 77% of Australia's electricity is generated from coal-fired power. The government's proposed policies will gradually begin to level the playing field between clean energy, such as wind, compared with more carbon intensive electricity.

2.4 The Garnaut Review

The lack of climate change action from the previously conservative Australian federal government prompted independent state governments to commission an independent economic inquiry into Australia's climate change response. The new federal government has endorsed this inquiry, under professor Ross Garnaut, to continue examining the impacts of climate change on the Australian economy. The review will provide the federal government with recommendations regarding medium to long-term policies and frameworks to further improve the prospects for sustainable opportunities in Australia. In particular, the review is considering the details for implementing an Emissions Trading Scheme (ETS) in Australia. Information relating to this analysis is available by visiting www.garnautreview.org.au. The review is due to be completed by 30 September 2008.

In 2008, the Clean Energy Council will focus on ensuring the design of the Emissions Trading Scheme, such as the build-up of electricity retailer liabilities and project eligibility. The Council will focus strongly on policy details to ensure that investment certainty for

Figure 2 Wind turbines courtesy of Hydro Tasmania.

wind and clean energy developers is achievable.

Bipartisan acceptance of the need for strong supportive policies for technology deployment, including and beyond research and development programs, reflects a major shift in the policy landscape. This acceptance will help drive deployment in the near term to ensure that costs are lowered in the long-term and that emissions targets are met.

2.3 Emissions Trading Scheme (ETS)

Development of Australia's Emissions Trading Scheme is still in its early stages. On 20 March 2008, Professor Ross Garnaut released his discussion paper on an Australian ETS, stating that the introduction of an ETS signaled the opportunity for profound, long-term structural changes for Australia. The clean energy industry added their voice to the Garnaut Review by calling for the early introduction of an Australian emissions scheme.

The Clean Energy Council submission to Professor Garnaut's review recognized that an effective ETS design, resulting in significant reductions to meet Australia's Kyoto and internal targets, must include a framework of complementary measures, such as:

- the announced renewable energy target
- defined energy efficiency targets
- the removal of market and systemic barriers, and
- a funding stream to support the rapid commercialization of new clean technologies.

3.0 Benefits to National Economy

3.1 Market characteristics

The wind power industry is already making a significant contribution to the Australian economy, particularly in rural and regional locations (Table 4). Drought has forced farmers across the nation to seek out new sources of income, and hosting wind turbines is becoming increasingly attractive to them as a means of (at least partially) drought-proofing their businesses. By the same token, much of the industry that has built up as a result of the recent growth in wind energy has been established in regional areas. Other areas are looking to renewable energy generally as a source of future prosperity. Wind sector turnover, assuming 35% capacity factor and 75 AUD/MWh power price, is 189.5 million AUD. This does not include gains from the sale of wind farms.

Table 4 Australian Wind Energy Industry 2007: Economic, environmental, and social benefits*

Installed megawatts	824
Average number of Australian households powered by wind energy	350,863
Number of wind energy projects (two or more turbines)	31
Annual greenhouse gas emissions displaced	3,284,078 tones CO_2/yr
Equivalent number of cars taken off the road	758,448/yr
Landholder lease payments	2.56 million AUD/yr
Operations and management costs	20.71 million AUD/yr
Total capital investment	1.41 billion AUD
Manufacturing jobs	303
Construction jobs	377
Operations and management jobs	121
Other jobs (project development, engineering, and finance)	177

*All figures are estimates only based on available information obtained by the Clean Energy Council.

Manufacturing in Australia will see a dramatic turn-around as the many stalled wind projects are revived as a result of the favorable policy environment. However, in 2007, Australia saw the ramifications of an industry that at the time was in decline; Vestas' closure of their Victorian blade factory came on the heels of their nacelle plant closure in Tasmania during 2006. However by the end of the year, it is expected that the market will have a significantly improved outlook with the increased renewable energy targets and the start of Victorian electricity retailers' renewable energy liabilities. Australia is also experiencing some stalling of projects due to world supply bottlenecks.

3.2 Grid connection issues

The increasing penetration of wind energy in the National Electricity Market (NEM) has identified the need for better forecasting of wind energy production. Under a federal government grant, NEMMCO (the market and system operator for the NEM) has contracted an international consortium to develop a sophisticated forecasting model. This will be implemented in mid 2008 and allow better management of the grid with the higher levels of wind generation expected.

3.3 Community and landscape issues

The Australian wind energy industry focused on managing and improving the community consultation processes in 2007. Auswind (now the Clean Energy Council) launched Certified Wind Farms Australia (CWFA), the world's first wind farm accreditation scheme. The aim of the scheme is to promote the sensitive and responsible uptake of wind energy in Australia by ensuring that the development and operation of wind farm projects is consistent with best practice standards. The scheme is based on the Best Practice Guidelines for implementation of wind energy projects in Australia, and incorporates principles of continual improvement. The guidelines include an auditable framework for managing the environmental, stakeholder consultation, and amenity aspects of wind farms. More information is available from www.cleanenergycouncil.org.au.

Renewable energy investment opportunities are growing from firmer foundations thanks to Australian government support toward climate change policy, the formation of one national renewable energy industry body – the Clean Energy Council, and the existence of a single national market operator – NEMMCO.

4.0 National Incentive Programs

The two major incentive schemes for the wind energy industry include the emissions trading scheme, due to begin in 2010, and the renewable energy target of 20% by 2020, to be introduced in 2009. Both of these initiatives will drive rapid deployment of wind energy in Australia, and potentially add an additional 6,000 to 8,000 MW.

4.1 State-based incentive programs

Total installed wind capacity operating in Australia in 2007 was 824 MW. The Northern Territory and ACT currently had no operating wind turbines and the territories had 0.68 MW installed capacity operating.

Victoria was the only state to legislate a state-based renewable energy target that began on 1 January 2007. Many of the remaining states were also planning to introduce targets in the absence of a nationally consistent scheme. With the election of the new Labor government, both active and planned targets will be incorporated into the national renewable energy target. Figure 3 shows the percentage of capacity in each of six Australian states.

4.2 Green Power national accreditation program

Renewable energy development was also encouraged by the nationally accredited program Green Power, which sets stringent environmental and reporting standards for renewable energy products offered by electricity suppliers to households and businesses across Australia. Since Green Power's inception in 1997, more than 138,000 domestic and commercial customers have contributed to reducing greenhouse gas emissions by buying green power across Australia, and have reduced greenhouse gas emissions by more than 2.5 million tons.

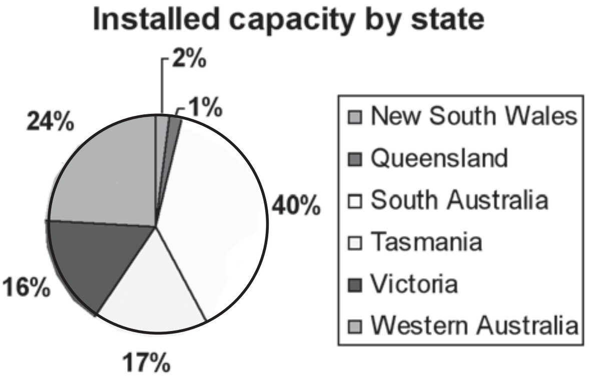


Figure 3 Australian States: Installed wind energy capacity 2007.

4.3 Australian Greenhouse Office initiatives

The Australian Greenhouse Office (AGO), established in 1998, has been replaced by the Department of Climate Change. This is a new senior department in Australia's federal government and is looking at climate change and water policies as well as ensuring Australia's participation in international negotiations. The Department of Climate Change website is www.greenhouse.gov.au.

5.0 R,D&D Activities

5.1 Significant funding announcements

Australian governments, both federal and state, have just released their next budget figures including billions of dollars for demonstration and commercialization of renewable energy projects. As these programs are recent announcements, the details, criteria, and outcomes are unavailable at this time.

5.2 Certified Wind Farms Australia

Certified Wind Farms Australia (CWFA) provides companies within the Australian wind energy industry with a mechanism to independently demonstrate that they are meeting environmental and social best practice requirements for the planning, siting, design, construction, operation, and decommissioning of wind farms. The requirements of the CWFA scheme are based on the proven environmental framework of ISO 14001, supplemented by the industry's Best Practice Guidelines for the Implementation of Wind Energy Projects in Australia. It is a robust scheme, and much effort has been applied to ensure that independent processes are in place to audit companies and ascertain whether they can be certified under the scheme.

The Clean Energy Council will issue certificates and recognition to companies that become certified under the scheme, and it is the role of independent certification bodies such as SAI Global, BSI Benchmark, Global Mark, DLIQ, and SGS to assess through the use of qualified auditors, whether a company has complied with the scheme requirements. Those auditors can also recommend to the Clean Energy Council where improvements to best practice standards need to occur. With a number of key companies such as Pacific Hydro, Wind Prospect, Roaring 40s, and Wind Power, working hard to be the "first" certified under the scheme, the Clean Energy Council is confident that other companies will follow their lead.

5.3 Wind Farms and Landscape Values project

Over 2006 and 2007, Auswind worked in partnership with the Australian Council of National Trusts to develop a National Assessment Framework for Landscape Values and Wind Farm Siting. This framework clearly documents the steps expected of a wind farm developer when undertaking landscape assessment for a wind farm site. It includes identifying and assessing landscape values, assessing the potential impacts of wind farms on landscape values, site impact assessment and mitigation, and community consultation procedures. It is a robust framework that provides consistency in approach but flexibility in application for different sites, communities, scale of development, and technologies and approaches applied by landscape assessors. Compliance with the framework is a requirement of CWFA, and all wind industry members are encouraged to implement the process.

In late 2006, the work of the consultant in developing the National Assessment Framework was recognised by the Planning Institute of Australia, Victorian Division, and on 14 April 2008 this work received a National Award with the Planning Institute of Australia along with the Ministers Award across all categories.

5.4 Industry achievements

On 14 April 2008, the Clean Energy Council was also presented with the Planning Institute of Australia's National Award for Environmental Planning or Conservation. This award was given for the National Assessment Framework for Landscape Values and Wind Farms developed by Auswind in partnership with the Australian Council of National Trusts (ACNT).

The Clean Energy Council also accepted the Minister's Award, judged by the awards panel, on behalf of the Planning Minister of Australia. The Clean Energy Council was heralded as the overall winner of the National Awards for Planning Excellence. The panel recognized the assessment framework as being applicable across Australia with climate change emerging as a national priority.

6.0 The Next Term

6.1. Priorities for industry growth

The Clean Energy Council has identified several key priorities for supporting progress in the wind energy industry in Australia. The most urgent priority is securing the details of the renewable energy target and emissions trading policies. The Clean Energy Council is advancing several other initiatives to address grid integration issues and market categorization in the Australian National Electricity Market (NEM). Projects are also underway to address community concerns with wind energy, ensure compliance with industry best practice, and increase national support for future wind energy projects.

The consolidation of state schemes into a single target and the expansion of the national renewable energy target have primed the Australian environment for secure investment opportunities. New wind project proposals welcome foreign investment to help meet Australia's growing demand for renewable energy deployment and goals for reducing global greenhouse gas emissions. Australia's committed target guarantees the production of 45,000 GWh of clean, zero emission energy from sources like wind – enough to power 6.25 million households or avoid 60 million tons of CO_2 gas from coal-fired electricity.

The Clean Energy Council is working with industry and regulators to deliver a suite of sustainable energy policies that will effectively cut greenhouse gas emissions with the least cost to the economy and offer unprecedented opportunities in the Australian market.

Note on Australian Wind Data:

Following the 2007 amalgamation of Auswind and the BCSE, the Clean Energy Council databases were reconciled. The two organisations had adopted slightly different methodologies (namely the definition of 'operational') when calculating wind farm figures and as such, the last year has seen slight discrepancies in information provided. Please be assured that the two methodologies have now been reviewed and streamlined. The figures provided here are derived from one accurate and up-to-date source of wind farm figures produced by the Clean Energy Council.

Authors: Renee Lustman and Irena Bukhshtaber, Clean Energy Council, Australia.

Chapter 12
Canada

1.0 Introduction

Following on the success of the Wind Power Production Incentive, which funded approximately 1,000 MW of new wind capacity since 2002, the ecoENERGY for Renewable Power program was launched in April 2007 to provide the same kind of production incentive to all renewable energy technologies. The 14-year program will invest close to 1.5 billion CAD (Canadian Dollars) to increase Canada's supply of clean electricity from renewable sources such as wind, biomass, low-impact hydropower, geothermal, solar photovoltaic, and ocean energy.

The influence of the federal program on the development of wind energy in Canada can readily be seen when reviewing yearly installed capacities (Figure 1). The promising trend of 2006 was not replicated in 2007 because the ecoENERGY for Renewable Power program was not yet in place. It is expected that the promising trend will resume in 2008.

It can thus be concluded that wind energy in Canada still requires financial support to make it consistently appealing and competitive with conventional energy sources. Research support measures are also needed to stimulate domestic manufacturing and assembly operations.

While wind capacity represented less than 1% of total capacity in 2007, future growth will depend on how well new capacity can be integrated into the grid. It is expected that major investments in transmission and distribution infrastructure will be needed in the short to medium term for wind to reach significant levels of penetration.

2.0 Progress toward National Objectives

Although there are no national wind energy deployment targets, the federal government's wind and renewable energy programs provide considerable economic incentives for the accelerated introduction of new capacity. In April 2007, the federal government launched a new ecoENERGY for Renewable Power program to pursue the efforts that began with the Wind Power Production Incentive (WPPI) program. The new program will fund an additional 4,000 MW of renewable energy technologies by 2011 out of which 3,000 MW is expected to be wind capacity. This program, along with numerous provincial initiatives, is the main driver for future wind energy deployment in Canada.

By December 2007, a total of 1,845 MW of wind power had been installed in Canada. In 2007, Canadian wind installed capacity increased by 26% from 2006 with the addition of 386 MW of installed capacity (Figure 1). This annual increase ranks Canada tenth in the world in annual installed capacity for 2007 and eleventh in the world in total cumulative capacity.

In 2007, the expansion of wind energy production continued across Canada's large and geographically diverse landmass. By December 2007, the mid-western province of Alberta had the largest total installed wind capacity, with 524 MW, followed by the central provinces of Ontario at 502 MW, and Québec at 422 MW (Figure 3). Only two out of Canada's ten provinces do not have installed wind capacity; the western province of British Columbia and eastern province of New Brunswick. Both British Columbia and New Brunswick are expecting the

Table 1 Key Statistics 2007: Canada	
Total installed wind generation	1,845 MW
New wind generation installed	386 MW
Total electrical output from wind	[4.3] TWh*
Wind generation as % of national electric demand	[0.8]%*
Target:	N/A

* Estimated and based on installed capacity with a 30% capacity factor and new capacity with 15% capacity factor.
Source: StatsCan: 57-601-XWE

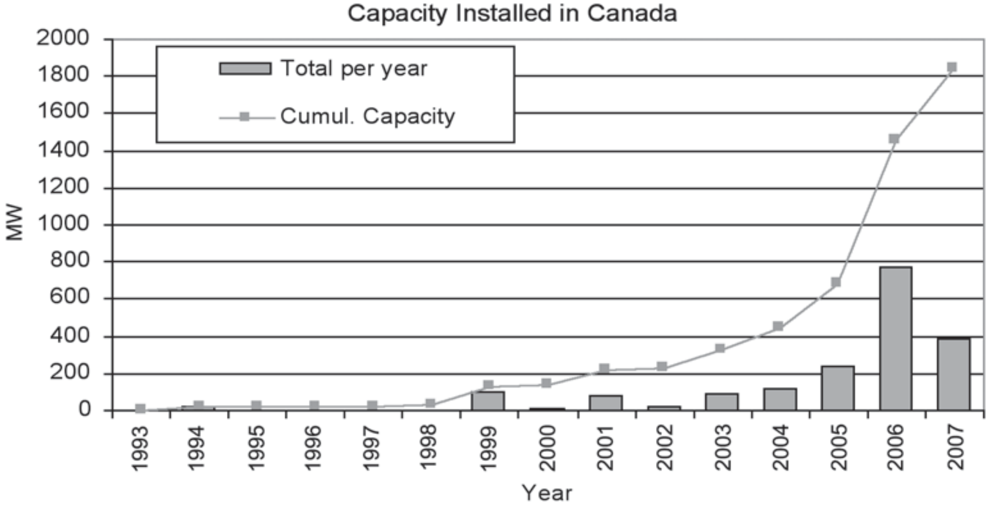


Figure 1 Installed capacity per year in Canada. Source: Natural Resources Canada (NRCan) 2008.

commissioning of their provinces' maiden wind farms in 2008, and both provinces anticipate the installation of over 300 MW by 2010.

The largest increase in capacity of 2007 was 139 MW added in Alberta. The majority of this new capacity resulted from the commissioning of the Kettles Hill Project Phase 1 (54 MW) and the Taber Wind Farm (81.4 MW). In Québec, the Anse-à-Valleau Wind Farm (100.5 MW) represented the single largest commissioned wind farm in 2007. This farm is the second project to be commissioned under the 990-MW Request for Proposal (RFP) process issued in 2004 by Hydro-Québec. In Ontario, the Ripley Wind Power Project (75.9 MW) was completed at the end of 2007. This project was awarded in 2005 as part of the provinces' 975 MW RFP process. Figure 2 shows another wind project in Ontario.

In Prince Edward Island (PEI), three projects totaling approximately 59 MW were commissioned in 2007. The Eastern King Wind Farm (30 MW) was operational in January, while the Wind Cape Wind Farm (19.8 MW) and the Norway Wind Park (9 MW) were commissioned in May and June respectively. In addition to previous installations, these wind farms have allowed PEI to preemptively achieve its target of generating 15% of the province's electricity supply (approximately 60 MW) from wind power by 2010.

Finally, in Nova Scotia the Glace Bay Lingan Wind Farm (10 MW) was completed in early 2007. This project contributes to Nova Scotia's Renewable Portfolio Standard requiring that 15% of total electricity requirements be supplied by renewable energy sources by 2010, rising to 20% by 2013.

2.1 Rates and trends in deployment

Installed wind power capacity in Canada has experienced an average annual growth rate of 54% over the past five years. Canada enjoyed its second best year in new capacity installations in 2007 with 386 MW installed. In spite of this achievement, Canada did experience a drop in annual installed wind power capacity from its record year in 2006 (776 MW). Factors contributing to this decrease include the uncertainty concerning the federal incentive for wind energy during 2006 and the renewal of the production tax credit in the United States, which increased the competition for equipment and reduced the availability of turbines in the Canadian market.

Canada is poised to set an annual installation record in 2008 with a minimum of 700 MW expected to be installed before year's end. This anticipated capacity growth is a result of the ecoENERGY for Renewable Power program launch in early 2007 coupled with a record number of provincial wind farms expected to be

Figure 2 Prince Wind Energy Project (189 MW) in Sault-Ste-Marie, Ontario. Source: Jimmy Royer 2007.

commissioned in 2008. Strong annual growth rates for wind power installation in Canada are expected to continue for the foreseeable future.

According to the Canadian Wind Energy Association (CanWEA), projects currently under construction or with signed Power Purchase Agreements (PPAs) amount to approximately 3,000 MW of additional wind energy capacity by 2012. All provinces either have wind energy targets or RFPs in place or being planned totaling a minimum of 10,000 MW of installed capacity by 2015 (see Section 4.1 for list of initiatives).

2.2 Contribution to national energy demand

In 2005, Canadian national electrical energy generation totalled 557 TWh (Energy Statistics Handbook 2007 File: 57-601-X) and was estimated to reach approximately 565 TWh in 2007. Total installed generation capacity, which includes hydropower, coal, nuclear, natural gas, oil-fired, wood-fired, tidal, and wind plants, totaled 124 GW in 2006 and was estimated to reach a similar level in 2007. The installed wind capacity was 1,845 MW at the end of 2007, producing an estimated 4,340 GWh of wind energy per year (about 0.8% of total electricity production).

3.0 Benefits to National Economy

3.1 Market characteristics

In Canada, wind farms are usually owned by private corporations (independent power producers or IPPs), by utilities, or by income funds. The electricity is sold to utilities by means of a 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 provincial utilities can obtain the electricity at the best rate.

The main constraints for wind energy development in Canada are the lower cost of conventional energy, a surplus of generation capacity in many areas, and a lack of transmission capabilities in areas with promising wind potential. Another constraint is Canada's weather. Wind turbines installed at high elevations are affected by rime ice. Icing can occur anytime between October and May and reduce wind energy production substantially. In addition, icing can be a

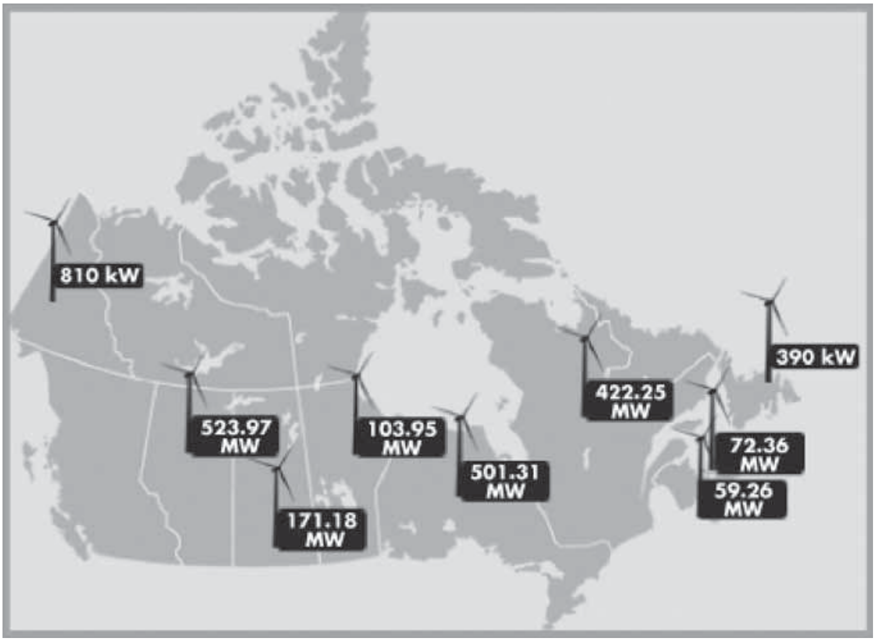


Figure 3 Canada's installed wind capacity. Source: Canadian Wind Energy Association Web site, February 2008.

safety concern and also negatively impacts the fatigue properties of turbine materials. Cold air temperatures also increase loading on turbines due to increased air density. Components such as the gearbox and generators are affected by the resulting increased power output.

To reach its full potential, the Canadian wind energy industry will also have to overcome the following barriers:

- While no fuel cost is associated with wind energy, the cost of wind power is still higher than the current cost of electricity from conventional sources of energy in Canada.
- Wind energy is a variable source of electricity. As a result, local wind installations cannot be relied on for base load requirements, posing challenges to electricity generation and transmission system operators.
- Although wind energy is a clean technology, it is not completely free of environmental effects, such as visual impacts, noise pollution, and potential effects on wildlife such as birds and bats. Community acceptance of wind projects depends on these challenges being addressed.
- Codes and standards need to be developed for local interconnection and safety issues. These are usually harmonized with international standards and should be adapted to ensure Canadian conditions are addressed.

The issue of variability does not yet appear to be a major problem for most regions of Canada, namely because of the wide availability of hydropower facilities, which can act as storage of energy, and because wind energy is still only a small fraction of total electricity production. For levels of penetration higher than 20%, more sophisticated network management strategies will be needed. These issues are now being addressed in Europe, and Canada could benefit from Europe's experience.

The lack of grid transmission availability can be a problem in regions where the wind resource is promising but the grid capacity is inadequate. This is particularly the case in southern Alberta where wind projects have been developing at a fast pace but accessibility to the one transmission line is limited. Recently, a 900 MW cap limit for wind was lifted but development to increase grid capacity has been slow.

Canada also has more than 300 off-grid remote sites that could benefit by integration of their capacity with diesel mini-grids. Demonstration projects in the past have not been very successful, but there is a renewed interest in developing the market for wind/diesel systems.

3.2 Industrial development and operational experience

3.2.1 Industry development and structure

The Canadian industry is composed mainly of companies that manufacture wind-related components such as rotor blades, control systems, inverters, nacelles, towers, and met towers. The rapid growth of Canada's wind energy industry has resulted in a growing number of firms entering the market. It has also caused increased activity in areas including resource assessment, project development, manufacturing, construction, and operations. In fact, CanWEA's corporate membership has grown from 86 members to more than 300 members over the last four years. This growth has had an impact on the Canadian economy in terms of job creation, direct investment, contribution to Gross Domestic Product (GDP), and induced benefits.

A recent survey conducted by Insightrix and commissioned by CanWEA shows that the Canadian wind industry consists of a wide variety of organizations (1). Among the respondents, 66 companies (30% of the total) identified their primary activity as wind power development. A further 49 companies (22%) identified themselves as wind energy consultants; 19 (9%) indicated that they are accessory equipment manufacturers, and another 14 (6%) identified themselves as wind turbine manufacturers.

The industry remains largely Canadian and private-sector based, with 74% of respondents indicating that they are privately-held companies, and 77% indicating that their head offices are in Canada. There is some diversity in terms of scope of project activity: 43% indicated that their organizations' scope of operations were "international," another 30% indicated "provincial or regional," and 22% are "national."

3.2.2 Manufacturing

As shown above, the Canadian industry is mainly comprised of developers backed by large energy firms, industrial corporations, and income funds that bring with them financial resources and commercial credibility. SaskPower and other leaders such as TransAlta, Suncor, and Canadian Hydro Developers have significant operations behind them. In addition, income funds such as Creststreet Power and Income Fund, and Northland Power Income Funds have invested heavily in the development of the wind farms themselves. Large energy related firms, such has TransCanada with Cartier Wind Energy Group, Epcor, Nexen, and Brookfield Power, have created subsidiary power firms to develop wind projects. International firms such as Airtricity, Suez Renewable Energy, and Acciona/EHN have also purchased shares in companies and projects. This phenomenon points to the continuing role of major energy companies in the growth of the industry and the challenge and increased competition ahead for existing market leaders.

Canada is still in the early stages of developing a local manufacturing industry but several promising activities began in 2007. As a result of the two Québec RFP processes, GE Wind Energy has established facilities in the province that have enabled up to 60% of wind turbine components to be manufactured and assembled locally. LM Glasfiber has installed a blade-manufacturing unit in the Gaspé region; Marmen is manufacturing towers in Matane; and Composites VCI is manufacturing nacelles in the area. Elsewhere, DMI Industries (U.S.) acquired a manufacturing plant in Fort Erie, Ontario, to expand its heavy steel wind tower fabrication operations, and Hitachi Canadian Industries is manufacturing wind towers in Saskatoon, Saskatchewan. AAER has started blade and tower manufacturing in Bromont, Québec, and licensed Fürhlander and American Superconductor Corp. technologies. AAER plans to manufacture complete turbines ranging from 1 to 2 MW in Bromont, Québec.

From the Insightrix survey of the 19 companies who are primarily involved in accessory manufacturing, six companies manufacture electrical components, five companies produce wind turbine towers, three companies manufacture monitoring devices, and the remainder produce other accessories. Of the 14 companies primarily involved in turbine manufacturing, six manufacture turbines of more than 300 kW capacity, six manufacture turbines with a capacity between 20 kW and 300 kW, and another three manufacture turbines with a capacity of less than 20 kW.

The small wind turbine manufacturers are comprised of the following:

- Wenvor Technologies, Plastiques Gagnon, and Vergnet Canada are developing small wind turbines in the size range of 10 kW to 30 kW
- Entegrity Wind Systems Inc., Vergnet Canada, Wind Energy Solutions, Cleanfield Energy, and Atlantic Orient Canada Inc. are offering turbines in the size range of 50 kW to 250 kW.

In addition, several companies are proposing small wind turbines that are at various stages of development. Some of the designs feature a vertical axis. The Wind Energy Institute of Canada (WEICan) has recently completed an RFP process for companies wishing to have their wind turbines tested by WEICan at its site in North Cape, PEI. The turbines being considered under this program should have a capacity of 100 kW or less.

3.3 Economic details

No fuel costs are associated with wind energy; therefore, capital costs and operating and maintenance costs largely determine generation costs. Recent calls for tenders and RFPs have shown that the capital costs to install wind farms in Canada range from 1,800 CAD/kW to 2,200 CAD/kW, while the generation costs are estimated to be between 0.075 CAD/kWh and 0.12 CAD/kWh. For example, provincial calls for power in British Columbia, Ontario, and Québec, and the Renewable Portfolio Standard (RPS) in PEI resulted in electricity prices from wind energy in the range 0.0775 CAD/kWh to 0.096 CAD/kWh. In most cases, the latest price proposals have shown the highest prices. The primary variables associated with this cost range are the cost of the wind turbines themselves, the quality of wind resources, transmission connection fees, scale of operation, and size of turbines.

Although the cost of wind power has declined steadily in the past 20 years, recent cyclical factors (the ongoing boom in prices for commodities such as steel and oil, variations in currency exchange, and shortages in wind turbine supply due to a sudden increase in world and U.S. demand) have led to an increase in capital costs of approximately 20%, mitigated slightly by the strength of the Canadian dollar against the U.S. dollar. Thus, in Canada, wind power is still more expensive than electricity generated by conventional sources, and federal and provincial support is still needed to close the price gap.

Canada has also experienced an increase in size of wind farms, especially in provinces with existing wind installations. This is mainly because smaller projects (less than 50 MW) can cost from 10% to 30% more because of economies of scale. This trend may be reversed in regions where a focus on decentralized generation is made, such as in Ontario, which intends to attract new capacity on its distribution lines by providing a fixed-price tariff for clean energy projects less than 10 MW in capacity.

According to the survey by CanWEA referenced above, Canada's wind energy industry contributed 1,490 million CAD to the country's gross domestic product in 2006, which is double the impact in 2005. That same year, there were 3,340 full-time-equivalent jobs in the wind energy industry, an increase of 178% over 2005. This reflects the intense activity carried out in 2006 - a record year for wind energy installation.

4.0 National Incentive Programs

4.1 Main support initiatives and market stimulation incentives

Since 2002, the most influential market stimulation instrument had been the federal government's Wind Power Production Incentive (WPPI) program for wind energy developers. Qualifying wind energy facilities received an incentive payment of 0.01 CAD/kWh of production. The incentive is available for the first ten years of production and helps to provide a long-term stable revenue source. The program is intended to help address climate change and improve air quality. The ecoENERGY for Renewable Power program, launched in April 2007 to replace the WPPI, provides the same incentive under similar terms and conditions as WPPI for an additional 3,000 MW to be built by 2011.

The 14-year ecoENERGY for Renewable Power program will invest close to 1.5 billion CAD to increase Canada's supply of clean electricity from renewable sources such as wind, biomass, low-impact hydropower, geothermal, solar photovoltaic, and ocean energy. The objective of the ecoENERGY for Renewable Power program is to help position low-impact renewable energy industries to make an increased contribution to Canada's energy supply, thereby contributing to a more sustainable and diversified energy future. The program will provide the same production incentive of 0.01 CAD/kWh for up to ten years for electricity generated from eligible renewable energy projects commissioned between 1 April 2007 and 31 March 2011. The program will encourage the production of 14.3 TWh of new electricity from renewable energy sources, enough electricity to power approximately one million homes.

Currently, Classes 43.1 and 43.2 of the federal Income Tax Act provide an accelerated rate of write-off for certain capital expenditures on equipment that is designed to produce energy in a more efficient way or to produce energy from alternative renewable sources. In 2007, the tax write-off was increased from 30% to 50% per year on a declining-balance basis.

In addition, the Canadian Renewable and Conservation Expense (CRCE) category in the income tax system allows the first exploratory wind turbines of a wind farm to be fully deducted in the year of its installation or transferred to investors using flow-through share financing.

Provincial governments provide market stimulation through an array of initiatives. Request for Proposals are a popular method of allowing market participants to bid and compete for a specific wind capacity target. Some provinces, notably Nova Scotia and Prince Edward Island, have implemented Renewable Energy Standards, similar to Renewable Energy Portfolios, where the government legislates that a designated percentage of the provinces' electricity capacity is sourced from wind energy. North America's first Standard Offer Program, or feed-in tariff program, was launched in Ontario in late 2006. Through this program the Ontario government establishes a fixed price for production from various renewable energies, including wind, and allows the market to determine the amount produced. Ontario's program aims to reduce the barriers for small renewable generators and therefore is limited to projects under 10 MW. Table 2, compiled by CanWEA, shows the wind objectives and level of commitment from each province.

In parallel, various agencies are working to provide tools needed by industry to address the market created by these incentives. Provincial and federal governments working directly with industry have supported a better understanding of the wind resource in Canada. The Canadian Wind Energy Atlas developed by the Meteorological Service of Canada (MSC) of Environment Canada is now well established and is used by most developers in pre-siting their projects. The provinces of British Columbia, Ontario, Québec, PEI, and New Brunswick have also produced their own wind atlases, often using the database generated by the Canadian Wind Energy Atlas to provide maps with greater resolutions.

The Alberta Electricity System Operator and CanWEA have started a one-year pilot project to provide wind data to a centralized forecasting service. Industry is also developing its own commercial forecasting services.

5.0 R, D&D Activities

5.1 National R, D&D efforts

The fiscal year 2007/2008 budget for the Wind Energy R&D (WERD) group at Natural Resources Canada (NRCan) was about 3 million CAD, with contributions of about 2.5 million CAD from contractors, research institutions, and provinces.

The Canadian government's Technology Early Action Measures (TEAM) program provided funds for activities falling under the Climate Change Initiative, which included renewable energy deployments. The funds from this program, which was in its last year of activity, were available for wind energy projects that involve nearly developed technologies ready for field trial in the short term.

The focus of the Canadian national wind energy R&D activities continues to be the development of safe, reliable, and economic wind turbine technology to exploit Canada's large wind potential, as well as supporting field trials. NRCan also supports a recently formed national wind institute. Since 1981, the Atlantic Wind Test Site (AWTS), located in North Cape, PEI, has been Canada's primary facility for wind turbine testing, technical innovation, and technology transfer. Now WEICan, which evolved from the regionally based AWTS, focuses on four strategic areas: testing and certification, research and innovation, training and public education, and technical consultation and assistance. WEICan supports the development and implementation of wind power generation and wind energy products and services for Canada and export markets. It has recently signed an exclusive framework agreement with Deutsches

Table 2 Federal and Provincial Objectives for Wind Energy		
Jurisdiction	Initiative	Status
Federal	Launched the ecoENERGY for Renewable Power program in April 2007 to support the deployment of 3,000 MW of wind energy between 2007 and 2011	Program launched in April 2007 and heavily subscribed.
British Columbia	Fifty percent of new generation to come from clean energy sources.	Call for Power 2006 awarded 325 MW of power purchase agreements for wind projects. New Call for Power for 5,000 GWh of power expected to be awarded in spring 2008. Large wind component expected.
Alberta	Eliminated initial 900-MW cap on wind energy production. Now designing transmission upgrades to connect 3,000 MW of wind in Southern Alberta.	Alberta is the first province to pass 500 MW of installed wind energy capacity in Canada.
Saskatchewan	Provincial energy plan seeks to have 300 MW of wind energy in Saskatchewan by 2012.	Currently, 171 MW in place.
Manitoba	Manitoba Government seeking 1,000 MW of wind energy within a decade.	More than 100 MW in place; expected to award another 300 MW of contracts in early 2008.
Ontario	Renewable Portfolio Standard (5% by 2007; 10% by 2010)—potentially four-fifths of this will be wind energy—2,100 MW by 2010. Energy Plan calls for 4,600 MW of wind energy by 2020.	More than 1,500 MW in place and/or contracted; Will release a new 500-MW RFP for renewable energy in Spring 2008. Standard Offer Contract program launched seeking 1,000 MW of renewable energy from projects of 10 MW or less in size.
Québec	Québec Government seeking 4,000 MW of wind energy by 2015.	More than 1,400 MW in place and/or contracted; 2,000-MW of new contracts to be awarded in Spring 2008. 500 MW of new RFPs (for First Nations/Municipalities) to be issued in 2008.
New Brunswick	NB Power seeking 400 MW of wind energy by 2016	Ninety-five MW of wind energy contracted—REP seeking 300 MW of new capacity in place by 2010. Province now expected to meet 400 MW target by 2010.
Nova Scotia	Regulations mandate that almost 20% of electricity must come from renewable sources by 2013.	Sixty MW of wind energy in place; 240 MW of new wind energy of new contracts expected to be awarded by end of 2008 and installed by end of 2009.
Prince Edward Island	Government target of 15% of electricity coming from wind power in 2010 (60 MW); goal of 100% by 2015.	More than 70 MW of wind energy now installed or contracted.
Newfoundland	Target of 80 MW of wind energy.	Fifty-four MW now contracted.

Windenergie-Institut (DEWI) in order to provide the North American wind industry with type testing services. Type testing is undertaken in order to demonstrate a turbine's power performance and is typically comprised of safety tests, load and power performance measurements, as well as static and fatigue blade tests.

In the province of Québec, the Wind Energy TechnoCentre, as part of a collaborative effort involving several Québec universities closely connected to the wind energy industry, has set up the Corus Centre. Located in Murdochville, on the Gaspé Peninsula, the Corus Centre is an organization in North America dedicated to research, development and the transfer of technology. It is surrounded by two wind farms with a total capacity of 108 MW. This location makes the research center a unique natural laboratory in which to study the impact of the Nordic environment on the extraction of wind energy (Figure 4). NRCan has supported the Corus Centre through the acquisition of scientific material.

NRCan's WERD group continues to support new technology development activities related to:

- Small wind turbines (< 300 kW), including the testing of turbines connected in single-phase for net-metering applications, verifying electricity production, reliability of system components, and ability to withstand the Canadian climate
- Large wind turbines (>300 kW), including the support of market infrastructure for large wind technologies through the development of industry standards and planning aids such as the Canadian Wind Energy Atlas, a tool that identifies areas best suited for wind power
- Remote applications, including the development of a 60-kW direct drive permanent magnet turbine that can be connected in single- or three-phase mode, the development of a wind/diesel control system for remote communities, and the support of a wind/diesel/hydrogen demonstration project.

NRCan is currently involved in the development of a wind energy technology roadmap (TRM). A key objective of this TRM is to identify the priority areas for stakeholders, both the technology providers and technology adopters or ultimate users. This will help determine investment areas in research and development required to achieve overall (social, environmental, and technological) cost reductions, and increased Canadian industrial and economic benefits. Reducing the cost will increase the deployment of wind energy in Canada, addressing the government's goal of increasing the contribution of renewable energy to Canada's energy supply. Increased Canadian industrial benefits address the government's goal of "Providing Effective Economic Leadership for a Prosperous Future." Taken together, these two goals support Canada's strategy for greenhouse gas reductions and address energy, economic, and environmental priorities of Canadians.

NRCan is one of the sponsors of the newly formed Canadian Wind Energy Strategic Network (WESNet). WESNet is the first network of its kind in Canada and is comprised of leading Canadian wind energy researchers from 16 universities working in collaboration with 15 contributing partners from Canadian industry, wind institutes, and government. WESNet will realize its vision and achieve its objectives through a research program organized into four wind energy theme areas each led by internationally recognized Canadian researchers:

- Theme 1 Wind Resource Assessment
- Theme 2 Wind Energy Extraction
- Theme 3 Wind Energy in Power Systems
- Theme 4 Techno-Economic Modeling and Optimization of Wind Energy Systems.

5.2 Collaborative research

Canada participates in the following tasks of the IEA Wind Implementing Agreement:

- Task 11—Base Technology Information Exchange,
- Task 19—Wind Energy in Cold Climates, and
- Task 24—Integration of Wind and Hydropower Systems.

Canada participates in the International Electrotechnical Commission's Technical Committee TC88 on Wind Turbines.

6.0 The next term

Although a sustained effort is required to address both technical and non-technical issues, the cost of generation in Canada remains the most important barrier to increased wind

Figure 4 Mount Copper wind farm in Murdochville, Québec. Source: Jimmy Royer 2005.

deployment. Since wind is not yet cost competitive with more traditional sources of electricity in Canada, incentives will still be required in the next few years to sustain the actual growth rate of commercial turbine installations.

The federal wind incentive by itself is insufficient to bridge the cost gap, but it has provided partial funding along with a stable planning framework for both industry and the provinces. This has made a difference, and the Canadian wind market is now growing rapidly. Provincial initiatives requiring minimum regional manufacturing content have contributed to the inception of a wind industrial base in Canada. Some provinces have required a portfolio share for wind electricity or have found other means to encourage wind development.

In the past, cost reductions have come about mainly through a combined effort of improved design and manufacturing. This has led to the development of a growing sustainable market serviced by large, globally competitive, mostly European companies that have the means to fund R&D and improve products and manufacturing methods.

Another key to cost reduction has been better siting of wind turbines and wind farms; this is directly dependent on better knowledge of the geographical distribution of the wind resource. The development of the Canadian Wind Energy Atlas and the development of detailed provincial wind atlases are providing assistance in this area.

Technology and standards development will emphasize the adaptation of international standards to the Canadian context and remote communities. For example, NRCan is currently supporting the demonstration of a wind-hydrogen-diesel system for a remote community in the province of Newfoundland.

Renewable Energy Technology Networks: Canada will continue to maximize information exchange with national and international collaborators through the IEA Wind Implementing Agreement, the Wind Energy Institute of Canada, and through a newly-formed network of Canadian university researchers.

Resource Assessment: Canada will pursue its valuable work quantifying and qualifying wind resources through continued work with onshore and offshore resource assessment and forecasting tools.

Environmental Impact and Mitigation: Environmental impact and mitigation studies are shedding new light on turbine/wildlife interaction as well as noise and radiofrequency interference assessment and mitigation.

Interest in offshore wind projects in Canada is growing with the West coast and Great Lakes being considered as the first areas that will be developed.

Reference:

(1) CANSIA: The Economic Contribution of the Wind Energy Industry to Canada in 2006 A Summary of Results of the 2007 Annual Survey of CanWEA Members, Insightrix 2007.

Authors: Antoine Lacroix, Jimmy Royer, and Jonathan Brady, NRCan, Canada.

Chapter 13
Denmark

1.0 Introduction

Approximately 16.2% of Denmark's energy supplies came from renewable sources in 2007, and the production from wind turbines alone corresponded to 20% of the electricity demand. Another 20% of energy supplies came from natural gas and 23% from coal. Dependence on oil has been about 41%.

The installation of new wind power capacity in Denmark has been low during the past four years. In 2007 the net capacity installed was negative for the first time as 14.1 MW were removed and only 2.6 MW of new wind generation was installed. The key statistics for 2007 are shown in Table 1. However, the Danish wind industry was once again able to maintain a very substantial annual export in 2007 of more than 5,000 MW, which corresponded to a global market share of 25%. The Danish Wind Industry Association estimates that including sub-suppliers and joint ventures/subsidiaries, the Danish wind industry supplied 40% of the world market in 2007.

The Danish government has continued the energy policy introduced in 2006 (based on the Strategy 2025, published June 2005) including initiatives that emphasized globalization and the improved use of renewable energy sources, including stronger support for energy research, development, and demonstration.

In its energy policy proposal, *A Visionary Danish Energy Policy 2025*, of 19 January 2007, the government presented its proposals for the cost effective fulfillment of overall energy policy objectives for security of supply, environmental impact, and competitiveness. The initiatives in the proposal combine political regulation and market mechanisms. With a view to realizing its vision, the government has set the following targets prior to 2025:

- A minimum 15% reduction in the use of fossil fuels compared with today,
- Preventing an overall increase in energy consumption, while sustaining economic growth. With this in mind, the energy saving initiative will be increased to 1.25% annually,
- The share of renewable energy must be increased to at least 30% of energy consumption by 2025,
- A doubling of publicly funded R&D and demonstration of energy technology to 1 billion DKK annually from 2010 onward.

At the end of 2007, the Danish government established a new Ministry for Climate and Energy to strengthen efforts against climate change and to prepare for the Climate summit COP 15 in Copenhagen in 2009.

2.0 Progress toward National Objectives

To reach the goals mentioned above and fulfill the Energy Strategy 2005, several priorities were set. These include additional support for R, D&D in fuel cells, development of second-generation bio-ethanol production, and promotion of new research in wind energy and other renewables. The R&D initiatives are integrated into a new public program focusing specifically on demonstration of new technologies. The program was established at the beginning of 2007 and has a total budget of about 1 billion DKK annually. The Danish Energy Authority prepared projections to 2025 on the production

Table 1 Key Statistics 2007: Denmark	
Total installed wind generation	3,124 MW
New wind generation installed*	-11.5 MW
Total electrical output from wind	7.171 TWh
Wind generation as % of national electric demand**	19.9 %
Target:	Not applicable for wind
* 2.6 MW installed; 14.1 MW removed ** In 2007 the wind index was 108%	

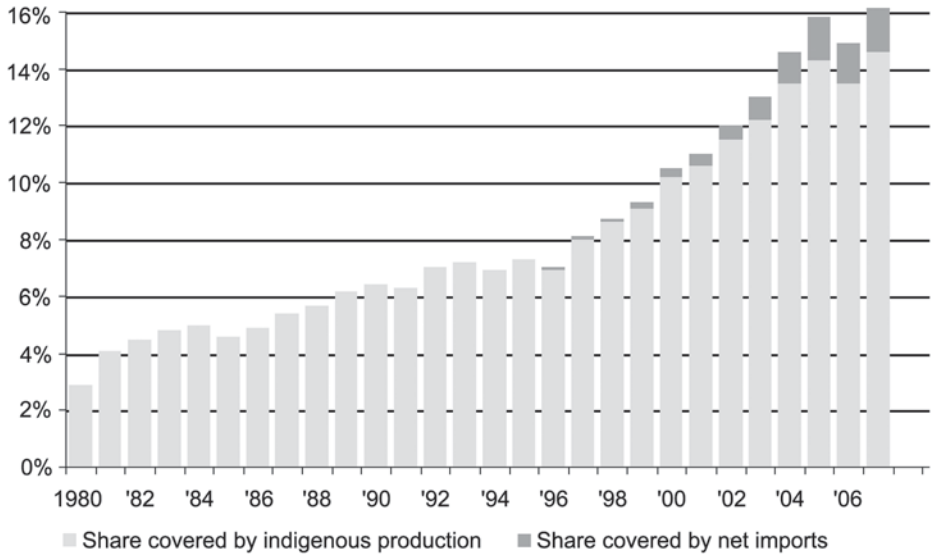


Figure 1 Production and consumption of renewable energy in Denmark and its share of gross energy consumption.

of electricity and district heating; these projections were also reported in the previous years' IEA Wind Annual Reports.

It was expected that a new political agreement with even more fixed targets would take place in 2007, but the parliamentary negotiation dragged on and was postponed by an election in November 2007. A new Ministry for Climate and Energy was established at the end of the year further prolonging the negotiation into 2008.

Information about the Danish wind energy policy can be downloaded from the Danish Energy Authority's (from March 2008 Danish Energy Agency) Web site (www.ens.dk).

2.1 Siting new wind turbines

As reported in 2006, the Danish Energy Authority undertook a new plan for siting the next generation of offshore wind farms between 2010 and 2025. Three committees were set up. One committee's purpose was to lay out plans for future Danish offshore wind turbine development and two committees were to identify sites for future turbines on land and to position new industrially developed turbines (0-series) for testing by manufacturers and developers.

2.1.1 Offshore wind farms

In April 2007, a Committee for Future Offshore Wind Turbine Locations under the Danish Energy Authority published the report: *Future Offshore Wind Turbine Locations – 2025.* The report charts a number of possible offshore areas where offshore turbines could be built to an overall capacity of some 4,600 MW.

Offshore wind turbines with a capacity of 4,600 MW could generate approximately 18 TWh, or just over 8% of total energy consumption in Denmark. This corresponds to approximately 50% of Danish electricity consumption. The committee has examined in detail 23 specific possible locations each of 44 km^2 for an overall area of 1,012 km^2 divided into seven offshore areas.

The committee assessed society's interests in relation to grid transmission conditions, navigation, the natural world, the landscape, raw material exploitation, and so on. The committee also assessed options for connecting major offshore wind farms to the national grid, including examining the engineering, economic, and planning options for landing power, and the consequences for the underlying grid of the various potential areas for construction. At the same time, the committee described scenarios for technological development of wind turbines capable of installation at greater sea depths. The committee attached importance to a planned and coordinated expansion of wind power and the transmission network with a view to obtaining the greatest possible economic benefits.

The committee recommends that the first farms be constructed at Djursland-Anholt in the Kattegat, and Horns Rev in the North Sea. From the economic standpoint, an expansion in Jammerbugten off the coast at Ringkøbing in the North Sea would be almost identical. Finally, the committee recommended locations at Store Middelgrund in the Kattegat, and Kriegers Flak and Rønne Banke in the Baltic Sea.

Taking into consideration the costs involved, the committee recommended that any expansion of offshore wind farm construction should take place in a prioritized order. As the majority of interests were taken into consideration when the potential areas were selected, the recommendations for following a particular sequence in constructing sites are primarily based on the economic consequences regarding the additional costs for installation relative to water depths, the landing of power, the expansion of the land network, and the expected energy production.

The report also discusses a number of areas, several designated previously, which the committee does not believe to be suited to the installation of large-scale offshore wind farms. The committee's report can be downloaded at www.ens.dk.

The nature of completed and planned offshore wind development in Denmark are described in Figures 3 and 4.

2.1.2 Siting on land

The committee for siting on land finished its task early in 2007. The Danish municipalities have been reorganized into larger units, and the former regional authorities will be handing over their responsibility for wind turbine planning to the new, larger municipalities. The following are important recommendations from the working group:

- A large concentration of turbines at selected locations is favored rather than a broad scattering of turbines in every type of landscape,
- The new, larger municipalities should maintain a leading role in the planning process,
- Consideration must be given to neighbors and to various technical and planning matters such as supply of power, energy, and climate policy,
- National authorities must provide background information, planning tools, and knowledge about wind resources and natural constraints.

Furthermore, the group has, in their report, pointed to eight sites suited for positioning test turbines. The final report can be downloaded at www.ens.dk.

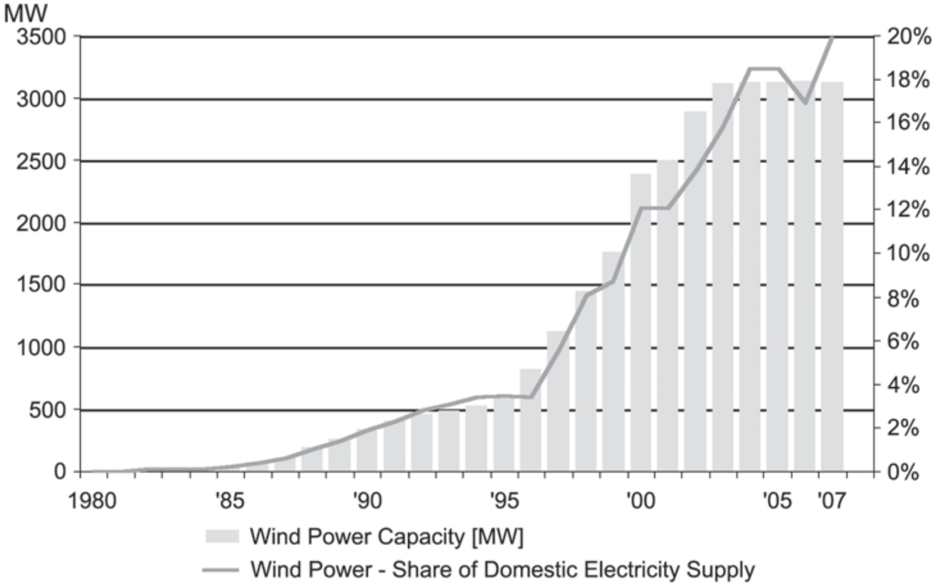
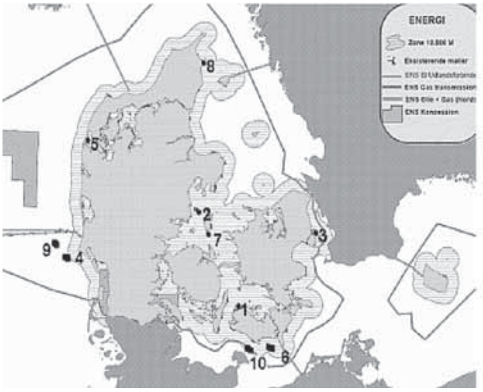


Figure 2 Danish wind power capacity and its share of domestic electricity supply.



1. Vindeby	11 windturbines, 5 MW, 1991
2. Tunø Knob	10 windturbines, 5 MW, 1995
3. Middelgrunden	20 windturbines, 40 MW, 2000
4. Horns Rev 1	80 windturbines, 160 MW, 2002
5. Rønland	8 windturbines, 17 MW, 2003
6. Nysted	72 windturbines, 158 MW, 2003
7. Samsø	10 windturbines, 23 MW, 2003
8. Frederikshavn	4 windturbines, 10.6 MW, 2003
9. Horns Rev II	95 windturbines, c. 200 MW, 2009
10. Rødsand II	92 windturbines, c. 200 MW, 2010

Figure 3 Location, composition, and commissioning date of offshore wind farms in Denmark.

2.1.3 Siting large 0-Series

Also in spring 2007, a committee also under the Danish Energy Authority finalized a report on sites for large MW test and demonstration turbines. The committee estimates that 30 sites will be needed during the next two to three years. It is indicated that coastal areas at sea can be utilized for the purpose. The committee identified eight sites that are considered suited for the purpose.

The identified sites are expected to hold a total of 37 turbines with a total height of up to 200 m. The selected locations are primarily areas with excellent wind resources, areas that have previously been planned for test sites, areas in connection to larger industrial sites such as harbours, and areas that are robust regarding visual impact to on the surroundings. This committee's report can also be downloaded at www.ens.dk.

2.2 Installed capacity and production in 2007

The total capacity of wind power in Denmark decreased by 11.5 MW in 2007, which brought the end-of-year total to 3,124 MW. The total number of turbines was reduced to 5,212. During 2007, only 11 new wind turbines were installed, and 65 turbines were dismantled. The average capacity of those installed in 2006 was slightly higher than in 2005 - 1.28 MW compared with 1.23 MW. In 2007, new turbines in Denmark were only medium-sized, with an average of about 240 kW. A detailed history of installed capacity and production in Denmark was shown in the IEA Wind Annual Report of 2006.

As was shown in Table 1, electricity from wind energy covered 19.9% of the electricity consumption in Denmark in 2007 compared to 16.8% in 2006. The total electricity production from wind energy in 2007 was 7,171 GWh, an increase from the unusually low value of 6,108 GWh in 2006.

The largest turbines installed in Denmark on land by the end of 2007 were one 3.6-MW Siemens turbine and one 4.2-MW Vestas (NEG Micon) turbine at the Risø DTU test site at Høvsøre. The 4.2-MW turbine was taken down in January, 2008. Other sites with large turbines include three Vestas 3-MW turbines on the Island of Lolland, two Vestas 3-MW turbines in Frederikshavn, and five 2.75-MW turbines at the Tjæreborg site near Esbjeg. The two largest offshore wind farms are still the 160-MW offshore wind farm at Horns Rev (80 Vestas 2-MW wind turbines placed in the North Sea 14 km to 20 km offshore Blaavands Huk) and the wind farm at Nysted south of Lolland in inland waters (72 Bonus 2.3-MW wind turbines).

Following the political agreement of 2004, two more offshore wind farms of 200 MW each will be established. The two new sites will be located near existing offshore farms- one at Horns Rev and one at Rødsand.

2.3 Horns Rev II

The offshore wind farm Horns Rev II is to be located about 10 km west of the existing wind farm at Horns Rev (Figure 3). The wind farm where construction starts in 2008 will cover a total area of about 35 km^2, and the wind farm will be commissioned during 2009.

Figure 4 Potential locations for offshore wind farms.

Energinet.dk is responsible for extending the electricity grid to the wind farm. The energy company DONG Energy will own and build the farm. The price to be paid for the electricity was negotiated with the government, and is set to 0.518 DKK/kWh for the first 50,000 full-load hours, which corresponds to about 12 years of electricity production. DONG Energy conducted feasibility studies and prepared an environmental impact assessment report that clarifies environmental and natural conditions. During the fall of 2007 the final project plan was sent in for approval.

2.4 Rødsand II

Rødsand II had previously been open for competitive bidding and was won by a consortium of Energi E2, DONG Vind, and E.ON Vind Sweden. The project was later turned over solely to E.ON Vind, which decided in late December 2007 not to construct the wind farm under the specified terms. Now a new solicitation of tenders has been announced. The deadline for submission is 21 April 2008. Since the project's environmental impact has already been assessed and described in an EIA report that will be made available to the new contractor, the project is not starting completely over, but can draw upon the work already done. The Danish Energy Authority expects that a winning bidder will be named before the 2008 summer holidays, which will make it possible to have the wind farm connected to the Danish electrical grid by 2011.

2.5 Information on Danish offshore projects

More information about the deployment of offshore wind is available in the Danish Energy Authority's publication "Offshore Wind Power—Danish Experiences and Solutions," which was published for the Copenhagen Offshore Wind Conference, October 2005 (www.ens.dk/graphics/).

Post-construction environmental studies initially showed almost complete absence of the birds called divers and scoters within the Horns Rev 1 wind farm and significant reductions in long-tailed duck densities within the Nysted wind farm. Other species showed no significant change or occurred in too few numbers to permit statistical analysis.

Although such bird displacement represents effective habitat loss, it is important to assess the loss in terms of the proportion of potential habitat affected relative to the areas that remain available outside the wind farms. It has to be emphasized that foundations and scour protection for the two projects only take up around 50,000 m^2 of sea-bed area corresponding to 0.2% of the entire wind farm area. For most of the species studied, that proportion is relatively small and therefore of little biological consequence.

Common Scoters, (Melanitta nigra) a large sea duck, 43-54 cm in length, dramatically changed their distribution in the Horns Rev area during the period from 1999 to 2007 for reasons other than the presence of the turbines. They were virtually absent from the Horns Rev area prior to the construction of the wind farm. Post-construction, their distribution included the Horns Rev area, but their absence inside the wind farm area lead to the perception that they had been forced out of previous feeding grounds, even though in general this has had only insignificant effects on population levels. Then, in late 2006 and early 2007, Vattenfall A/S maintenance crews and helicopter pilots reported increasing numbers of Common Scoters present within the wind farm site. On that background a series of four surveys of water bird distribution in the area was conducted during January to April 2007 (1). On 25 January 2007, 2,112 birds, on 15 February 2007, 4,624 birds, on 3 March 2007, 1,359 and on 1 April 2007, 35 Common Scoters were encountered within the footprint of the wind farm.

The results from the four aerial surveys carried out in 2007 show that, in contrast to the earlier years post construction, Common Scoters were present in significant numbers between the turbines at Horns Rev 1. It can therefore be concluded that Common Scoters may indeed occur in high densities between newly constructed wind turbines at sea, but this may only occur a number of years after initial construction. It cannot be excluded from the explanation that this may reflect changes in food supply rather than a change in the behaviour of the birds themselves.

Figure 5 Two of the eighty turbines at the Horns Rev 160-MW offshore wind farm (published with permission of DONG Energy and Vattenfall).

3.0 Benefits to National Economy

3.1 Market characteristics

The sale of wind turbines from Denmark in 2007 is estimated at 6.6 GW. As it is noted above, the Danish home market was an extremely low contributor to this market in 2007. Therefore, nearly all turbines manufactured were exported, contributing more than 35 billion DKK/year to the national economy. In 2006, the two large manufacturers Vestas and Siemens together had a world market share of more than 35%, now somewhat lower about 30%. It is estimated that more than 28,000 people are employed in the Danish wind sector.

The market for onshore wind power in Denmark in 2007 was still characterized by a low electricity purchase price based on the market-based price plus a CO_2 premium of 0.10 DKK/kWh, with a cap of 0.36 DKK/kWh, which was introduced in 2002. The new political agreement for energy is, however, expected include higher purchase prices.

Offshore, the future market will be driven by political decisions based on the plan described above.

3.2 Industrial development and operational experience

3.2.1 Manufacturing

Today, the major Denmark-based manufacturers of large commercial wind turbines up to a size of some MW are Siemens Wind Power (formerly Bonus Energy A/S) and Vestas Wind Systems A/S. Only one company, Gaia Wind Energy A/S (owned by Mita teknik A/S), today produces wind turbines for households. A couple of small companies are planning to produce micro-turbines.

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, which produces controller and communication systems; and Svendborg Brakes A/S, a leading vendor of mechanical braking systems.

The 3-MW turbines are still the largest commercial turbines installed in Denmark. Vestas has, as a result of experiences at Horns Rev and the problems with the 3-MW turbines, made a strong effort to improve the quality of its offshore wind turbines, and the 3-MW turbines are once again for sale to offshore projects.

3.2.2 Operational experience

The technical availability of new wind turbines on land in Denmark is usually in the range of 98% to 100%. Offshore, the availability of turbines on the small near-shore farms is also high. Since 2005, all Horns Rev offshore turbines operated at nearly 100%, with an availability of 95% to 97% in 2007. During the same time period, the Siemens (Bonus) turbines at Nysted were at the same level and reached 97.5% in 2007 until the main transformer broke down in June and left the farm out of production for several months. The transformer was put back in operation in October.

3.3 Economic details

No new data on operation and maintenance costs (service, consumables, repair, insurance, administration, lease of site, and so on) have been reported. Growing commercialization in the wind energy market makes it more difficult to have data on hardware and O&M costs. Information from a study by the Danish Wind Turbine Owners' Association about O&M for turbines between 600 kW and 1,300 kW was reported in the *2004 IEA Wind Energy Annual Report*.

3.4 Certification of wind power installations

Wind turbines installed in Denmark must fulfill the Danish Wind Turbine Certification Scheme. The scheme is based on the IEC WT01 System for Conformity Testing and Certification of Wind Turbines. In September 2007, a supplementary set of rules for micro turbines up to 2.5 m in rotor diameter was implemented. All documents related to the certification scheme can be found on the Web site: www.wt-certification.dk.

4.0 National Incentive Programs

In 2007, Denmark followed the incentive system introduced in June 2004 with a premium of 0.10 DKK/kWh paid on top of the market price for 20 years. The system includes a cap of 0.36 DKK/kWh for turbines installed before the end of 2004 plus an allowance of 0.023 DKK/kWh. For turbines installed after 2005 there is no cap. For the many turbines that were still in a transition period, the fixed prices depend on the turbine's age. Turbines included in the re-powering scheme get an extra premium of 0.12 or 0.17 DKK/kWh. Details about the purchase prices were listed in the *2004 IEA Wind Energy Annual Report* and can be found at www.ens.dk.

5.0 R, D&D Activities

5.1 National R, D&D efforts

A major increase in funding of wind R, D&D was introduced in 2006, and a large increase was again initiated in 2007. In 2006, energy R, D&D funds totaled 326 million DKK, and the budgets for 2008 showed an increase to 457.1 million DKK. In 2008, the Energy Research Program (EFP) will become part of the Energy Development and Demonstration Program (EDDP). Additionally, the national research councils and the newly established High Technology Foundation may also provide funds for energy research. The aim is a doubling of publicly funded research, development, and demonstration to 1 billion DKK annually from 2010 onward. The programs and available funds are shown in Table 2.

The Danish Energy Authority is responsible for the administration of the EFP and the new

Table 2 Programs and Available Funds for Renewable Energy R&D Projects Including Wind Energy (million DKK)				
Program	2005	2006	2007	2008
Energy Research Program	73.0	74.0	76.0	210.6
Energy Development and Demonstration Program	—	—	110.0	
PSO*—electricity production	130.0	130.0	130.0	130.0
PSO*—electricity utilization	25.0	25.0	25.0	25.0
Renewable energy R&D—Danish Agency for Science Technology and Innovation	45.0	108.3	107.1	91.5
Total	273.0	337.3	448.1	457.1
*PSO = public service obligation				

EDDP, which covers research in both conventional energy and renewable energy. In 2007, the administration has been carried out according to the EFP regulations. Additionally, the EFP supported international R&D cooperation through IEA.

Of the EFP budget, 7 million DKK is reserved for quality assurance for renewable energy devices, including wind turbines. A description of the EFP and the projects it supports is available (in Danish) on the Danish Energy Authority's Web site (refer to www.ens.dk).

The total grants to wind energy projects supported by the EFP and the EDDP in 2007 were 33 million DKK. The projects are listed in Table 3 together with projects funded by other Danish programs.

The secretariat of the Danish Wind Turbine Certification Scheme is allocated 1.5 million DKK to manage quality assurance of turbines. The actual certification of turbines and installations is carried out by private certification companies like DNV and GL. Denmark has also been active in international standardization through IEC and CEN/CENELEC for several years.

5.2 Danish Council for Strategic Research

For 2007, the budget for energy and environmental research of the Danish Council for Strategic Research was increased to 108 million DKK. In 2007, two wind energy projects were funded with a total of 24.5 million DKK.

5.3 The PSO program of transmission system operators

Transmission system operators have had PSO-subsidized R&D programs for noncommercial projects concerning new and environmentally friendly energy technologies since 2000. The programs focus on development of renewable energy technologies including wind power. Priority areas and the total budget are to be approved by the responsible minister and the Danish Energy Authority. The PSO program emphasizes the interaction between turbines and the power system, including the wind-power plants' abilities to contribute to regulation and stability. Grants from the PSO program in 2007 totaled 15 million DKK.

5.4 Nordic Energy Research

Nordic Energy Research's goal is to be conducive in maximizing the results of energy-related research and development in the Nordic Region and their adjacent areas. Nordic Energy Research is financed by the Nordic Countries. In 2007, a project regarding Large-Scale Integration of Wind Energy into the Nordic Grid was commenced. The budget is 4.9 million NOK. The project participants are: Risø DTU, SINTEF (Technical Research Centre of Norway), and VTT (Technical Research Centre of Finland).

5.5 Risø DTU

On 1 January 2007, Risø National Laboratory, the Danish Institute for Food and

Table 3 Important Wind Energy Projects Funded by Danish R&D Programs in 2007.		
Project title (funding source) (million DKK)	Applicant	Support
Physical and numerical modeling of monopole for offshore wind turbines (EFP)*	AAU	2.3
Program for research in applied aeroelasticity (EFP)	Risø DTU	3.5
Wind resource mapping analyses in complex terrain (EFP)	Risø DTU	2.5
Experimental rotor- and airfoil aerodynamics on MW wind turbines (EFP)	Risø DTU	3.9
(Anisotropic girder model for analyses and design of passively controlled wind turbine blades (EFP)	Risø DTU	2.4
Improved methods for fatigue evaluation – A pre-study (EFP)	Risø DTU	0.9
Estimates of extreme responses and failure probabilities for wind turbines (EFP)	AAU	1.0
Nano filtering of oil (EFP)	C. C. Jensen Ltd.	1.9
Noise emission from wind turbines in wakes (EFP)	Delta	1.7
Wind turbine economy (EFP)	EMD	1.7
Design and optimization of wind turbine blade tips (EFP)	DTU MEK	2.1
Integrated design of wind turbine systems (EFP)	AAU	1.5
Program for applied aero- elasticity (EFP)	Risø DTU	4.2
Improved design basis for large turbine blade fiber composits (Phase 4) (EFP)	Risø DTU	2.0
Wind turbine components knowledge centre (EFP)	Danish Wind Industry Association	1.5
Concurrent aero-servi-elastic analysis and design of wind turbines (EnMi)**	Risø DTU	10.0
Seabed wind farm interaction (EnMi)	DTU MEK	14.5
Mesoscale atmospheric variability and variation of wind Nd production for offshore wind farms (PSO)***	Risø DTU	2.5
Shadow effects of large wind turbines (PSO)	Risø DTU	2.4
Aero-hydro-elastic simulation platform for floating systems (PSO)	Risø DTU	2.7
Offshore wind dynamics (PSO)	Risø DTU	1.4
Main electrical components in wind turbine gears (PSO)	DTU Ørsted	4.0
Wind farms noise and energy optimization (PSO)	Delta	2.0

* EFP = Energy Research Program, Danish Energy Authority
** EnMi = Danish Strategic Research Program, Energy and Environment Committee
*** PSO = Public Service Obligation, Power Sector

Veterinary Research, the Danish Institute for Fisheries Research, the Danish National Space Center, and the Danish Transport Research Institute merged with the Technical University of Denmark (DTU), with DTU as the continuing unit. Risø still owns and manages the test site for multi-MW wind turbines at Høvsøre, a site on the northwest coast of Jutland with high wind speeds. The annual average wind speed at the site at a height of 78 m is 9.1 m/s. The test site consists of five test stands allowing turbines with heights up to 165 m and a capacity of up to 5 MW each. The test site is shown in Figure 6.

5.6 Collaborative research

At the level of the European Union, Risø DTU plays a leading role in the large project called UpWind. This project aims to design a wind turbine of 8 to 10 MW that will be able to operate onshore and offshore on wind farms of several hundred megawatts. With Risø DTU as the coordinator, thirty-eight partners participate in the project, which started early in 2006.

Denmark participates in the following IEA Wind Tasks: Task 11 – Base Technology Information Exchange; Task 20 – HAWT Aerodynamics and Models from Wind Tunnel Measurements; Task 21 – Dynamic Models of Wind Farms for Power System Studies; Task 23 – Offshore Wind Energy Technology Deployment; Task 25 – Power System Operation with Large Amounts of Wind Power; and Task 26 - Cost of Wind Energy. In Task 23, the Department of Wind Energy, Risø DTU serves as one of the task Operating Agents.

6.0 The Next Term

It is expected that focus on wind power and other renewables will continue over the next years with emphasis on the new, large, offshore projects that are currently in the planning process in the framework of the COP 15 Climate Change Meeting to be held in Denmark in late 2009. The new political agreement for energy begun in 2008, including more offshore wind power and better terms for the wind power on land in Denmark, emphasizes that there is a political will. The recently enacted new initiatives that aim to fulfill the Energy Strategy 2025 will strengthen wind energy R, D&D in Denmark. It is expected that focus of the new EDDP program will be shifted to increase demonstration of new technologies.

Reference:

(1) *Changes in bird habitat utilisation around the Horns Rev 1 offshore wind farm, with particular emphasis on Common Scoter*, Report request Commissioned by Vattenfall A/S 2007, National Environmental Research Institute, University of Aarhus, Denmark.

Authors: Jørgen Lemming and Flemming Øster, Wind Energy Department, Risø National Laboratory; Hanne Thomasssen and Steffen Nielsen, Danish Energy Agency, Danish Ministry of Climate and Energy, Denmark.

Figure 6 Test site at Høvsøre for multi-MW wind turbines.

Chapter 14
European Commission

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1.0 Introduction – Wind Energy Deployment in the EU During 2007

Europe has historically been and continues to be the world's strongest market for wind energy development. In 2007, the European Union (EU) saw another record year with installations above 8 GW, thereby reaffirming its undisputed status as the world's biggest wind market (1). Industry statistics released by the EWEA show that in 2007 cumulative wind capacity increased by 18% to reach a level of 56.535 GW; this was up from 48.069 GW at the end of 2006 (Figure 1). This 8.554 GW of new wind power capacity represents a wind turbine manufacturing turnover of some 11 billion €.

1.1 Overall capacity increases

In the EU, wind power continues to be one of the most popular electricity generating technologies for expanding capacity. Since 2000, the more than 158 GW of new electricity generating capacity has been installed in the EU. During that time, the installed wind capacity has increased almost six-fold from 9.7 to 56.5 GW. Over these last eight years, according to figures from Platts PowerVision and EWEA, new gas installations totaled 88 GW, while wind energy installations totaled 47 GW; representing 30% of the total new generation installations over the period.

In 2007, wind power installations alone made up 40% of new power installations in Europe and grew more than any other power-generating technology. Total wind power capacity installed by the end of 2007 will produce 119 TWh, or 3.7% of EU power demand in an average wind year, and will avoid about 90 million tons of CO_2 annually. In 2000, less than 0.9% of EU electricity demand was met by wind power.

The 2007 capacity increase was driven by Spain representing 40% of the total (Figure 2). Indeed, Spain set a new record in 2007, installing 3.522 GW – the highest amount of any European country in any year. Now, 10% of Spain's electricity comes from wind. There was also sustained growth in France – which added 888 MW to reach 2.454 GW – and Italy, which installed 603 MW for a total of 2.726 GW. The new Member States performed well and increased their installed wind capacity by 60%, with Poland, the most successful, reaching a total of 276 MW. The Czech Republic installed 63 MW, its best year ever, and Bulgaria installed 34 MW.

Over the last ten years, cumulative wind power capacity in the EU has increased by an average of 28% per year. In terms of annual installations, the European market has grown by an average 21% over the same period. Nevertheless, a handful of the largest markets (Figure 3) did not grow as much as expected including Germany, Portugal, and the UK. As a result, the overall market growth in 2007 was 12%, not as striking as it could have been. Looking beyond Europe, the global market for wind turbines grew by approximately 30% last year to 20 GW.

The change of pace 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 approval of the Commission's proposed renewable energy directive (23 January 2008) by the 27 Member States and the European Parliament.

1.2 Offshore wind

Offshore wind, seen as a key market for European expansion, continues to progress slowly. By 2007, the industry had developed 25 projects in five countries, many of them large-scale and fully commercial, with a total capacity of around 1,100 MW (Figure 4). In terms of electricity production, at the end of 2006, offshore wind farm installations represented 1.8% of the total installed wind power capacity but generated 3.3% of the electricity from wind energy. Denmark, the United Kingdom, the Netherlands,

Wind power installed in Europe by end of 2007 (cumulative)

EU Capacity (MW)	End 2006	Installed 2007	End 2007
Austria	965	20	982
Belgium	194	93	287
Bulgaria	36	34	70
Cyprus	0	0	0
Czech Republic	54	63	116
Denmark	3,136	3	3,125
Estonia	32	26	58
Finland	86	24	110
France	1,567	888	2,454
Germany	20,622	1,667	22,247
Greece	746	125	871
Hungary	61	4	65
Ireland	746	59	805
Italy	2,123	603	2,726
Latvia	27	0	27
Lithuania	48	7	50
Luxembourg	35	0	35
Malta	0	0	0
Netherlands	1,558	210	1,746
Poland	153	123	276
Portugal	1,716	434	2,150
Romania	3	5	8
Slovakia	5	0	5
Slovenia	0	0	0
Spain	11,623	3,522	15,145
Sweden	571	217	788
UK	1,962	427	2,389
Total EU-12	**419**	**263**	**675**
Total EU-15	**47,651**	**8,291**	**55,860**
Total EU-27	**48,069**	**8,554**	**56,535**
Of which offshore	*870*	*210*	*1,080*

	End 2006	Installed 2007	End 2007
Candidate Countries (MW)			
Croatia	17	0	17
FYROM*	0	0	0
Turkey	50	97	146
Total	**67**	**97**	**163**
EFTA (MW)			
Iceland	0	0	0
Liechtenstein	0	0	0
Norway	325	8	333
Switzerland	12	0	12
Total	**337**	**8**	**345**
Other (MW)			
Faroe Islands	4	0	4
Ukraine	86	3	89
Total Europe	**48,563**	**8,662**	**57,136**

*FYROM = Former Yugoslav Republic of Macedonia

Note: Due to previous-year adjustments, project decommissioning of 88 MW, re-powering and rounding figures up and down, the total for the 2007 end-of-year cumulative capacity is not exactly equivalent to the sum of the 2006 end-of-year total plus the 2007 additions.

Source: EWEA

Figure 1 Wind power installed in Europe by end of 2007.

Sweden, and Ireland had operating offshore wind farms. In 2007, three projects were completed in the United Kingdom and Sweden (Figure 5).

The short-term prospects for offshore wind, however, look promising with several projects scheduled to be delivered in 2008 and 2009: the UK (800 MW), Denmark (200 MW), Sweden (140 MW), the Netherlands (120 MW), France (105 MW), Germany (60 MW), and Belgium (30 MW). One critical element for an acceleration of the development of offshore wind energy in the EU is the rapid publication of the Commission's proposal for an action on offshore wind power.

2.0 The EU Legislative Framework for Wind Energy

2.1 The RES-E Directive

Up until now, an important factor behind the growth of the European wind market has been strong policy support both at the EU and

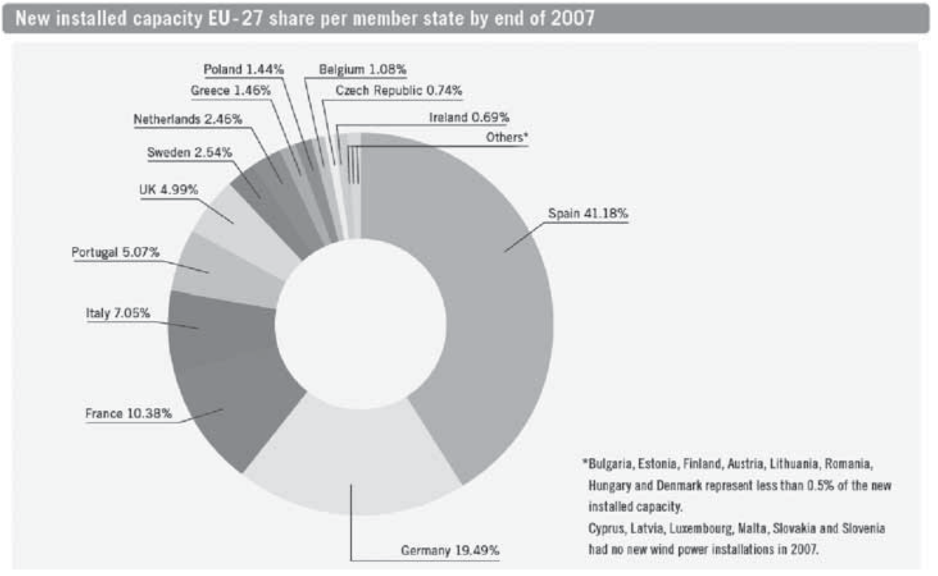

Figure 2 New installed capacity per Member State by end of 2007.

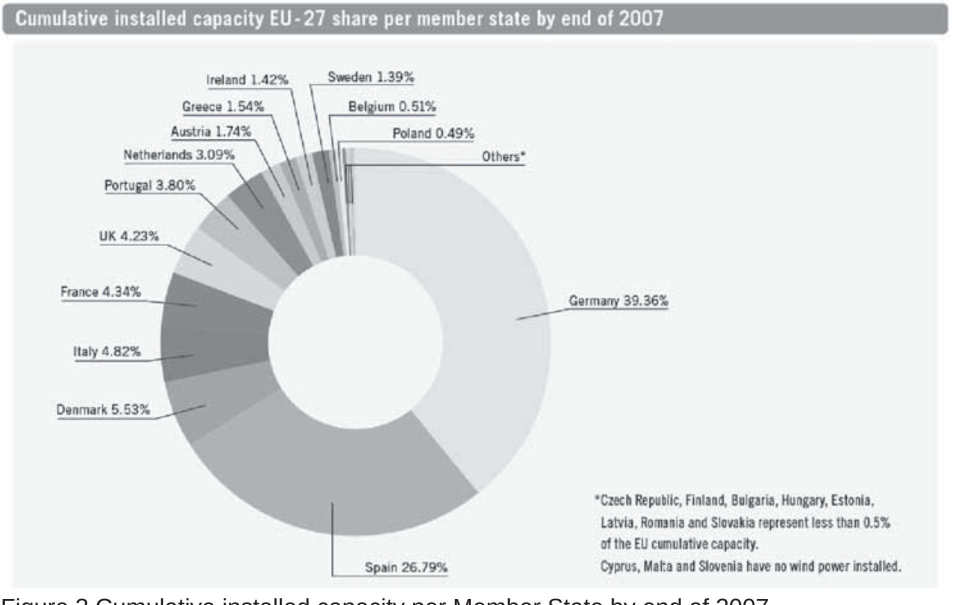

Figure 3 Cumulative installed capacity per Member State by end of 2007.

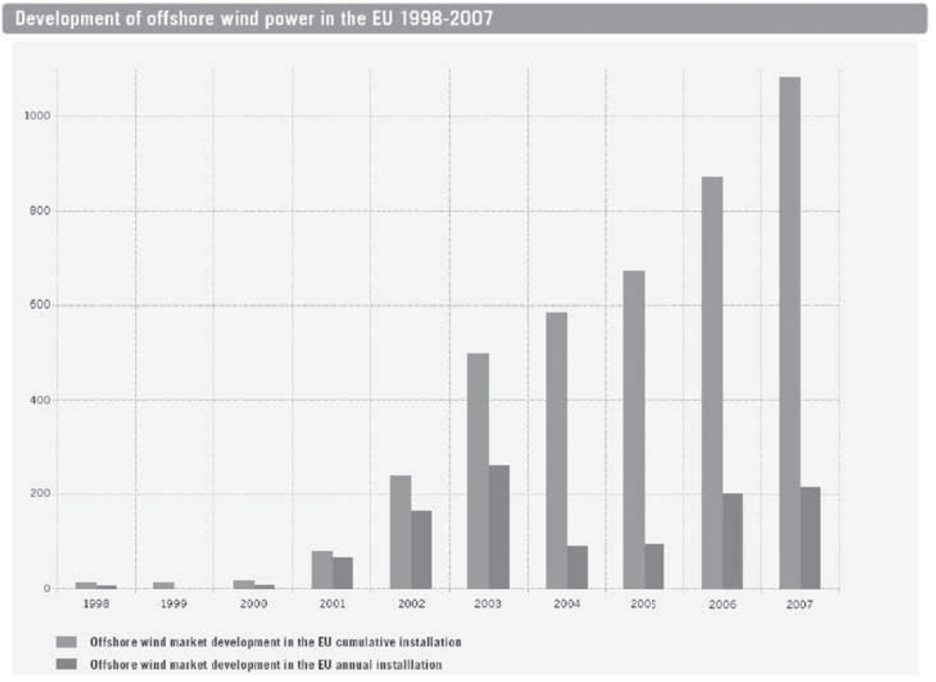

Figure 4 Historical development of offshore wind power in the EU 1998 – 2007.

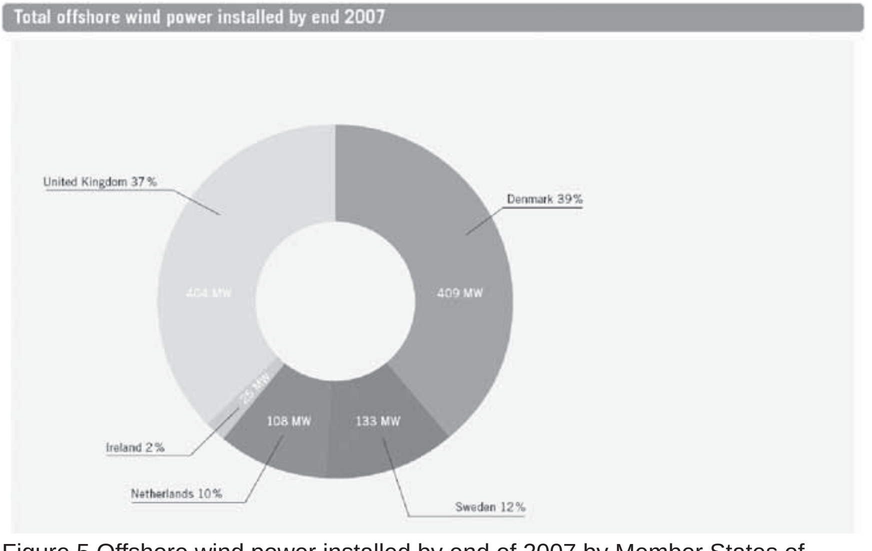

Figure 5 Offshore wind power installed by end of 2007 by Member States of the EU.

at the national level. The EU's *Renewables Directive (77/2001/EC)* has 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 a target of 15.2% expressed in 2001), thus helping the EU reach the RES target of contributing 12% of overall energy consumption by 2010. This target was established by the EU Renewables (RES-E) Directive, which set out differentiated national indicative targets. The RES-E Directive has been a historical step in the delivery of renewable electricity and constitutes the main driving force behind recent policies being implemented.

In the pursuit of the overall target of 21% of electricity production from renewable sources by 2010, the RES-E Directive gives EU Member States freedom of choice regarding support mechanisms. Thus, various schemes are operating in Europe, mainly feed-in tariffs, fixed premiums, green certificate systems, and tendering procedures. These schemes are generally complemented by tax incentives, environmental taxes, contribution programs, or voluntary agreements.

The European Commission (EC) reports *COM (2005) 627* and *COM (2008) 19* have highlighted that despite the requirements of *Directive 77/2001/EC*, the efforts of Member States, and some improvements of the regulatory frameworks, major barriers to the growth and integration of renewable electricity remain. In relation to wind, the progress report highlights that even if the level of payment is sufficient to cover costs, it may not increase deployment of wind. The main cause of the slow development in some Member States is not deliberate policy barriers, but delays in authorization, unfair grid access conditions, and slow reinforcement of the electric power grid. The reports invite the Member States to give a high priority to removing administrative barriers and improving grid access for renewable energy producers.

Finally, the EC reports conclude that the harmonization of support schemes for economic efficiency, single market, and state aid remains a long-term goal, but that harmonization in the short-term is not appropriate. By adopting best practices or combining national support schemes Member States can continue to reform, optimize, and coordinate their efforts to support renewable electricity. According to the European Wind Energy Association, a hasty move toward a harmonized EU-wide payment mechanism for renewable electricity would have a profoundly negative effect on the markets for wind power and put European leadership in wind power technology and other renewables at risk.

2.2 The future EU Legislative Framework for wind energy

In March 2006, the EC launched a consultation process to discuss the medium and long-term strategy for an EU energy policy, including renewable energies. The Green Paper "A European Strategy for Sustainable, Competitive and Secure Energy" (COM (2006) 105) proposed the preparation of a "renewable energy roadmap" that would include: an active program with specific measures to ensure that existing targets are met; consideration of which targets or objectives beyond 2010 are necessary; and research demonstration and market replication initiatives.

In January 2007, the EC released its "Strategic Energy Review" - also called "Energy Package." This comprehensive set of 19 documents is intended to plan the EU energy landscape in the medium and long-term. It proposes an overall binding target of 20% of EU energy consumption coming from RES by 2020 without specifying how that overall target should be split among the different sectors (electricity, heating and cooling, and transport).

In March 2007, the EU Heads of State responded by adopting a binding 20% target for renewables by 2020 and called the EC to put forward a legislative package. On 23 January 2008, the EC published its proposal for an energy and climate package for 20% RES by 2020, together with a review of the ETS from 2013, CCS and greenhouse gas targets for 2020. The 20% target at the EU level has now been translated into concrete figures for the 27 EU Member States. The "national action plans" will contain an indication of how the agreed upon target for each Member State is going to be achieved in each energy sector (thus, sector-specific breakdown), and the measures that will be put into place. The proposal also contains measures which positively address obstacles that wind energy is currently facing, such as heavy administrative procedures and grid access issues.

The draft directive proposes a stable and flexible EU framework in which Member States keep control of their renewable energy policies through successful national support systems. In addition, cross-border transfer of guarantees of origin (GoO) can only take place where Member States have met or exceeded their interim targets. By introducing a voluntary trading mechanism controlled by Member States, the proposal maintains market stability, increases investor confidence, and will help Member States to reach their ambitious yet achievable targets. Related to the national action plans, EWEA argues that these plans should become "fixed" once they have been approved, and that sector targets/figures (i.e. a certain amount of RES-E to be produced by 2020) should not change easily, otherwise, investors will face uncertainty.

3.0 R&D Wind Energy Projects Funded by the EC

In 2007, more than 20 R&D projects were running with the support of the Fifth, and Sixth 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 among 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 (DG TREN) 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 2007.

3.1 DG Research activities

In 2007, the two projects POW'WOW and UPWIND continued their activities.

POW'WOW: which stands for Prediction Of Waves, Wakes and Offshore Wind (powwow.risoe.dk), is a three-year coordination action which started in October 2005 with the aim to co-ordinate 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 the work on some roadmaps for the future. A first workshop on "Best Practice in the Use of Short-Term Forecasting of Wind Power" was held in Delft in 2006. In September 2007, a workshop on "Integration of Wind and Wave Resource Assessment" was organised in Porto. In May 2008, a second workshop on "Best Practice in the Use of Short-Term Forecasting of Wind Power" will be held in Madrid.

UPWIND: UPWIND, which stands for Integrated Wind Turbine Design (www.upwind.eu), started in March 2006 to tackle, over five years, the challenges of designing very large turbines (8 to 10 MW), both 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 with a consortium composed of 40 partners and brings together the most advanced European specialists in the wind industry.

Following the first call for proposals by the EC's Seventh Framework Programme, three wind-related proposals were selected for funding in 2007. Assuming a successful negotiation procedure, those proposals, summarised below, will become projects and begin in early 2008.

RELIAWIND: The EU Council of Ministers held on 8 and 9 March 2007 examined these issues and agreed, amongst other things, that "renewable energy will cover at least 20% of the EU's energy demand by 2020." Wind power can make the most important contribution to this target, if sufficient emphasis is placed on technological R&D and market development. Because of the current European scenario and its forecasted evolution toward 20% renewables by 2020, offshore wind energy is called to play a key role. 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 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. 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 WTG 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 prenormative 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 consortium 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.

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 urge for dedicated approaches to reduce large prediction errors or scale up local predictions of extreme weather (gusts, shears) to a European level as 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 proposal is to substantially improve wind power predictability in challenging or extreme situations and at different temporal and spatial scales. Going beyond this, wind predictability is 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. The project concentrates on:

- Using new measuring devices for a more detailed knowledge of the wind speed and energy available at local level
- 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.

3.2 DG TREN activities

The five projects discussed below represent a selection of demonstration actions funded within the Sixth Framework Programme of the EU and managed by the DG TREN.

SEEWIND: In the SEEWIND project, newly developed practices for measuring wind streams in complex terrains (like LIDAR and tools for micro-scale simulation of wind flow) will be applied and examined. For testing wind turbine performance, three pilot turbine test sites (two in mountainous areas and one at a coastal site) have been chosen in South-East Europe. The building codes and related standards for wind turbine construction in Western Balkan countries will be evaluated and compared with other European standards.

TOPFARM: In order to achieve the best economic output from a wind farm, the project TOPFARM aims to determine, on a rational background, an optimal balance between costs (capital, operation, and maintenance), fatigue lifetime, consumption, and power production. The design variables for the optimization model are the relative position of the wind turbines (including the possibility for positioning a given number of turbines in one or more wind farms) and wind turbine control strategies on the wind farm level as well as for the individual wind turbine.

ANEMOS.PLUS: The aim of the ANEMOS.PLUS project is to fully integrate forecasts of the power output of wind farms and their uncertainty into management and decision support tools. In the first stage, the wind forecasting tools currently in use will be enhanced with new functionalities such as probabilistic forecasting. In the second stage, new operational tools for managing wind generation and for trading in electricity markets will be developed. The tools are demonstrated at two levels: 1) the wind power prediction tools are brought into everyday practice by using the results for decision making, and 2) in a highly integrated approach, the new operational tools act to weld together the worlds of fluctuating wind power and traditional energy systems. The use and integration of the needs and knowledge of daily users like operators and traders are key parts of this project.

EWIS: The European Wind Integration Study (EWIS) project proposes to identify and investigate the impacts of introducing a large number of wind power plants into the electric power systems in Europe and to develop different models for operating and planning a transmission system with a significant electrical generation from wind power. The consortium involves fifteen TSOs representing thirteen countries and the four main synchronous electricity systems in Europe. The objective for the short term (2008) is to bring solutions to the actual problems of load flows due to wind power that have been identified in each synchronous power system. For the longer term (2015), the goal is to institute common pan-European recommendations, such that the present problems do not reoccur in other European areas whenever wind power is introduced at a larger scale.

WINDSEC: In this project, the Secretariat of the European Technology Platform for Wind Energy, will optimize the activities of the Platform and develop its infrastructure. The objectives are to comprehensively model the market development and technology research needs and resources of the wind energy sector, with a view to cost reduction through economy of scale and new technology. The platform reaches out to stakeholders from private industry, Member States, EU institutions, financiers, research institutions, and others. The goal is to achieve maximum representation, building intra-sector sensitivity for greater collaboration, and development of new synergies.

3.3 Future R&D projects

Several wind projects are expected to start in 2008 under the Seventh Framework Programme. The new projects will address the demonstration of innovative multi-MW machines and wind mapping for offshore applications.

3.4 European Commission contacts

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

DG TREN
Roberto GAMBI
European Commission
Office DM24 3/35
B-1049 Brussels Belgium
Tel. direct: +32-2-299.81.75
Fax: +32-2-296.62.61
Email: roberto.gambi@ec.europa.eu

4.0 The European Wind Energy Technology Platform

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. Energy Commissioner Andris Piebalgs and Member of Parliament Mechtild Rothe gave the opening address. The TPWind is an industry-led initiative. The Secretariat is composed of the European Wind Energy Association, 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, and one Finance Group responsible for exploring and proposing funding mechanisms for implementing the strategy. Altogether, this represents a group of 150 high-level experts representing the whole industry.

In May 2008, TPWind will issue its Strategic Research Agenda and Market Deployment Strategy documents. These documents were debated during the two General Assemblies of the Technology Platform. In parallel, TPWind is setting up its Mirror Group, including Member States representatives. TPWind is thus the indispensable forum for the crystallization of policy and technology research and deployment pathways for the wind energy sector. It also provides an opportunity for informal collaboration and coordination between Member States, including those less developed in wind energy terms.

The following diagram (Figure 6) reflects the structure of the now fully-operational TPWind. The secretariat of the platform is funded by the Sixth Framework Programme.

TPWind Secretariat contact

TPWind Secretariat
Renewable Energy House
Rue D'Arlon 63 - 65
B-1040 Brussels Belgium
Tel.: +32-2-546.19.40
Fax: +32-2-546.19.44
Email: secretariat@windplatform.eu
www.windplatform.eu

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.

Authors: Thierry Langlois d'Estaintot, European Commission, DG Research; Roberto Gambi, European Commission, DG TREN; Loïc Blanchard, European Wind Energy Association.

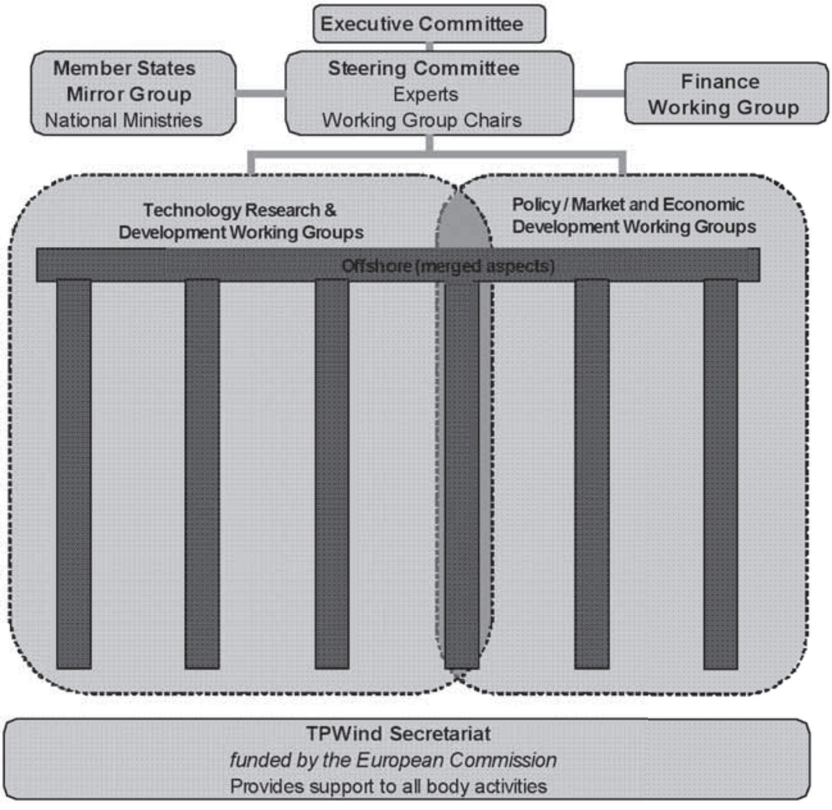

Figure 6 Structure of TPWind. SOURCE: European Wind Energy Technology Platform. Available at http://www.windplatform.eu.

Chapter 15
Finland

1.0 Introduction

Energy in Finland is generated using a large share of renewables, mainly hydropower and biomass. Finland's generating capacity is diverse; in 2007, 25% of gross demand was produced by nuclear, 15% by hydropower, and 29% from combined heat and power (coal, gas, biomass, and peat). Gross electricity demand is about 90 TWh and is dominated by energy-intensive industry. About half of the electricity is consumed by the paper and metal industries.

Most of Finland's hydropower resource has already been used; there is potential for about 1 TWh/yr more. Biomass is used intensively by the pulp and paper industry, raising the share of biomass-produced electricity to 11% in Finland. There is still biomass potential available, and this is reflected by the national energy strategy, which foresees biomass as providing most of the increase in renewables.

Wind energy potential is located mostly on coastal areas. There is a huge technical potential offshore, with ample shallow water sites available. Offshore, nearly 10,000 MW of wind power potential has been identified in the process of renewing regional plans in Finland.

2.0 Progress Toward National Objectives

In the energy and climate strategy approved in 2005, the target for RES was set to 31.5% of the total electricity consumption in 2010, with no specific goal for wind power. Although the 100-MW milestone of installed wind capacity was surpassed in 2007, the progress in wind power capacity has been slow compared with other European countries. The funds available for investment subsidies are inadequate to achieve any large increases in wind power capacity. With the existing support mechanisms, only 200 to 300 MW of wind power capacity is foreseen for 2010.

In 2007, the EU published a renewable energy target of 20% of energy consumption by 2020. The target proposed for Finland by the European Commission is 38% of final energy consumption by RES (current RES share is 28.5%). This means that the previous target for RES electricity (31.5%) will be increased. Currently, 2,000–3,000 MW of wind power in 2020 is discussed as the possible contribution of wind power for achieving the RES target. This means that a change in the incentive program will be needed. Feed-in tariffs are discussed as one alternative option in future.

The development of wind power capacity and production is presented in Figure 1. In 2007, 11 new turbines totalling 24 MW were installed, bringing the total capacity to 110 MW (28% growth from the previous year). Total wind energy production in 2007 increased by 23% compared to 2006. The production of 188 GWh corresponds to 0.2% of the annual gross electricity consumption of Finland. The environmental benefit of wind power production in Finland is about 0.1 million tons of CO_2 savings per year.

There were 107 wind turbines in operation in Finland at the end of 2007. Average wind turbine size passed the 1 MW benchmark at 1,030 kW at the end of 2007. About 47% of the turbines and related components originate from Denmark, 26% from Germany, 22% from Finland, and 5% from the Netherlands. The size of the installed capacity ranges from 75 to 3,000 kW with the new turbines in 2007 from 1,000 to 3,000 kW.

There are two projects in the building phase, and so 30 to 40 MW of new capacity is

Table 1 Key Statistics 2007: Finland	
Total installed wind generation	110 MW
New wind generation installed	24 MW
Total electrical output from wind	0.188 TWh
Wind generation as % of national electric demand	0.2%
Target:	No specific target for wind power; target 31.5% share of RES electricity in 2010

expected in 2008. In addition, more than 100 MW of projects are planned. The largest projects are in Kemi (30 MW in 2007 to 2008), Pori (offshore demonstration; 45 MW in planning phase), Tornio (28 MW in 2009) and Eckerö (18 MW in 2009). Two large offshore project plans were published in 2007: Suurhiekka off Oulu and Ii in northern part of the west coast (400 MW), and Korsnäs (600 MW). The Environmental Impact Analyses have been started and building could start in 2012.

The Åland islands between Finland and Sweden constitute an autonomous region with its own legislation, budget, and energy policy. Wind energy deployment there is steady and, considering the population, the targets are ambitious. In 2006, wind energy was expected to cover 10% of electricity consumption in the region. This figure stood at 14% in 2007, and will rise to about 23% after the 13.8-MW semi-offshore project in Båtskär, built in 2007, has produced all year.

3.0 Benefits to National Economy

3.1 Market characteristics

Most of the turbines in Finland are located along the coast and are owned by power companies and local energy works (Figure 2). Green electricity is offered by most electric utilities; however, the marketing is not very active. 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, although they are located inland where the wind resource is limited.

Good sites for larger wind farms on the coastal areas are scarce. This is one reason for interest in offshore projects. The first semi-offshore projects were built in 2007; six 2.3-MW turbines were installed in Åland Båtskär (Figure 3) and five 3-MW turbines in Kemi (of which only one turbine was operational at the end of 2007) (Figure 4). The first demonstration project in Pori (45 MW) is in the planning phase as well.

3.2 Industrial development and operational experience

3.2.1 Industrial development

The Finnish manufacturer WinWinD presented its first 1-MW pilot plant in spring 2001 and erected the 3-MW pilot plant in Oulu in 2004. Their turbines operate at variable speed

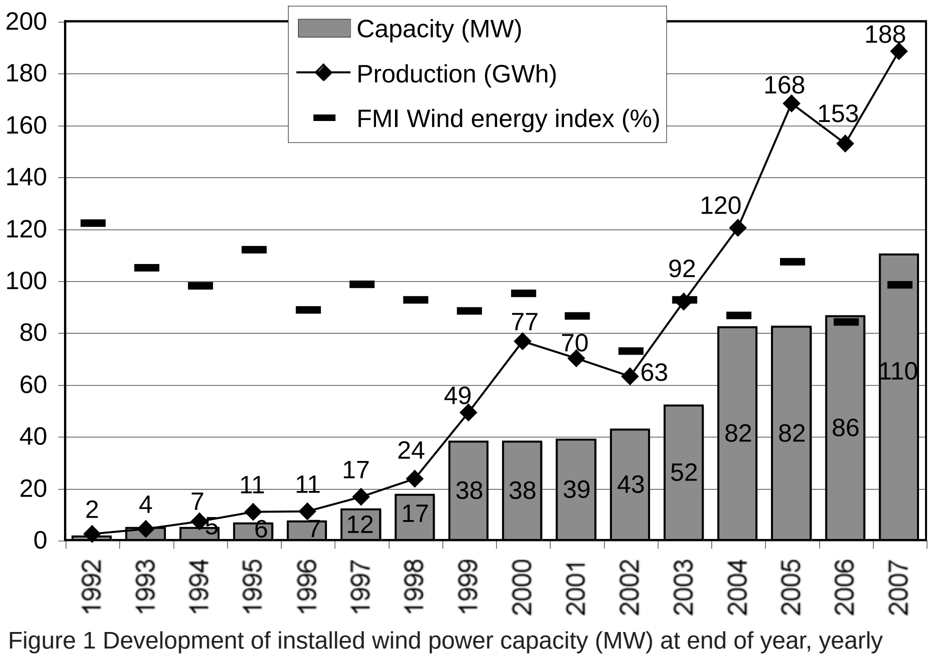

Figure 1 Development of installed wind power capacity (MW) at end of year, yearly wind power production (GWh), and wind production index (calculated from Finnish Meteorological Institute wind-speed measurements converted to wind power production, 100% is average production for 1987–2001).

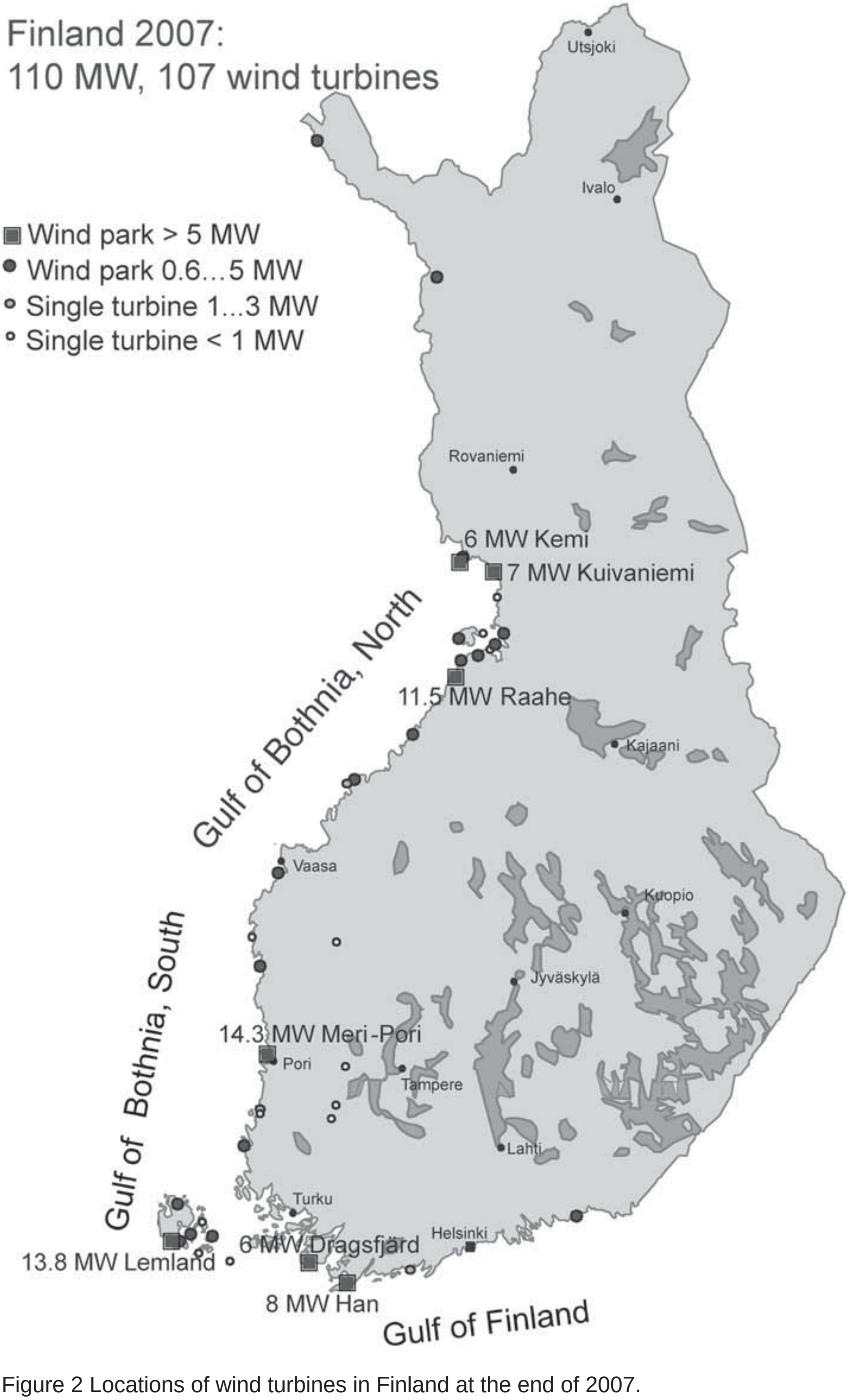

Figure 2 Locations of wind turbines in Finland at the end of 2007.

Figure 3 New semi-offshore wind farm (6 x 2.3 MW) installed on the cliffs and small islands in Åland archipelago, Båtskär (Photo: Henrik Lindqvist).

Figure 4 Erecting semi-offshore wind turbine in Kemi, where ten 3-MW turbines are to be built in 2007 and 2008. (Photo: WinwinD).

with a slow-speed planetary gearbox and a low-speed permanent magnet generator. This solution combines the best features of a direct drive and gear system, producing efficient and reliable turbines. WinWinD has manufactured 22% of all turbines in Finland (24 MW) (Figure 5). By the end of 2007, WinWinD had installed 87 MW in seven different countries including Estonia, France, Portugal, and Sweden, with over 140 MW contracted. This includes what will be the largest wind park (thirteen 3-MW turbines) in the Baltic countries, which is under construction in Estonia. Since 2006, the main owner of WinWinD is Indian Sterling Infotech Group (SIG). This has led to a steady expansion in the company and an increase in the production capacity to meet the demand for turbines.

Several industrial enterprises have developed important businesses as suppliers of major components for wind turbines. For example, Moventas Oy (earlier Metso Drives Oy) is the largest independent manufacturer of gears and mechanical drives for wind turbines. ABB Oy 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, designed and built to withstand harsh conditions, to meet the needs of wind turbine applications. In 2005, Hollming launched a new assembly plant in Loviisa for wind turbines and components. WinWinD's 3-MW turbines, as well as direct-drive generators for Switch, are assembled there. In addition, materials such as cast-iron products, tower materials, and glass-fiber products are produced in Finland for the main wind turbine manufacturers. The total turnover was about 500 million € in 2007 (400 million € in 2006) (Figure 6).

The manufacturing industry has a branch group under technology industries in Finland, to promote technology development and to export wind technology. This group estimated the benefit to the national economy in its road map for wind power technology in November 2005. According to the calculations, investing a total of 220 million € for wind energy from 2006 to 2020 could result in raising the yearly wind technology exports from 200 million € to 1,400 million €/yr by 2020 and creating 18,000 new jobs. According to this scenario, total investment for wind power in Finland would be 100 million €/yr on average from 2006 to 2020 (1,500 MW), and this would result in a CO_2 reduction of 7 million tons during those years (10 TWh total).

3.2.2 Operational experience

According to the statistics, performance of wind power production has improved (Figures 7 and 8). The average capacity factor was higher between 2000 and 2007 than it had been in the 1990s, even though the FMI wind energy production index has been lower in recent years.

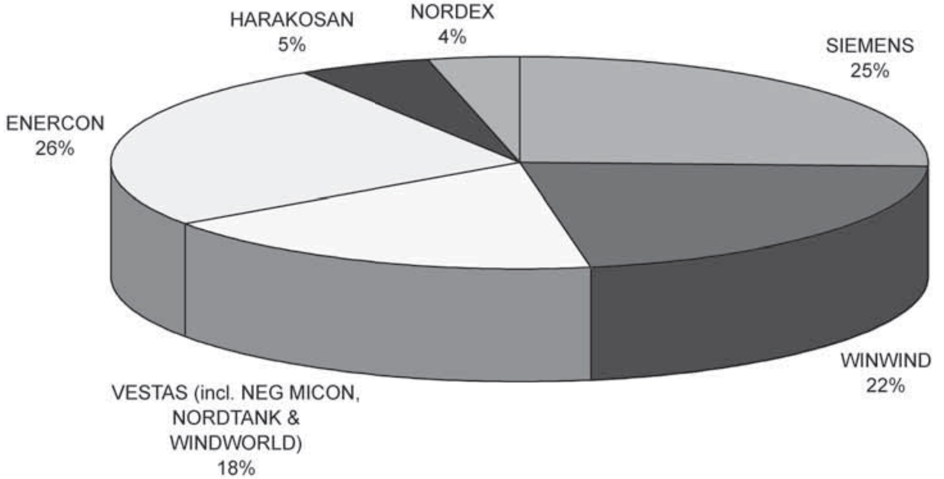

Figure 5 Market shares of turbine manufacturers in Finland as a percentage of the total capacity at the end of 2007 (110 MW).

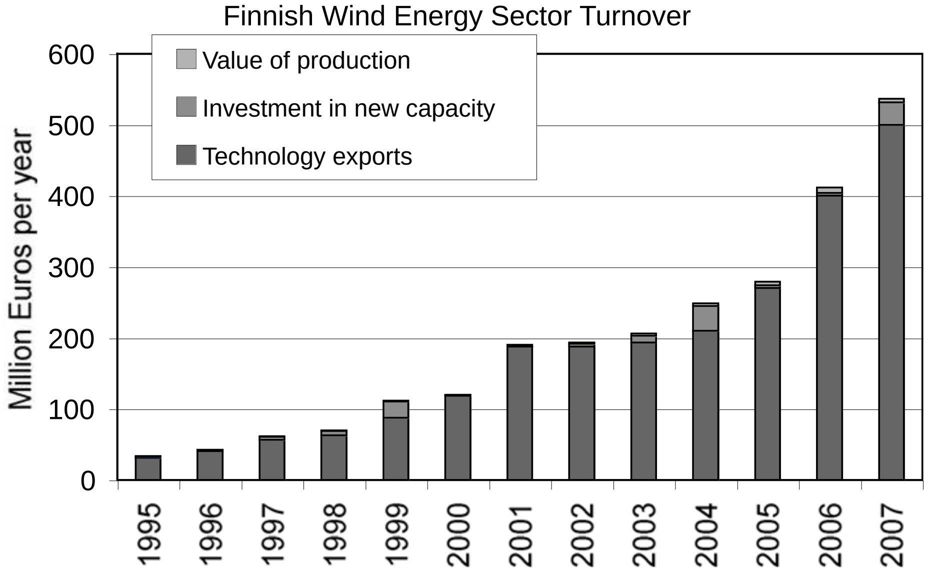

Figure 6 Finnish wind-sector turnover: wind power technology exports, investments, and production turnover. Turnover from electricity production sales has been estimated from the average spot price.

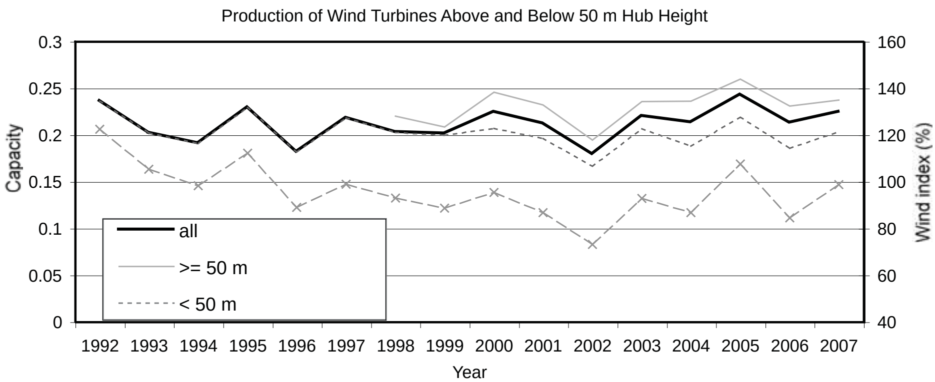

Figure 7 Average capacity factor of wind turbines in Finland for all turbines and for higher- and lower-hub-height turbines. The production index calculated from FMI wind-speed measurements is also shown (100% corresponds to average production in 1987–2001). Turbines with low availability (< 80 %) have been excluded in this analysis.

This improved production is mainly because more megawatt-scale machines are reaching a greater wind resource.

Average availability of the wind turbines operating in Finland was 94% in 2007 (93% in 2006). Two old 300-kW turbines were un-operational all year after gearbox problems late in 2006. Also two old 200-kW turbines had a low availability as they are reaching the end of their operational life. For the 96 turbines operating the whole year, two blade failures, five gearbox failures, and two bearing failures were reported in 2007.

3.3 Economic details

The cost of wind energy production in Finland without investment subsidies (15 years, 7% internal rate of return), would be about 60 to 80 €/MWh for onshore costal sites, and about 80 to 100 €/MWh for offshore sites. The average

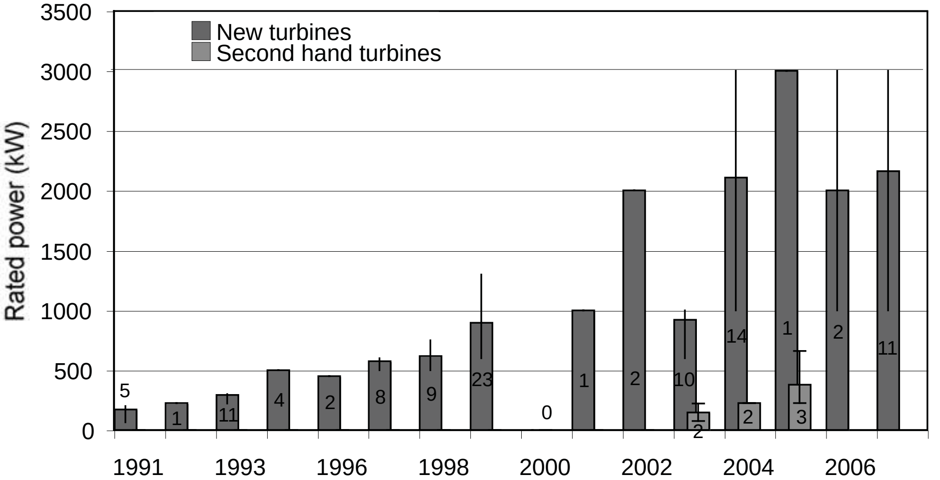

Figure 8 The average size of installed capacity (rated power in kilowatts) is indicated by the bar (for new and second-hand turbines). The number of installed turbines is marked in the bars. The vertical line represents minimum and maximum capacity of turbines installed.

spot price in the electricity market Nordpool was 30 €/MWh in 2007 (49 €/MWh in 2006). Emission trade effects on the operating costs of thermal power have resulted in an increase of spot market prices and can be seen in the future and forward prices that are above 40 €/MWh for 2008 to 2009. Wind power still needs subsidies to compete even on the best available sites.

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. Several companies offer green or specifically wind electricity certified by the Association for Nature Conservation.

If the impacts of emission trading continue to raise electricity market prices, this will improve the cost competitiveness of wind. A possible feed-in tariff for wind energy would greatly increase the wind power market in Finland.

4.0 National Incentive Programs

Depending on the level of novelty of a wind energy installation, an investment subsidy of up to 40% can be awarded. Projects that applied for a subsidy between 2001 and 2006 received an average investment subsidy of 35%. In addition to the investment subsidy, a tax refund of 6.9 €/MWh is awarded (Figure 9).

The national energy and climate strategy was updated in 2005. The target for electricity production from RES in Finland is 31.5% of gross demand; this is the same target as in the European Union RES-E-Directive on national objectives concerning electricity produced from renewable energy sources. This target requires electricity production from renewable sources to increase by 8.3 TWh from the 1995 level. The major part, 75%, would be generated from biomass. No major changes in measures were suggested. The wind-specific target was dropped.

In spring 2007, a new coalition government was formed in Finland. Implementation of a new wind atlas and a feed-in tariff for biogas-based electricity production were included in the program for the new government.

In 2007, the EU published a target of 20% of energy consumption by renewable energies in 2020. The target proposed by the Commission for Finland was set to 38% of final energy consumption by RES (the current share is 28.5%). This means that the previous target for RES electricity (31.5%) will be increased. Work began on a new energy strategy late in 2007. Currently, 2,000–3,000 MW in 2020 is discussed as a possible contribution by wind power for achieving the RES target. This means that a change in the incentive program will be needed. Feed-in tariffs are discussed as one alternative option in future. There is currently a feed-in tariff for peat-based electricity production and a proposal for a feed-in tariff for biogas-based electricity production.

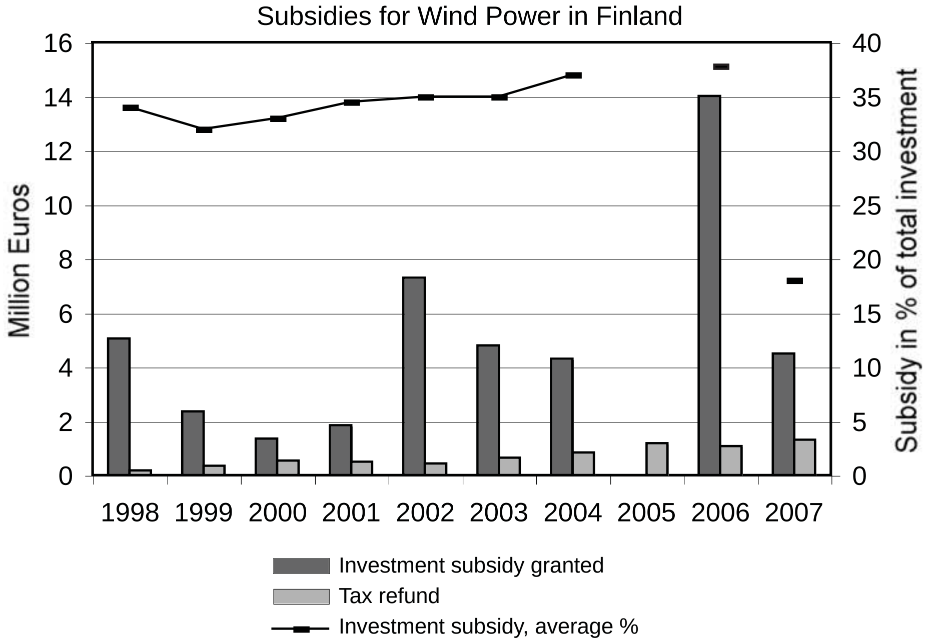

Figure 9 Investment subsidies granted for wind power and the total amount of tax refunds for wind electricity in Finland. The average investment subsidy as a percent of total investment costs is also shown. Most of the capacity granted with investment subsidies in 2006 (total 25 MW) was built in 2007.

An addition to the Electricity Market Act was approved in 2007 where a ceiling to the distribution network charges was set for distributed generation, including wind. The distribution charges vary across the country and in some areas have hindered local generation. The act also stated that grid reinforcement payments be borne by the consumers, not by the producer. Before becoming effective in February 2008, project size for grid reinforcement exemption was limited to 2 MW, reduced from the original 20 MW. This means that the promoting effect of the grid reinforcement exemption will remain small for wind power.

Wind energy deployment is slow in Finland, but there is still continuing discussion of the environmental impact of wind turbines. Land-use restrictions and visual pollution, especially in relation to summer residents and vacation activities, might yet prove a significant obstacle to development. To overcome these problems, the Ministry of Environment published guidelines for planning and building permission procedures for wind power plants. Sites for wind power have also been added to regional plans by the authorities. This will help future wind power projects. Large areas, mostly offshore, have already been added for the Northern Gulf of Bothnia (about 4,000 MW) and the Western Gulf of Finland (about 200 MW). The planning process is ongoing for the Southern Gulf of Bothnia, and the Eastern Gulf of Finland.

5.0 R, D&D Activities

5.1 National R, D&D efforts

Since 1999, Finland has not had a national research program for wind energy. Individual projects can receive funding from the National Technology Development Agency (Tekes) according to the general priorities and requirements for technical R&D (Figure 10). Benefit to industry is stressed, as is the industry's direct financial contribution to individual research projects. Priority is given to product development and the introduction of new products. The technology program DENSY (Distributed Energy Systems) (2003 to 2007) contained wind related research projects on the grid connection of distributed energy systems (protection and voltage regulation) and on storage of energy from distributed energy systems. National projects for collaboration with IEA Wind Tasks 19, 21, 24, and 25 have been under the DENSY program. The technology program CLIMBUS (Business Opportunities in Mitigating Climate Change) (2004 to 2008) aims to develop technology and business concepts related to reduction of greenhouse gas emissions.

In the DENSY project WINTEG, which is the Finnish national project for IEA WIND Tasks 24 and 25, there have been two Master's theses published in 2007 in Helsinki Technical University. The first thesis estimated the balance settlement costs for wind power in Finland with different balance settlement systems (so-called one and two-price models) and compared these costs to the costs incurred by the power system from increased use of the balancing market due to wind power. The results show that the estimated cost for the Finnish power system due to day-ahead forecast errors is less than 0.3 €/MWh for 500 MW wind power and rises to 1.5 €/MWh for 4,000 MW wind power (10% wind penetration). The balancing costs that wind power producers pay are already at that level even if the current wind power does not incur these costs. The one-price model for balance settlement was shown to follow the true costs, whereas the two-price model currently in use will make the balancing costs for the producers higher than what they impose on the power system. In the second Master's thesis, grid reinforcement due to wind power in Finland was estimated to be around 50 €/kW for 5 to 10% wind penetration (2,000 to 4,000 MW wind).

Technical Research Centre of Finland (VTT) is developing technologies, components, and solutions for large wind turbines. As part of the EU project UPWIND, technologies to control the shape of composite structures have been developed at laboratory scale. In 2007, a one-meter-chord blade section with controllable trailing edge was manufactured using shape memory alloys integrated into the composite and tested in a wind tunnel.

Several enterprise projects for wind technology development are in progress. WinWinD has developed 1-MW and 3-MW turbines for different weather conditions. ABB has developed a direct-drive, multi-pole, permanent-magnet wind turbine generator. The Switch Company is developing multi-megawatt generators and modular series-connected frequency converters. Moventas has several projects on gearbox load management. Pem-Energy Oy is developing small-sized wind turbines. Oivallin has developed an embedded condition-monitoring system to be used in wind turbines.

5.2 Collaborative research

VTT has been active in several international collaborative projects in the EU, Nordic, and IEA frameworks. In a demonstration project called HISP, three 2-MW direct-drive turbines (Harakosan Europe) are connected to a weak network. VTT is also involved in projects

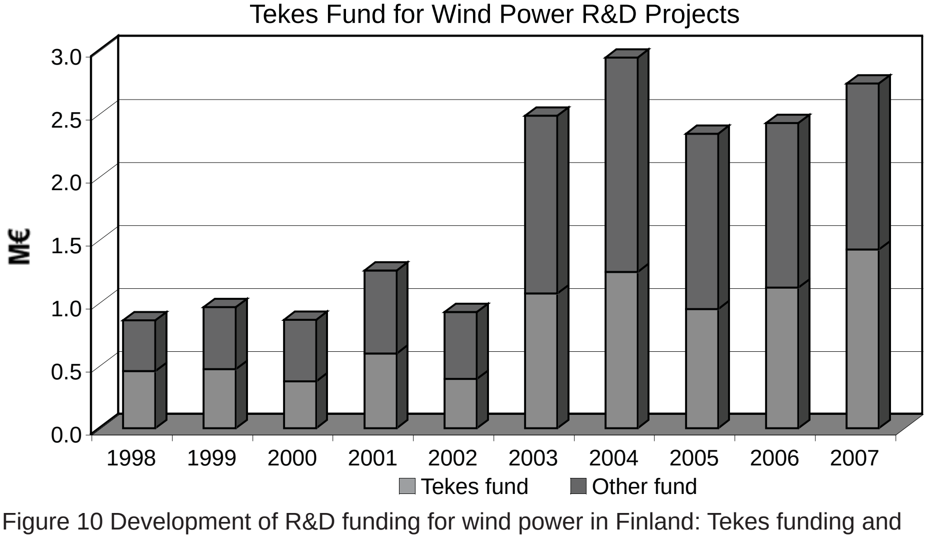

Figure 10 Development of R&D funding for wind power in Finland: Tekes funding and total funding.

UPWIND and TRADEWIND, which started in 2006.

The Finnish Meteorological Institute (FMI) has been active in the EU collaboration for wind and ice measurement technology. FMI is coordinating the COST collaboration "Measuring and Forecasting Atmospheric Icing of Structures," in which VTT is also participating.

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.

VTT takes part in the following IEA Wind research tasks:

Task 11 Base technology information exchange

Task 19 Wind energy in cold climates (Operating Agent)

Task 21 Dynamic models of wind farms for power system studies

Task 24 Integration of wind and hydropower systems

Task 25 Design and operation of power systems with large amounts of wind power (Operating Agent)

Task 26 Cost of wind energy.

The work of Tasks 21, 24, and 25 have been closely related to the national technology program DENSY in Finland. Task 19 work is connected to cold climate technology development in some national enterprise projects.

6.0 The Next Term

A slight growth of the wind-power market in Finland is anticipated for the next year. About 20 MW are currently in the building phase, and in 2008 up to 40 MW of new capacity will be added. In addition, projects totalling more than 100 MW are in various planning phases in Finland. The expected impact of emission trading on electricity market prices will enhance the cost competitiveness of wind power. If a feed-in tariff is introduced, the future for wind power in Finland will be good.

A bottleneck in wind promotion is the update of wind resource mapping in Finland. The current wind atlas is from 1992, and a lot of uncertainty remains when estimating the production for the taller multi-megawatt machines being planned for the forested coastal areas of Finland. A new wind atlas has received government budget funding and will be realised in 2008 to 2009.

The wind potential in the arctic fell areas in Finland still needs a next-generation blade heating system to materialize. Increasing global demand for ice-free turbines is foreseen.

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

Chapter 16
Germany

1.0 Introduction

Total installed wind power in Germany exceeded 22 GW in 2007. While the wind energy world market grew by about 30% in 2007, the rate of growth in the German market for wind turbines decreased, as was predicted. In 2007, 883 wind turbines were installed (2006: 1,208) with a rated power of 1,667 MW (2006: 2,233 MW). This is a decrease of about 25% in growth compared to 2006. Nevertheless, the overall development of wind energy in Germany is remarkable (Figure 1) and the growth of the German wind industry is disproportionately high compared to most sectors of the economy. The wind industry is developing into a powerful industrial market segment with high potential for employment and high demands on R&D activities in a broad spectrum of technical sciences.

Renewable energy amounted to 8.5% (2006: 7.5%) of the German total energy consumption (electricity, heat, fuel). This is equivalent to the prevention of 114 million tons of CO_2. Wind energy is the leading renewable energy source in Germany with a share of 6.4% of national electrical energy consumption. It is followed by hydropower (3.4%), electrical energy conversion from biomass (2.8%), and photovoltaics (0.6%). In 2007, the wind supply was above the long-term average, and because of this, wind energy production increased to 39.5 TWh (2006: 30.7 TWh). This is equivalent to 34.0 million tons of CO_2.

In 2007, about 6% of new wind energy installations were repowering projects (replacing existing onshore turbines with new multi-megawatt turbines), which are becoming an increasing factor in wind energy deployment. In 2007, 108 old turbines totalling 41 MW of capacity were replaced by 45 new turbines with 103 MW (2006: 135 MW were re-powered). A large repowering project was started on Fehmarn Island in the Baltic Sea. In this project, 170 different turbine types with a total power of 45 MW were removed and will be replaced by 68 Enercon E 70 turbines adding up to 156.4 MW (1).

The main offshore activity in 2007 was the establishment of an offshore test site in the North Sea with twelve 5-MW turbines next to the FINO 1 research platform, 45 km north of the island Borkum. The operator (DOTI Ltd.) concluded contracts for the installation of the first six Multibrid M5000 turbines in 2008 as well as for six tripod foundations and for the transformer station. Work on the cable connector is in progress by E.on Netz AG. Also of importance is the commissioning in June 2007 of the offshore research platform FINO 2 in the Baltic Sea.

2.0 Progress Toward National Objectives

The German government acknowledges the importance of renewable energy sources, and in this regard the national policy was generally continued. In 2007, Germany exceeded the EU target (12.5% contribution of all renewables by 2010) with 14.2% contribution of renewables. New targets were therefore set in 2007. By 2020, the government aims to increase the proportion of primary energy consumption generated from renewables to 16%, as compared with the 5.6% realized in 2006. The proportion of electricity consumption from renewable sources will be increased to 20% by 2020 (1).

Although offshore development in Germany is currently behind the strategic goal set by the government in 2002, medium- and

Table 1 Key Statistics 2007: Germany (2)	
Total installed wind generation	22,247 MW
New wind generation installed	1,667 MW
Total electrical output from wind	39.5 TWh
Wind generation as % of national electric demand	6.4%
Target:	12.5% from RES in 2010 (status in 2007: 14.2% from RES)

long-term targets for offshore expansion in the German seas (1,500 MW by 2011; up to 25,000 MW by 2030) are still relevant. Important steps toward meeting these targets were taken with the Infrastructure Acceleration Act by improving the conditions for investors in offshore wind. The Act obligates transmission system operators to pay for and install the grid connection from the onshore grid access point to the offshore wind farm. In 2007, the draft bill of the revised Renewable Energy Sources Act (EEG) was submitted by the government to the parliament with a considerable increased feed-in tariff for offshore wind energy.

3.0 Benefits to National Economy

German turbine manufacturers participated in the growing world wind market and increased their production capacity in 2007. Further, new production capacity to make 5-MW-class turbines is under construction in the northern near coast parts of Germany. Generally, turbines with a capacity of less than 2 MW are increasingly difficult to place in the market. The average rated power of new turbines installed in 2007 was 1.9 MW. Eight turbines greater than 5 MW each have been installed; among them was the Enercon E 126 turbine with a rated power of 6 MW.

Harbour and shipyard sites such as Bremerhaven, Cuxhaven, and Emden have been suffering from a crisis in Europe's marine industry over the last decades but have benefited from the expansion of the wind industry sector and the beginning offshore wind business. Other industrial branches such as the steel construction industry are preparing for the future offshore market with remarkable investments. For example, installation and transportation vessels and platforms have been developed at a cost of several hundred million €.

The number of employees in the wind industry has grown continuously and amounted to 84,300 in 2007 and 249,300 for all renewable energies- an increase of 55% since 2004 (3). Economic turnover in the wind industry (inland and export) exceeded 11 billion €. Turnover resulting from the operation of wind turbines amounted to 3.5 billion €. Investments totalling 2.2 billion € have been made for new wind energy installations (3).

The three leading manufacturers on the German market for turbines installed in 2007 were Enercon, Vestas, and REpower Systems (Table 2 and Figure 2) (2).

4.0 National Incentive Programs

The EEG (see the report for Germany in *IEA Wind Annual Report 2005*) provides the main stimulation and incentives for the German wind market. Grid operators must pay 0.0819 €/kWh to the turbine owner for turbines

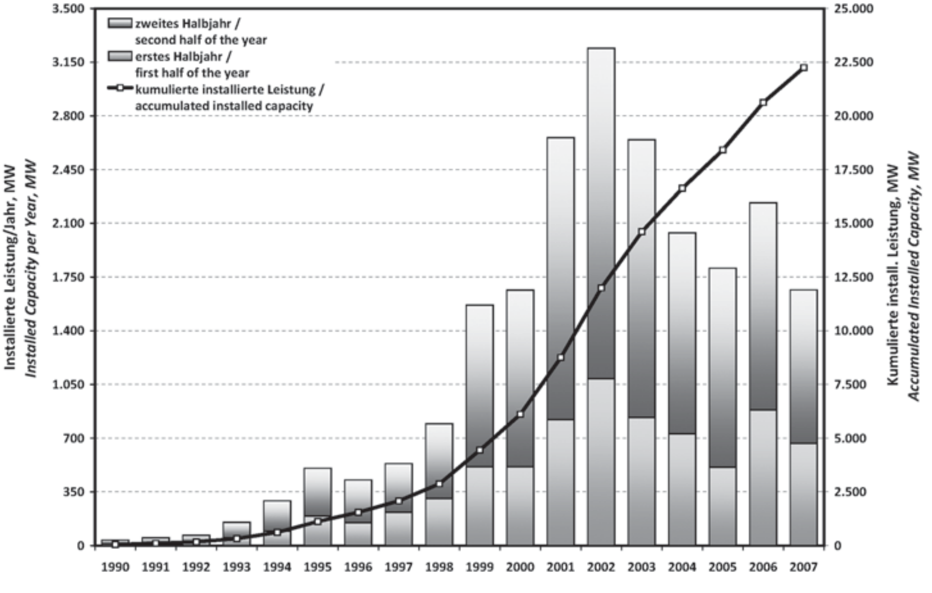

Figure 1 Development of the yearly and total installed capacity, DEWI 2008.

Table 2 Leading Manufacturers of Turbines Installed in 2007		
Company	Market share 2006 (%)	Market share 2007 (%)
Enercon	38.4	50.3
Vestas	34.6	24.1
REpower Systems	7.6	10.9

installed in 2007 for at least five years (0.0836 €/kWh for turbines installed in 2006, 0.0853 €/kWh for installations in 2005). Depending on how local wind conditions compare to a reference value, the tariff will be reduced after five years. So the median feed-in tariff over 20 years for turbines installed in 2007 will range from 0.0819 €/kWh to 0.060 €/kWh. The EEG requires the starting tariff to be reduced by 2% yearly. Special tariffs exist for onshore repowering and for offshore wind farms.

The EEG was audited in 2007 to adapt prices for renewable energies to new market conditions and technological developments. A draft bill of the revised EEG was submitted by the government to the parliament in December 2007. The bill proposes a considerably increased feed-in tariff (more than 50%) for offshore wind energy and proposes to decrease the annual reduction (from 2% to 1%) of the feed-in tariff for onshore turbines taking into account the growing world market prices for raw materials. The new proposed offshore tariff is adopted from the incentives of other European countries. The new EEG is still under discussion in the responsible parliamentary commission and shall be decided in June 2008.

5.0 New R, D&D Activities

5.1 Funding by the federal government

The most recent funding announcements were published in the Bundesanzeiger (Federal Gazette) No. 179 on 21 September 2006, and may be accessed via the Internet at www.erneuerbare-energien.de/inhalt/37850/4595/.

As part of the high-tech strategy of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the budget for research and development in the field of renewable energy is scheduled to increase by 5 million €/yr as of 2007. Whereas in 2006, the budget totalled around 83 million €, by 2007 this figure had already jumped to 88 million €, with 93 million € being set aside in the 2008 budget. Additional expenditure of up to 10 million € is anticipated under the German government's climate protection initiative (1).

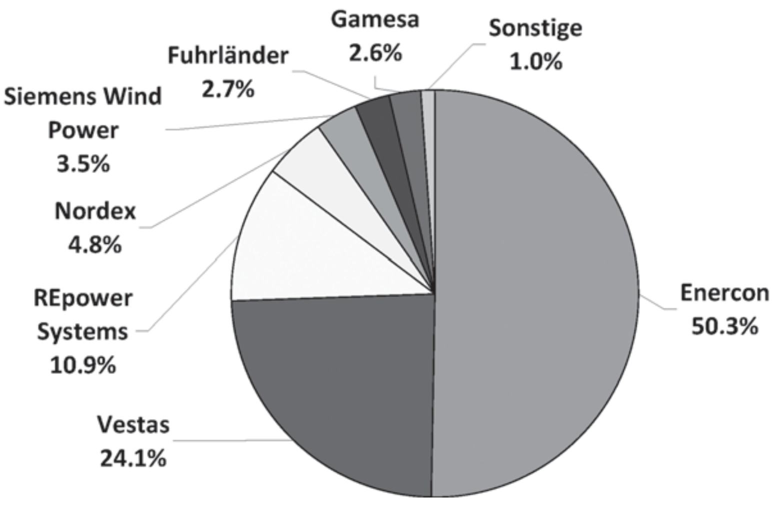

Figure 2 Market share of turbine manufacturers in Germany 2007, DEWI.

In 2007, the BMU approved new research projects in the field of renewable energy technologies totalling 102 million € exceeding 100 million € for the first time. The lion's share went to photovoltaics, where the volume of new project approvals totalled around 41.6 million € (2006: 43.4 million €). This was followed by wind power, which achieved a record new approval volume of around 34.7 million €, almost double the previous year's figure (2006: 16.1 million €). Wind power research was significantly expanded (Figure 3).

Two-thirds of newly approved wind power research projects in 2007 were in the offshore sector. However, plants also need to be developed for onshore use in order to cut costs and improve earnings and reliability. Furthermore, the integration of rising quantities of wind power into the national grid is an increasingly important topic. Figure 4 shows how all 111 ongoing projects in 2007 were allocated to the main topics of wind energy research.

In 2007, a total of 15.7 million € was allocated to ongoing wind power projects. By way of comparison, in the years 1998 and 1999, the funding of wind power research had almost disappeared, with expenditure of just 2.3 million € in each of those years (1).

5.2 Offshore test site alpha ventus – RAVE

The offshore test site "alpha ventus" (formerly known as "Test site Borkum West") plays a particularly important role in the expansion of wind power. It will be the first offshore wind farm in German waters. In 2008, the company DOTI GmbH, founded by three German power utilities, will begin construction of 12 wind

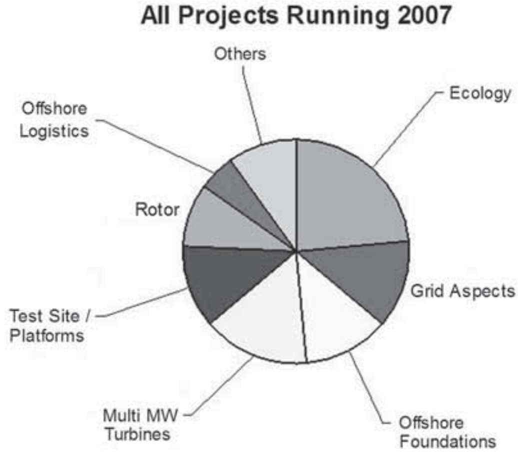

Figure 4 Topics of all projects ongoing in 2007, PtJ.

turbines in the 5-MW class in a water depth of 30 m. In total, the BMU has earmarked some 50 million € for research at the test site over a five-year period. As of March 2008, it approved 15 projects with a total funding of 24 million €.

Research at the test site involves a large number of different players, so coordination among them poses a particular challenge. With this in mind, a coordination project has been initiated and is being implemented by the Institut für Solare Energieversorgungstechnik (ISET) in Kassel and the Deutsches Windenergieinstitut (DEWI). DWEI is in charge of the technical planning of the overall measurement concept. In the spring of 2008, all RAVE projects are due to be presented to the public in Berlin (funding total: 1.1 million €).

The Federal Maritime and Hydrographic Agency (BSH) is supervising the installation of all measuring equipment within the test site

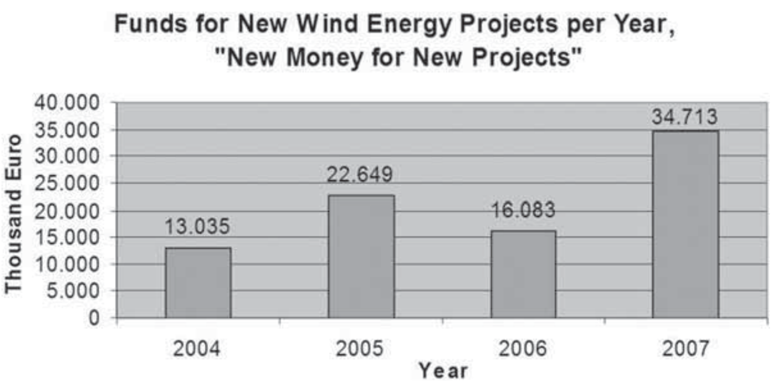

Figure 3 Funds for new wind energy research projects per year, BMU.

and the implementation and operation of the measuring campaigns over the next several years (funding total: 7.8 million €).

Modelled on the scientific measurement and evaluation program (WMEP), which was conducted over a 16-year period on some 1,500 onshore wind turbines, ISET is now investigating how a similar WMEP could be devised for the offshore sector as an OWMEP (funding total: 1.1 million €). The aim is to make the experience acquired from test site research accessible to others. So far, no confidential data of the industry are concerned.

Another aim of research funding for the offshore test site alpha ventus is to develop wind turbines in the multi-megawatt class for offshore conditions and to assure good reliability, high efficiency, and easy assembly and service. To this end, the BMU has provided almost 5 million € each for research projects by the turbine manufacturers Multibrid GmbH and REpower Systems AG. The advanced development of the Multibrid M5000 and the REpower 5M will be tested primarily at alpha ventus . One plant for each of the types M5000 and 5M are to be equipped especially for research purposes. Apart from turbine development, there are also plans to ensure close collaboration with research institutes on fundamental issues associated with the use of offshore wind power in the research alliance RAVE.

As part of the test site research, the universities of Stuttgart and Oldenburg are further developing the technique for wind measurement at sea based on laser-optical LIDAR technology (light detection and ranging) with the involvement of the Deutsches Zentrum für Luft- und Raumfahrt (DLR/German Aerospace Centre) and the DEWI. In addition to techno-physical experiments, the project will also aim to develop standards for the use of LIDAR (funding total for the group: 1.3 million €).

Stuttgart University is coordinating another project for the use of LIDAR technology, which will be applied to determine the performance curves of offshore wind turbines and to investigate the wind flow conditions in the alpha ventus wind farm (wake effects). The data will be compared with wind measurements from the research platform FINO 1. The universities of Oldenburg and Hanover, together with DEWI and the wind turbine manufacturers REpower and Multibrid, are likewise involved in this project (funding total: 1.6 million €).

The BSH has developed a standard for analyzing the effects of offshore wind turbines on the marine environment. The "standard analysis concept" (StUK 3) prescribes binding ecological investigations e.g. on marine mammals, birds, and fish for applicants and licence-holders. Within the context of test site research, the BSH is initially planning to develop a concept for accompanying ecological research in the offshore test site (BMU funding for a pre-phase project total: 34,000 €), in which the standard analysis concept will be used for the first time. Additional queries will serve to evaluate the StUK 3. The standard experiments to be carried out in accordance with StUK3 are funded by the licence-holder of the offshore test site, DOTI GmbH, while accompanying ecological research above and beyond StUK 3 will be financed by the BMU.

The Institut für Physik und Werkstoffe (Institute of Physics and Materials) at Flensburg University is investigating the sound emissions of wind turbines during the operational phase. To this end, underwater sound and vibration measurements are conducted on two selected plants. Based on the results, the team will draft recommendations for operational or structural measures to minimise noise and hence protect the marine environment (funding total: 417,000 €).

A research alliance of Hanover University and the Fraunhofer Center für Windenergie und Meerestechnik (CWMT), in collaboration with the Federal Institute for Materials Research, will conduct extensive analyses of the foundations to be used in the test site.

Another research project is in preparation to investigate the grid aspects of the wind farm alpha ventus.

5.3 Technological research

Technological research is at the heart of the BMU's research funding. The focus here, even for non-test site-related projects, is on the offshore sector, but onshore-specific and general projects are also supported. Priorities include the optimization of supporting structures and rotor blades, the further development of open- and closed-loop control and monitoring technology, offshore assembly techniques and logistics, and the management of maintenance and repairs.

5.3.1 General aspects

In 2007, Deutsche WindGuard GmbH celebrated the topping-out of a new, acoustically optimized wind tunnel in Bremerhaven. The wind tunnel offers good conditions for the aerodynamic and aero-acoustic optimization of a wide range of components. Thanks to its 14-meter working section, experiments may be conducted on fairly large models and use original segments of wind farms. The turbines in the wind tunnel allow the simulation of wind fields with wind speeds of up to 250 km/h. The wind tunnel is expected to begin operation in spring 2008 (funding total: 750,000 €).

A joint project between the Wind Energy Research Group at the Hochschule für Technik und Wirtschaft des Saarlandes and Vensys Energiesysteme GmbH & Co. KG is working on the development of a gearless 2.5-MW wind turbine with alternator excitation of the high-power generator by permanent magnets and a significantly reduced nacelle weight. The fully encapsulated design of the nacelle is particularly suitable for offshore conditions. The aim is to build a prototype and perform initial testing in 2008. The drive train, rotor, nacelle, machine housing, and generator weigh only 150 t. Because reduced weight directly reduces foundation costs, the new design may help offshore wind power to achieve an important cost breakthrough (funding total: 1 million €).

5.3.2 Foundations

In a joint project on "Seabed/pile interactions," Karlsruhe University, the Federal Institute for Materials Research, Germanischer Lloyd, and Berlin Technical University are examining the stability of offshore foundations and methods of fixing them into the seabed. Data is collected in laboratory experiments, and used to improve arithmetic models so that the stability of offshore foundations can be predicted more accurately. The aim is to save materials and improve the technical safety of offshore wind farms. Part of the investigation will be done at the test site (funding total: 2.5 million €).

The OGOWin alliance is dedicated to new design principles for foundations in lattice-like structures (jackets) for serial production of foundations. In this alliance, representatives of the structural steel industry (WeserWind GmbH, EUROPIPE GmbH) and the construction industry (HOCHTIEF Construction AG) are collaborating with the wind turbine manufacturer REpower and a number of research institutes (Fraunhofer Gesellschaft, Hannover University, Bundesanstalt für Materialforschung/BAM). The aim is to optimize foundations and construction principles and to develop condition monitoring systems for the foundations. To this end, cast steel joints are used to which foundation pipes are fitted on a modular principle (funding total: approximately 3 million €).

5.3.3 Rotor blades

The research project PREBLADE, by the Bremer Institut für Konstruktionstechnik (BIK) and the rotor blade manufacturer Abeking & Rasmussen Rotec GmbH, will focus on the efficient production of rotor blades by replacing production stages that were once manual with a robot system. In this way, quality, working conditions, and process reliability can be improved and manufacturing costs reduced in future rotor blade production processes (funding total: 870,000 €).

The Fraunhofer Center für Windenergie und Meerestechnik (CWMT/Fraunhofer Center for Wind Power and Offshore Technology) in Bremerhaven and Bremerhaven University are investigating the aging of rotor blades after many years in service. In collaboration with industry partners, they are analyzing rotor blades that had been in operation for more than 20 years. Their analysis also incorporates available weather and operating data, detailed production documents, and the static and dynamic blade tests conducted after construction. The project partners will compare the calculations and tests performed more than 20 years ago with the actual loads and current test results. In this way, they are able to calculate fatigue levels and ascertain material aging. By incorporating environmental conditions into their analysis, they hope to facilitate lifecycle forecasts for the rotor blades made from composite fiber materials that are suitable for the extreme application conditions in the offshore sector (funding total: 200,000 €).

5.3.4 Control, monitoring, and test technology

The use of wind power in the offshore sector poses increased demands in terms of load regulation and operational management of multi-megawatt wind turbines. A joint project led by ISET aims to reduce the mechanical loads on the turbine components and thus lengthen their service life. The idea is to develop a control system that actively absorbs the material-stressing vibrations of the nacelle and tower. Depending on their load in the rotor circuit, the rotor blades will be individually turned "into the wind" or "away from the wind" by electric motors (load-reducing rotor blade pitch control). The new control systems will be tested first in the laboratory and then under real operating conditions on 5-MW turbines. Other project partners include LTi REEnergy GmbH and MULTIBRID Entwicklungsgesellschaft mbH (BMU funding total: 1.5 million €).

Offshore wind turbines must operate particularly reliably if they are to withstand the demanding conditions on the open seas. The company Multibrid is developing a special assembly device and two test units for the production of its offshore wind turbine Multibrid M5000. In this way, any defects can be detected and rectified before the time-consuming final assembly process takes place. Overall, this helps to reduce assembly costs and shorten assembly times (funding total: 304,000 €).

5.3.5 Offshore installation systems and logistics

Ed. Züblin AG in Stuttgart is planning to develop an innovative vertical lifting device for final assembly of the nacelles of offshore wind turbines, which can weigh up to 500 tons. This will eliminate the need for expensive equipment such as floating cranes or jack-up platforms when assembling the nacelles. Other project partners include Berg-idl GmbH, Offenburg University, and Karlsruhe University (TH) (funding total: 475,000 €).

SWATH ships (Small Waterplane Area Twin Hull) have a special hull shape that makes them comparatively insensitive to rough seas and suitable for use as service vehicles for offshore wind farms, even in high waves. Deutsche Wind Guard GmbH in VareI is conducting an in-depth study of the suitability of SWATH ships for offshore wind farms, including a comparison with various other access concepts for offshore wind farms. The results are to be used by industry as a strategic planning aid for offshore wind power logistics. The aim is to demonstrate the influence exerted by the choice of service vehicle on the overall efficiency of offshore wind farms (BMU funding total: more than 46,000 €).

A new jack-up platform is being planned and built by F+Z Baugesellschaft mbH (100 m long, 40 m wide, for water depths up to 45 m). In the future, this jack-up platform will be used to lower foundation structures into position, drive pipes into the ocean floor, and position wind turbines with rotors on their foundations. The new jack-up platform can withstand wave heights of up to 2.5 m and is therefore suitable for year-round use in at least 75% of all weather situations. The deck will have a usable area of 3,400 m^2 and can be loaded with weights of up to 4,000 tons, equivalent to four complete turbines in the 5-MW category. It can also accommodate up to 60 people, together with meeting rooms and workshops (funding total: 4.7 million €).

5.4 Research platforms in the North and Baltic Seas

FINO 1(www.fino-offshore.de) has been operational in the North Sea for five years. To date, the online database of the Federal Maritime and Hydrografic Agency (BSH) has been accessed more than 94 times (http://fino.bsh.de). In November 2006, a storm destroyed a number of installations below the platform deck. However, the design of FINO 1 meant that the deck installations, which provide all of the main functions of the research platform, were not impaired. After the storm, an additional camera was installed below the deck that is activated in rough seas. In autumn 2007, this camera recorded wave heights of 10 m. The photos allow researchers to monitor the behaviour of the waves as they collide with the foundation structures. FINO 1 will supply important reference data for the neighbouring offshore test site alpha ventus. The total funding to date for construction, operation, and data storage is just under 14 million €.

In June 2007, the first offshore research platform in the Baltic Sea began its operation. FINO 2 (www.fino2.de) was constructed at the Kriegers Flak site, around 40 km north-west of the island of Rügen. FINO 2 conducts analyses of wind and wave movements, marine ecology, and shipping traffic. The project was co-financed by the Federal State of Mecklenburg-Western Pomerania, which provided around 1.3 million

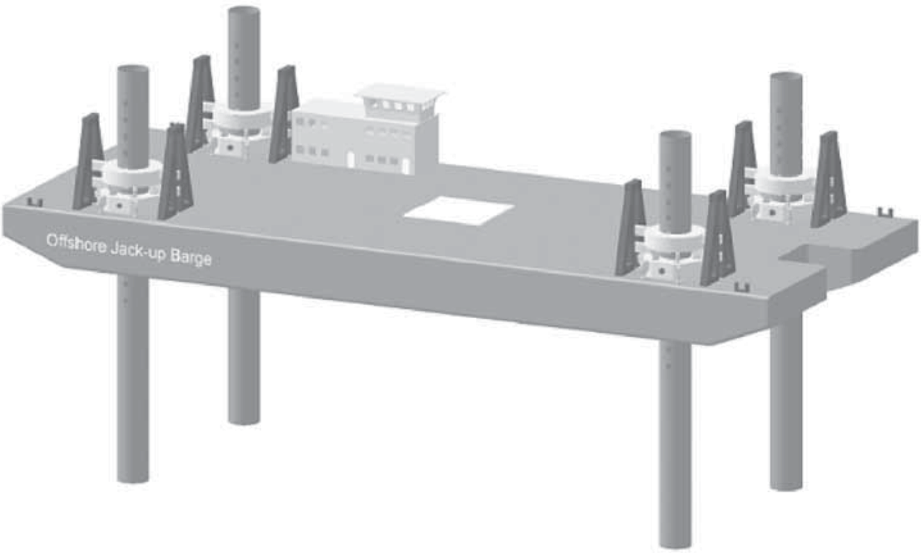

Figure 5 Basic design of the new jack up platform, (F+Z).

€ (BMU funding total: approximately 5.3 million €).

FINO 3 (www.fino3.de) is currently under construction in the North Sea around 80 km west of Sylt under the management of Forschungs- und Entwicklungszentrums der Fachhochschule Kiel GmbH. The platform will perform a series of measurements based on the FINO 1 measuring regime. In addition to this, there are also plans to perform measurements for analysing the fixing of the foundation into the seabed, together with a physical analysis of lightning at sea. Commissioning is scheduled for June 2008 (BMU funding total: 5.2 million €, Schleswig-Holstein: 6.4 million €).

5.5 Ecological research

The Institut für Angewandte Ökologie GmbH and the Alfred-Wegener-Institut für Polar- und Meeresforschung have prepared an "Autecological Atlas of Macrozoobenthos." This is a comprehensive compilation of findings into the lifecycles of invertebrates in the North and Baltic Seas and their environmental requirements. This new database will help make the expansion of offshore wind power as eco-friendly as possible. The results are due to be published on CD-ROM in early 2008 (funding total: 307,000 €).

In order to evaluate the potential effects of offshore wind farms on migrating and resting birds, scientists use cameras, thermal imaging, and radar systems to monitor bird flights at sea However, the tough offshore conditions and the remote-controlled application place highly demanding requirements on the equipment. As a result, there are a number of projects devoted to the development and testing of optimized techniques for accompanying ecological research at sea. In 2007, the following results were achieved:

- In August 2007, an automatic camera system (Visual Automatic Recording System, VARS) developed by the Institut für Angewandte Ökologie (IfAÖ/Institute for Applied Ecology) in cooperation with the company HaSoTec was installed on the research platform FINO 2. The video camera detects bird movements near the mast and documents any collisions (funding total: 235,000 €).
- When recording the movements of birds flying over the sea, radar signals are reflected by the water surface (so-called "sea clutter"), and even waves of 0.5 m or less can inhibit successful measurement. In order to counteract this problem, a horizontal radar system developed by the Institut für Vogelforschung has been undergoing offshore testing since 2007, and has already been successfully tested on land. The prototype was built by the company Gematronik (funding total: 1.2 million €).
- The Institut für Angewandte Ökologie (IfAÖ/Institute for Applied Ecology) has

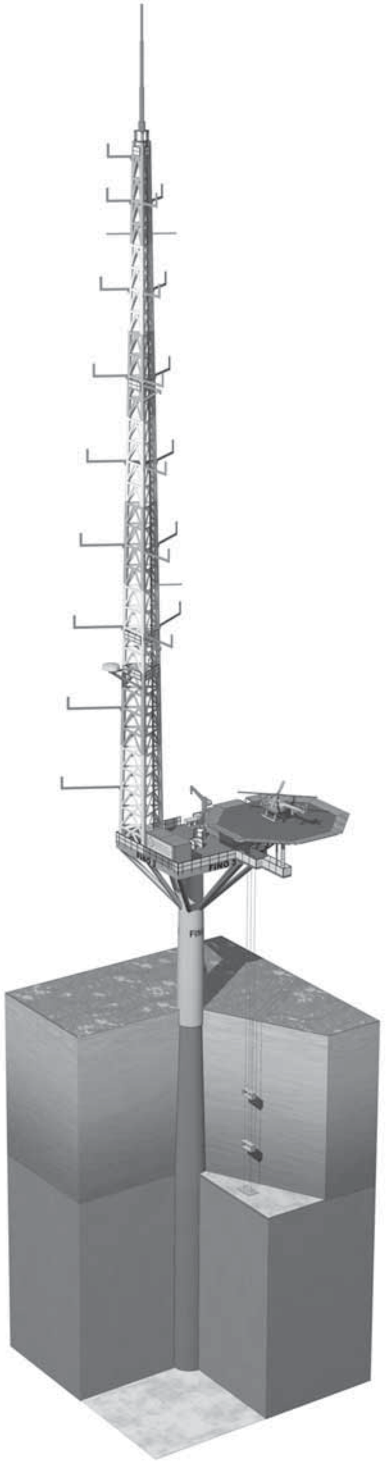

Figure 6 Basic design of FINO 3 research platform.

developed a radar unit with a fixed, heavily concentrated radar beam (fix beam radar), which allows precise quantification of bird movements. By analyzing wing beat patterns and frequencies, radar echoes can be attributed to specific groups of species. A prototype was successfully tested on the island of Rügen in autumn 2007 (funding total: 233,000 €).

A joint project led by the Michael-Otto-Institut, in collaboration with the company BioConsult SH and the Leibniz-Institut für Zoo- und Wildtierforschung, is systematically analyzing the reasons for collisions by red kites, sea eagles and Montagu's harriers with wind turbines in various parts of Germany. Based on the results, avoidance and prevention measures will be developed and field tested. The project is funded by the BMU and NABU (BMU funding total: 802,000 €).

The universities of Hanover and Erlangen, the company Enercon GmbH, and the Forschungsinstitut für Optronik und Mustererkennung (FOM/Research Institute for Optronics and Pattern Recognition) are working on the development of techniques for the analysis, prediction, and reduction of the collision risk between bats and wind turbines. The results could be incorporated into the site assessment process for future wind farms. In this way, species conservation-related issues within the context of the licensing procedure will be placed on a sound scientific basis (funding total: 1.1 million €).

5.6 Other R, D&D activities

Aside from the described research funded by the federal government, there is a broad spectrum of R&D activities financed by the industry or supported by state governments. For example, prototypes have been developed by Enercon and BARD Engineering, a new player among the turbine manufacturers.

In 2007, Enercon installed a first E 126/6 turbine with a rated power of 6 MW. The rotor diameter increased to 127 m (E 112: 114m). The rotor blades are composed of a shorter part made of steel and a longer outer part made of glass fiber. This design makes it possible for the long blades to be transported in two parts, which makes many onshore sites more accessible. The nacelle height increased to 135 m (E112: 124m)(4).

Figure 7 Roll out of the first VM nacelle, BARD Engineering GmbH.

At the same site near Emden, BARD Engineering, a new player among the turbine manufacturers, installed the first VM turbine - a 5-MW turbine for offshore purposes. (Figure 7) The company expects to produce 100 turbines of this type between 2010 and 2011 (5). BARD will use the turbines mainly in their own offshore wind farms as "BARD Offshore 1." The company's transportation and installation vessel "Wind Lift I" is currently under construction. Figure 8 shows an animation of the future construction process of "BARD Offshore 1" with the vessel and BARD's special type of tri-pile foundation.

5.7 Events in 2007

The BMU's Second Scientific Symposium on Offshore Wind Power Use was held at Berlin Technical University in February. It was attended by some 200 participants from 12 countries and examined the current status of offshore development in Europe. Germany's presentations focussed primarily on outlining the results of accompanying ecological research. The proceedings can be downloaded from http://www.erneuerbare-energien.de/inhalt/41059/36356. Alongside the Symposium, an IEA Wind Topical Experts meeting of Task 11, focussed on wind and wave measurements at sea.

A German-Danish-Swedish declaration on cooperation in offshore research was signed at the European Offshore Wind Energy Conference on 4 December 2007 in Berlin by the responsible Ministers of the countries.

Another event sponsored by IEA Wind Task 11, on 6 and 7 December, examined the current challenges facing wind power research. Experts from 13 countries convened in Berlin as guests of IEA and the BMU. This expert meeting, hosted by Projektträger Jülich (PtJ), lent impetus to the further development of national research strategies and could provide the basis for a new IEA Wind research strategy for the period up until 2020.

6.0 The Next Term

The opening seminar for the test site research initiative – RAVE (Section 5.2) will take place on 8 May 2008 in Berlin. All of the test site activities conducted so far and the state of the construction of the offshore wind farm will be presented to the public. The BMU regularly invites experts from research and industry for strategy meetings to discuss the direction of research and funding. The most recent meeting on wind power research took place in May 2006 in Bad Zwischenahn. The next meeting is scheduled for November 2008.

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(4) WINDBLATT, Enercon Magazin, No 1, 20008, pp.7-8.

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Authors: Joachim Kutscher, Forschungszentrum Jülich GmbH; Joachim Nick-Leptin and Ralf Christmann, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany.

Figure 8 Animation of BARD's construction of an offshore wind farm with VM, "Wind Lift I" and tri-pile foundations, BARD Engineering GmbH.

Chapter 17
Greece

1.0 Introduction

Greece is making profound institutional, regulatory, engineering, and funding efforts in order to meet the indicative target set by *Directive 2001/77/EC.* Among the aims of the Greek government is the substitution of expensive imported fuel, currently used for electricity production in a large part of the Greek territory, with energy supplied by exploiting the country's abundant wind potential.

According to the most recent estimates, the gross consumption of electric power in 2010 will reach the level of 72 TWh for Greece. Currently, the main fuel source is domestically extracted low-calorific-value lignite, which accounted for 50.5% of the total energy needs in 2007. Oil, mainly used by the power plants on the islands not connected to the mainland's system, is estimated to have a share of 13%. Natural gas imported from Russia and Algeria in the form of liquefied natural gas (LNG) covered 22.5%. In the same year, large-scale hydroelectric plants were estimated to produce 4.8%. Lastly, wind energy, small hydro, biomass, and photovoltaics combined contributed 3.6%, whereas the net of imports-exports made up the remaining 5.6% (1).

At present, the electricity sector operates within the framework set by law 2773/1999 "Liberalisation of the Electricity Market-Regulation of energy policy issues and other provisions" (Official Gazette A 286) enacted for the transposition of *Directive 96/92/EC* for the liberalization of the electricity market (OJ L27/30.1.1997). That basic law was revised by law 3175/2003 "Exploitation of the geothermal potential, district heating and other provisions" (Official Gazette A 207) and law 3426/2005 "Precipitation of the liberalization process of the electricity market" (Official Gazette A 304).

Today, the RES deployment regime is governed primarily by law 3468/2006 "Generation of electricity from renewable energy sources and through high-efficiency co-generation of electricity and heat and miscellaneous provisions" (Official Gazette A' 129). The text of the law and its circular D6/F1/oik.21691/30.10.2006 are posted on the Ministry of Development website (http://www.ypan.gr). The main actions of that serious legislative initiative are outlined below:

- Putting the national target for the share of RES on an official footing in the net domestic power consumption in the year 2010 at 20.1% and in the year 2020 at 29%;
- Taking initiatives in environmental permitting through the setting of strict deadlines within which approvals should be granted or consensus rendered by services and bodies involved in the interim stages of the overall licensing;
- Setting up of two intra-ministerial coordinating bodies, one on the level of secretaries general and the other made up of high-echelon civil servants, aiming at the coordination of the licensing processes control and the provision of support and guidance to authorities involved therein;
- Introduction of a regime of strict follow-up procedures for the holders of generation authorizations, in order to keep them bound to their legal commitments and making provisions for getting rid of those profiteering from license trading;
- Diversification of the previous unique feed-in tariff regime chiefly on behalf of PV in order to boost investments in that sector which are lagging behind so far. The tariffs set by the law are revised every year by virtue of a decision taken by the Development

Table 1 Key Statistics 2007: Greece	
Total installed wind generation	874 MW
New wind generation installed	125 MW
Total electrical output from wind	2,328 GWh
Wind generation as % of national electric demand	2.5%
Target:	3,370 MW

Minister on the basis of the weighted average increases of the incumbent utility's bills whereas after the full liberalization of the electricity market the revisions shall take place at 80% of the consumer price index;
• Enactment of provisions at variance with the economic development law 3299/2004 (Official Gazette A' 261) in order to make lawful the transfer to the responsible power transmission operator of the fixed assets of companies receiving public aid for investment schemes corresponding to the cost of grid extension works, connecting power generation plants to the grids even before the lapse of the five-year period generally provided for in the above law;
• Establishing of the right to install offshore wind farms following the successful precedent of similar projects in the Northern Sea;
• Licensing of hybrid stations without a prior tendering procedure and direct indexing of the energy tariff regime applicable to hybrid stations that will be installed in island systems not connected the mainland's interconnected system chiefly to the avoided cost of conventional plants whose operation is thereby supplanted to ensure the economic viability of the said stations;
• Completion of the package of efforts aimed at bringing national laws into line with the requirements set forth in article 5 par. 5 of *Directive 2001/77/EC* by setting up a system for issuing warranties of origin for renewable energy;
• Improvement of electricity sale terms with the aim of facilitating bank financing of the projects. More specifically, the initial 10-year validity period of the contracts may be extended by an equal period simply upon a producer's unilateral declaration to the responsible operator;
• Redrafting and legislative consolidation of the levy imposed on the gross proceeds from the sale of renewable energy (with the exception of photovoltaics) in favor of local governments, at 3% in lieu of the previous 2%;
• Increase of the limit of installed capacity up to which installation and production authorization, and operating permits are not required;
• Lifting of the 50-MW limit of installed capacity above which the provisions of article 35 of Law 2773/1999 did not grant priority to RES plants by load dispatch;
• Imposition of mandatory measurements of RES potential by a certified body.

Table 2 provides the feed-in tariff for the wind energy. The list of prices is based on the price in €/MWh of the electric energy absorbed by the grid for interconnected as well as non-interconnected islands.

2.0 Progress Toward National Objectives

Directive 2001/77/EC, On the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market, in its annex sets an indicative target for Greece to cover a part of its gross national electricity consumption by 2010 from RES equal to 20.1%, with the contribution of large-scale hydroelectric plants included. This target is also compatible with the international commitments of Greece resulting from the Kyoto Protocol. Based on the expected electricity consumption in 2010, the goal is set for production of electric power from RES on the order of 14,450 GWh (including large-scale hydro-electric plants) in 2010. In order to meet these goals, the installed capacity of wind farms should reach the level of 3,193 MW and the corresponding energy generated should be on the order of 8,100 GWh.

In 2007, the installed capacity of the wind turbines reached 874 MW, showing an increase over the previous year of 17%. In nine separate projects a total of 67 wind energy conversion systems with an installed capacity of approximately 125 MW were connected to the electricity supply network. The current estimation of wind energy production in 2010 ranges between 2,040 MW (conservative scenario) and 3,193 MW (optimistic scenario) (1). The development of the 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 2007 was approximately 2,328 GWh. The energy produced in the last five years has been: 2006 - 1,990 GWh, 2005 - 1,266 GWh, 2004 - 1,127 GWh, 2003 - 1,021 GWh, and 2002 - 651 GWh. Figure 2 shows the electricity produced from wind turbines during the past ten years.

Table 2 Energy Tariff		
Type of electric energy production	Interconnected	Non-interconnected islands
Wind onshore	75.82	87.42
Wind offshore	92.82	

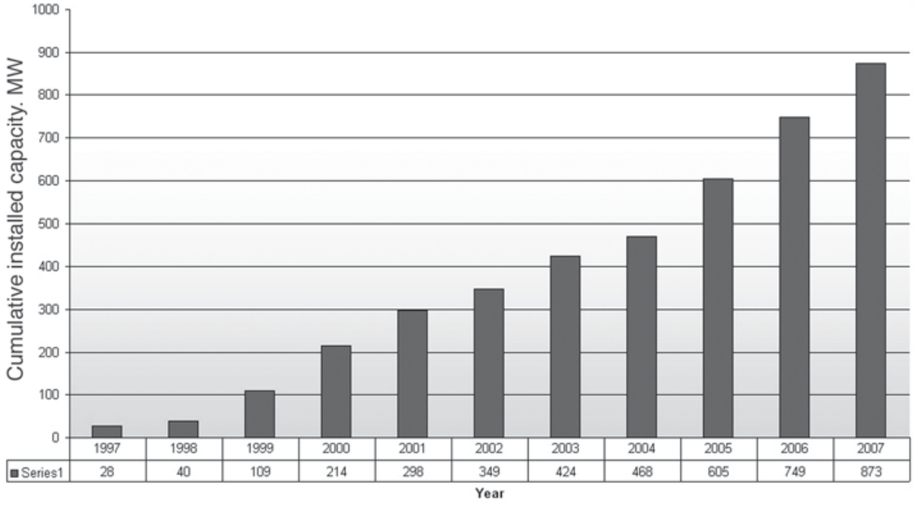

Figure 1 Cumulative installed wind capacity in Greece.

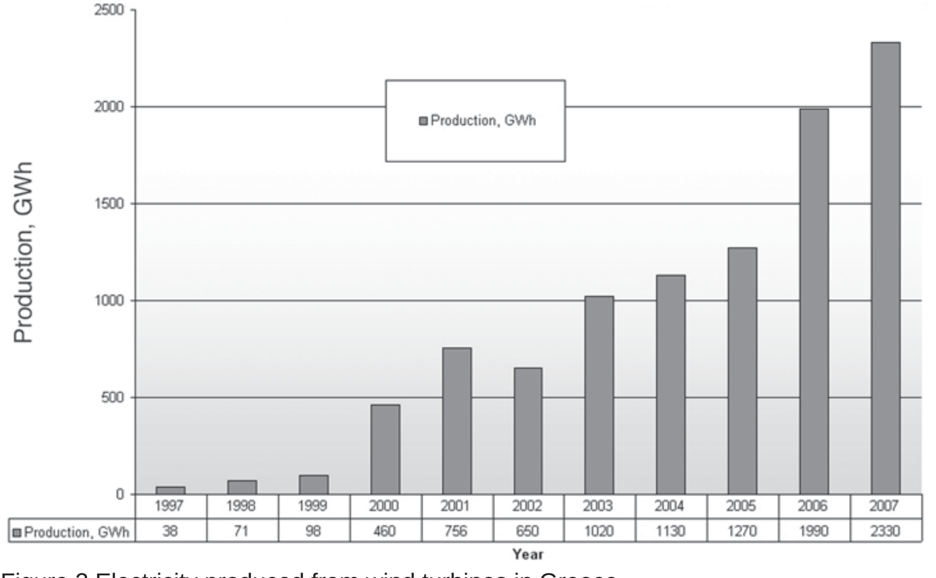

Figure 2 Electricity produced from wind turbines in Greece.

3.0 Benefits to National Economy

3.1 Market characteristics

Interest is increasing, mainly among construction companies and individual investors, in projects related to wind energy. Wind energy deployment has become a challenging area for development all over the country, especially in areas of poor infrastructure, where 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, especially with regard to the 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 the maintenance and operation of the wind farms in mainly underdeveloped areas. At present, an expanding network of highly experienced engineering firms has been created, which is currently working on all phases of the development of new wind energy projects. Thus, wind energy is gradually becoming a considerable player contributing to the development of the country. The distribution of installed wind farms all over the country is depicted in Figure 3.

3.2 Industrial development and operational experience

No significant manufacturing developments occurred in 2007 apart from the continuing involvement of the Greek steel industry in wind turbine tower manufacturing. The average capacity of the wind turbines installed in 2007 was 1,850 kW, while the average capacity of all the wind turbines operating in the country was 781 kW (Figure 4). The market share per manufacturer is depicted in Figures 5 and 6.

Wind farm malfunctions that have been reported up to now are mainly related to gearbox failure and lightning strikes. No major events

Figure 3 Installed wind farms distribution in Greece.

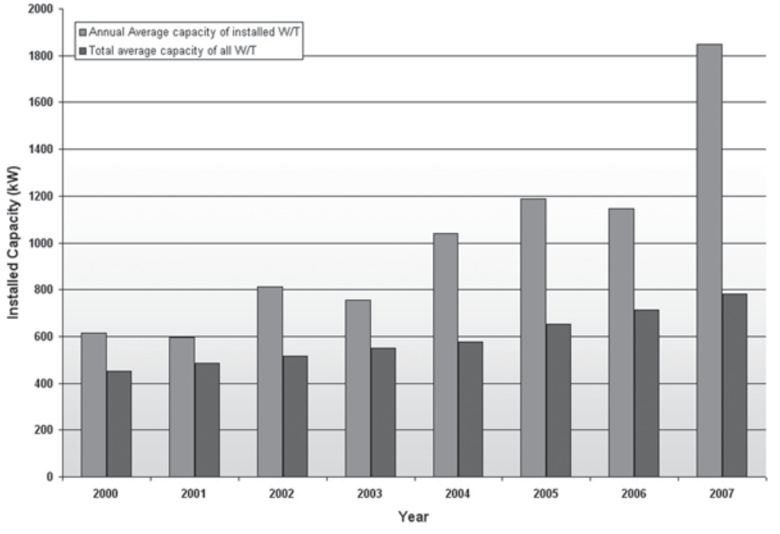

Figure 4 Average capacity of the wind turbines installed in 2007 and operating in Greece.

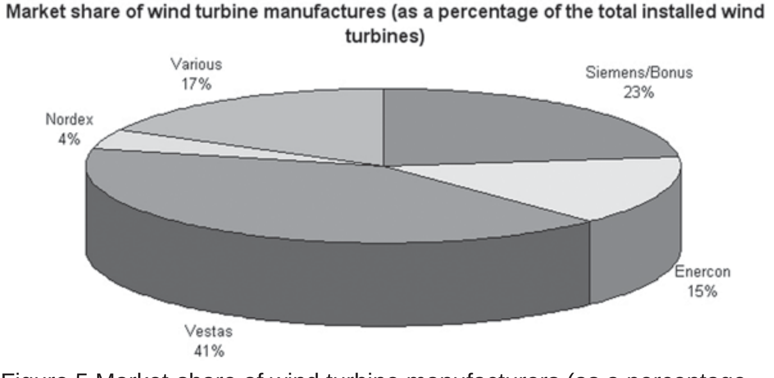

Figure 5 Market-share of wind turbine manufacturers (as a percentage of wind turbines installed).

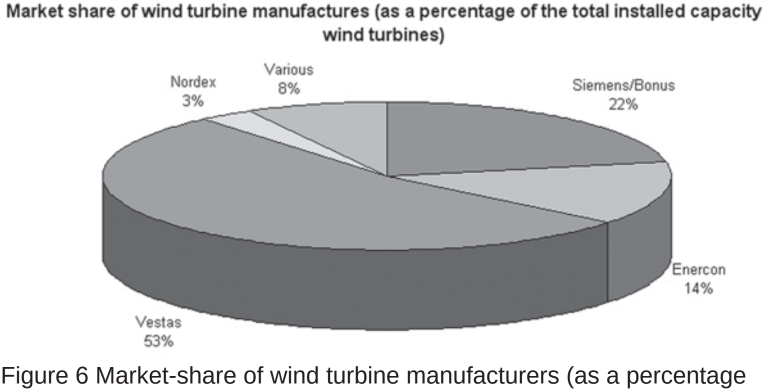

Figure 6 Market-share of wind turbine manufacturers (as a percentage of capacity installed).

leading to extensive wind farm outages have been reported.

3.3 Economic details

The total cost of wind power projects depends on the wind turbine type, size, and accessibility of the project. This cost varies between 1,000 and 1,200 €/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%.

The power generation system in Greece is divided into two categories: the so-called interconnected system of the mainland and the autonomous power plants of the islands. In the liberalized electricity market, as well as before, a single price exists in both systems, depending on the identity of the consumer and the voltage class. This price list concerns the tariffs of electricity purchased since August 2006 by the Hellenic Transmission System Operator according to the law 2244/94; the decision of the Minister of Industry, Energy and Technology numbered Δ6Φ1/ΟΙΚ.8295/19.4.95 (ΦΕΚ 385/10.5.95); and law 2773/99. This electricity either is produced by independent producers or is the surplus of auto-producers and comes from either RES or CHP. There is no capacity charge on purchases from producers in non-interconnected islands.

4.0 National Incentive Programs

Financial support for wind energy projects is provided by the state in the framework of the Operational Program for Competitiveness (OPC) and the Law for Development 3299/04. The OPC raises resources from the Third Community Support Framework to provide public aid to renewable energy sources, energy saving, substitution, and other energy-related actions. During 2007, the above-mentioned program was in action, however there was no announcement of new projects. The already approved projects within OPC will be finalized until the end of 2008, which is the end-year of the Third Framework Programme. Additionally, financial support for wind energy investments is foreseen through the Law for Development 3299/2004, which provides grants for up to 40% of the total investment.

In January 2008, the Greek Ministry of Economy and Finance announced a new program entitled National Strategic Development Plan (NSDP), 2007-2013. 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.

5.0 R, D&D Activities

The Ministry for Development promotes all R&D activities in the country, including applied and basic R&D as well as demonstration projects. Key areas of R&D in the field of wind energy in the country are wind assessment and characterization, standards and certification, wind turbine development, aerodynamics, structural loads, blade development, noise, power quality, wind desalination, and autonomous power system integration. There is limited activity in Greece concerning offshore deployment.

5.1 Activities of CRES

CRES is the national organization for the promotion of renewable energy in Greece. It is mainly involved in applied R&D in the fields of aerodynamics, structural loads, noise, power quality, variable speed, wind desalination, standards and certification, wind assessment, and integration. CRES has developed and operates its Laboratory for Wind Turbine Testing, which has been accredited under the terms of ISO/IEC 17025:2000.

Several research projects were running at CRES during 2007, co-funded by the European Commission (EC) and the Greek Secretariat for Research and Technology. These research projects had the following goals:

- Characterizing the main features of complex or mountainous sites and identifying the crucial parameters affecting both the power performance and the loading of different types of wind turbines operating in such environments
- Developing wind turbines for installation in hostile environments
- Improving the damping characteristics of wind turbine blades
- Developing new techniques for power quality measurement and assessment
- Increasing understanding of wind turbine standardization procedures

• Developing blade material testing techniques within the in-house experimental facility
• Understanding generic aerodynamic performance of wind turbine blades through computational fluid dynamics (CFD) techniques
• Developing cost-effective, micro-siting techniques for complex terrain topographies.

The Laboratory for Wind Turbine Testing of CRES was granted funding for a project entitled Development of Infrastructures and Laboratory Support of CRES. This project is in the framework of Measure 4.2, Action 4.2.2, of the Competitiveness operational program, which aims at upgrading the laboratory's equipment, infrastructure, and services. More analytically, the project involves the optimization and integration of equipment and services related to power quality measurements, load measurements, wind speed measurements, and so on. One of the most significant upgrades made under this project was the purchase of a state-of-the-art LIDAR system for wind speed measurements up to 150 m high.

CRES is responsible for the development of the New Wind Map of Greece, which aims at the exploitation of country's wind potential and at the promotion of wind energy technology through new investments. The work involves the installation of 40 new masts. The Regulatory Authority for Energy (RAE) has deligated the development of the new wind map to CRES. The project will be completed at the end of 2008.

CRES also participates in the project entitled Floating, Autonomous, Ecological and Effective Desalination Unit which is co-financed by Measure 4.5, Action 4.5.1 of the Competitiveness operational program. The project involves the design and development of an autonomous floating wind powered reverse osmosis unit (RO) for seawater desalination. The system mainly consists of a 30-kW wind generator, an RO unit of 80 m^3/day potable water capacity, a battery bank, and the control system.

5.2 University research

Basic R&D on wind energy is mainly performed at the country's technical universities. The Fluids Department of the of Mechanical Engineering school of The National Technical University of Athens (NTUA), is active in the fields of wind modeling, rotor aerodynamics and aeroelasticity, load calculation, fatigue analysis, noise, and wind farm design.

In 2007, NTUA, in collaboration with CRES, developed a new eigenvalue stability tool for the analysis of the complete wind turbine in closed loop operation (i.e. including the control loop). NTUA also participated in the EC-funded project UPWIND which is aimed at developing the computational framework for the design of future large-scale wind turbine applications (beyond the current 5-MW scale). Within this project, NTUA developed and tested new aeroelastic tools capable of treating the large deflections anticipated in future large-scale highly flexible blades. New load control techniques such as a trailing edge flap have also been tested in the context of advanced 3-D aerodynamic modeling using the in-house free wake code GENUVP.

In 2007, the Electric Power Division of NTUA continued its research activities on renewable and distributed energy resources, focusing on several aspects of their technologies and grid integration issues. Specific research areas include the following:

• Microgrids with high penetration from distributed energy resources, concentrating on simulation algorithms and on control and communication technologies
• Investigation of wind power integration potential to the Greek interconnected power system and development of grid code recommendations
• Application of pumped storage in order to increase wind penetration levels in isolated island grids
• Investigation of the PV penetration potential in isolated island grids
• Technical issues and feasibility studies for the interconnection of isolated island grids to the mainland power system
• Advanced short-term wind power forecasting functions for operational planning using numerical weather predictions and advanced artificial intelligence techniques
• Power quality analysis of wind turbines and wind farms, with a particular emphasis on harmonic emissions

- Design of electrical generators and converters for small wind turbine applications, with a particular focus on permanent magnet synchronous generators
- Research on small stand-alone systems fed by renewable energy sources, including the design of the electrical and control systems for completely autonomous, wind-driven desalination systems
- Development of laboratory infrastructure for renewable and distributed energy systems, and participation in relevant laboratory and pre-standardization activity networks.

Since 1990, the Applied Mechanics Section of the Department of Mechanical Engineering and Aeronautics, University of Patras (UP), has focused on educational and R&D activities involving composite materials and structures. Emphasis is given to anisotropic material property characterization, structural design, and dynamics of composite rotor blades of wind turbines. Experience has been acquired by participating in several national and EC-funded research projects. UP is the Task Group leader in the EC-funded research project OPTIMAT BLADES, an investigation of blade material behavior under complex stress states in which the effect of multi-axial static and cyclic loading on strength and life of composite laminates is assessed. Results are available in the form of design guidelines for rotor blade manufacturers, amongst others.

Other research activities of the Applied Mechanics Section are: (a) development of finite element formulations and dedicated code accounting for selective non-linear lamina behavior, e.g. in shear, in the laminate, in order to model property degradation due to damage accumulation so as to predict the life of large rotor blades under spectrum loading; (b) probabilistic methods in the design of composite structures; (c) residual strength and fatigue damage characterization of composite materials using wave propagation techniques; (d) smart composites and structures; and (e) structural damping, passive, and active vibration control.

5.3 Participation in IEA Wind tasks

Greece participates in Tasks 11 and 20. The participation in Task 11, Base Technology Information Exchange, is promoting wind turbine technology understanding through cooperative activities and information exchange on R&D topics of common interest with the other member countries. Extra emphasis has been given through the years, especially at NTUA and CRES, to the development of aerodynamic models of wind turbines. This activity is supported by the involvement in the activities of Annex 20, HAWT aerodynamics and models from Wind Tunnel Measurements.

6.0 The Next Term

The existing legal framework was reviewed in 2005 and a new law for the promotion of renewable energy sources and especially wind energy took effect in mid 2006. The new law aims to accelerate the licensing procedures as well as to alleviate major bureaucratic bottlenecks. The promotion of national land planning currently underway is expected to further facilitate investments in renewable energy systems. However, reaching the targets set for 2010 is still uncertain unless additional measures and policies- both institutional and technological- are undertaken. A critical point for the achievement of the targets is the completion of the extensive projects destined to boost transmission capacity of the grids in the areas of great interest for wind energy deployment (Eastern Macedonia-Thrace, South-eastern Peloponnese, and Euboea). The institutional measures are expected to be implemented in the new legal framework, while technological actions such as the interconnection of the Northeastern Cyclades islands complex with the interconnected system are still to be decided and implemented.

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(1) 4th National Report Regarding the Penetration Level of Renewable Energy Sources Up to Year 2010 (October 2007).

Authors: Kyriakos Rossis, Eftihia Tzen, and Pantelis Vionis; CRES, Greece.

Chapter 18
Ireland

1.0 Introduction

Wind energy continues to increase its contribution to Ireland's electricity supply. By the end of 2007, there were a total of 74 wind farms connected to the grid bringing the total installed capacity for wind to 803 MW. Non-renewable generation on the Irish system totalled 5,890 MW. Wind generation produced approximately 1.79 TWh of electricity thereby increasing its share of output from 5.6% in 2006 to 6.8% in 2007. Wind power displaced almost 1 million metric tonnes of CO_2 emissions from the conventional thermal plant mix and avoided imports of 375,000 tonnes of oil equivalent or 15.7 PJ of primary energy.

2.0 Progress Toward National Objectives

Ireland's target for renewable generation is to supply 15% of electricity demand by 2010. As further large-scale hydropower development in Ireland is unlikely, wind is expected to contribute the vast majority of the additional generation required. A total 1,350 MW of wind capacity is required to meet the target in 2010. With 744 MW connected at the end of 2006, if the targets are to be met a further 200 MW of wind generation needs to be added per year between 2007 and 2010. The new capacity connected to the network experienced a dip in 2007 with only 59 MW connecting compared to 250 MW in 2006. It is expected that this is indeed a dip and that the capacity connected will increase in 2008 to a level more in line with 2006.

By the end of 2007, there were 39 wind farms totalling 475 MW of wind generation contracted to connect to the grid, over half of which have target connection dates in 2008. If those contracted wind farms connect within the next 2 years the total installed capacity of wind will be within 70 MW of the expected target.

In addition to the contracted capacity, connection offers totalling a further 1,321 MW were issued to successful applicants in the most recent round of group processing for renewable generation –'Gate 2'. So-called 'Gate' processing involves the clustering of applicants in an effort to optimize network reinforcement. Those included in the process are taken from the applicant queue. Beyond Gate 2, more than 6,000 MW of wind generation or well over 300 wind farms are in the connection queue awaiting a decision on the methodology for the next round of connection offers – 'Gate 3'.

Looking beyond 2010 to 2020, Ireland aims to supply 33% of its electricity demand from renewable sources. Using current emission factors for Ireland's fuel mix a 33% penetration of renewable generation in 2020 could see a CO_2 saving in the order of 6 million tonnes/yr. Wind sourced electricity will be the key contributor to the estimated 4,400 MW of renewable generation required. It can be seen from the figures for current applicants, sites contracted, and wind farms connected that the wind industry should be capable of providing the generation required given the right conditions. Approximately 275 MW of new renewable capacity is required each year from 2007 to 2020 if the target is to be met.

During 2007, the Irish government published a number of documents of relevance to the wind industry. In February the National Development Plan 2007–2013 was published (1). In March, a white paper on energy entitled

Table 1 Key Statistics 2007: Ireland	
Total installed wind generation	803 MW
New wind generation installed	59 MW
Total electrical output from wind	1.79 TWh
Wind generation as % of national electric demand	6.8%
Target:	15% of electricity demand from renewables by 2010 33% of electricity demand from renewables by 2020

'Delivering a Sustainable Energy Future for Ireland' was published (2). It sets out the Government's Energy Policy Framework from 2007–2020 with regard to sustainability and energy security of supply, setting the 33% target. In April, the National Climate Change Strategy 2007–2012 was published outlining goals and plans for carbon reduction (3).

In December, the Commission for Energy Regulation (CER) published a consultation paper outlining proposed criteria for Gate 3 connection offers (4). The options include a date order approach (as per Gate 1), a mixed date order/optimization approach (as per Gate 2), or a new approach known as the Grid Development Strategy (GDS). The GDS would result in the issuance of offers to an amount of applicants in the connection queue at gate closure. Firm access to the network for these applicants would be granted in the order of the anticipated speed with which the required deep transmission reinforcement works can be completed.

3.0 Benefits to National Economy

3.1 Market characteristics

The value of the wind industry to the Irish economy is difficult to estimate for 2007. The amount of new capacity connected in 2007, 59 MW, belies the activity in the sector. Connection offers issued during 2007 and the amount of wind generation in the queue shows clearly that the wind industry in Ireland is very active. The design, development, construction, and connection of wind farm facilities in Ireland is estimated to be worth on average 300 million € per year 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 € per year (excluding carbon savings). The value of civil and construction costs to the local economies is approximately 30 million € per year.

The development of wind farms is undertaken by a wide range of individuals and organizations from farmers to subsidiaries of semi-state bodies to multinational developers. A land owner has the option of leasing land suitable for wind farm development without having to get personally involved in the development of the site. Typical costs for leasing such land are 6,000 € per MW installed.

As the equipment is imported, the operation and maintenance (O&M) costs associated are with international suppliers. Therefore the majority of the O&M expenditure, which is estimated to be 1.5–3% of the capital costs of a project, goes overseas. Current total capital costs are averaging 2,000 €/kW installed for wind developments. Figure 1 shows the breakdown of costs for a wind park development.

3.2 Industrial development and operational experience

No manufacturing industry of large scale turbines yet exists in Ireland. There is however a developing micro-scale manufacturing industry with a small number of companies developing their own units and masts. Also a number of companies are involved in manufacturing key components for both micro scale and large scale generators.

The average size of a newly installed wind turbine almost doubled in four years. In 2007, the average size grew to 1.9 MW. Thirty-two turbines were installed in five wind farms during 2007. Figure 2 shows the largest onshore turbines in Ireland, 3-MW Vestas machines.

3.3 Economic details

Turbine costs currently range between 1,100 and 1,500 €/kW depending on size of turbine and size of development. The trend in costs continues to be upward for hardware and connections. A typical cost for connection would be in the range of 150,000 to 300,000 €.

Current support mechanisms for renewable generation take the form of a Renewable Energy Feed-in Tariff (REFIT). REFIT is a PSO backed payment. Section 4 will provide details of the mechanism.

In November, an all-island market for electricity went live – the Single Electricity Market (SEM). Northern Ireland and the Republic of Ireland now trade almost all of their electricity through a gross pool operated by the SEM Operator with a portion of electricity still traded bilaterally outside of the pool. Generators with installed capacity of less than 10 MW can trade bilaterally if they chose, thus avoiding administrative burdens associated with market participation. All generators above the 'de minimis' of 10 MW must trade in the mandatory pool either directly or via an intermediary.

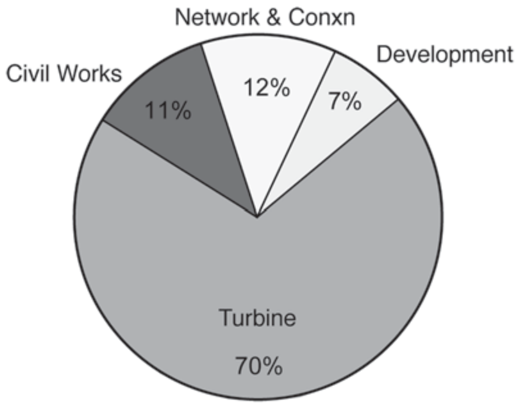

Figure 1 Breakdown of capital costs for wind plant developments.

Prior to the existence of a market-based wholesale price for electricity, the energy regulator utilized a 'Best New Entrant' (BNE) price as a benchmark price. The BNE was derived from the most efficient conventional generation available i.e. CCGT. The PSO guaranteed energy price for wind has been below this price for the past number of years, and it is expected to remain below the new benchmark price to be adopted in the SEM. The SEM Committee is currently consulting on the treatment of wind in the SEM moving forward (SEM-08-002). Issues such as the benchmark price to replace BNE, capacity payments, and firm access will be developed during 2008, all of which are considered to be crucial by the wind industry.

4.0 National Incentive Programs

REFIT is the form of support mechanism employed in Ireland with the aim of meeting the 2010 targets for renewable energy. The indirect beneficiaries of the aid are the renewable generators. Electricity suppliers receive the REFIT payment in return for entering into 15-year Power Purchase Agreements (PPA) with approved generators. Different levels of REFIT exist for different renewable technologies to reflect the variation in their set-up costs and to promote diversity. For wind generation, the value of the REFIT reference price originally announced was 57 €/MWh for large and 59 €/MWh for small-scale wind. This value is inflated annually by the Consumer Price Index. Therefore at the end of 2007, the value of REFIT for large scale wind was approximately 64 €/MWh.

Should the benchmark price fall below the REFIT reference price, suppliers are compensated through the PSO for the opportunity cost occurring due to their contract with a generator. Suppliers also receive 15% of the large-scale wind reference price on top of the energy payment to cover balancing costs in the old market.

In February 2008, the Department of Communications Energy and Natural Resources announced a REFIT reference price specific to offshore wind at 140 €/MWh.

During 2007, it became possible through revised regulations to export micro-generated electricity onto the grid although, as yet, no supplier will pay for output. In April 2008, the Department announced a pilot scheme for micro-generation in the commercial sector. It is envisaged that approximately 50 schemes will be grant aided and supported by Sustainable Energy Ireland.

5.0 R, D&D Activities

In 2006, work began on the All-Island Grid Study (5), a collaborative study to assess the ability of the transmission network on the entire island of Ireland to securely accommodate large penetrations of renewable energy generation, the vast majority being wind. The work was initiated by the government departments responsible for energy in both Northern Ireland and the Republic of Ireland. The work was completed during 2007 and published in January 2008. The steering group for the study included both departments, both system operators and both agencies responsible for the promotion of renewable energy.

Figure 2 Kilgarvan Wind Farm with 3-MW Vestas V90 turbines. Photo credit: TJ Hunter SWS Natural Resources.

The study analysed the technical feasibility and relative costs and benefits associated with six scenarios of increasing renewable penetration (23%–59% of installed capacity). For each scenario the study examined the required investment, the cost to society, and the potential CO_2 reduction. Portfolio 5 with 42% renewable penetration providing 27% of electricity demand was found to be technically feasible and deliver approximately 25% CO_2 reduction when compared to Portfolio 1 where renewable generation provided 23% of capacity.

In summary, the study indicates the potential to achieve significant environmental and fuel security benefits for little incremental cost to society or electricity customers. The limitations of the study may mean that, following further analysis, it is found that the benefits are not as extensive as indicated and the costs are higher.

The study concluded that achieving a high level of wind penetration and delivery of the associated benefits requires essential complementary actions. System security should be maintained with the addition of complimentary non-renewable plant. Capacity and ancillary service payments will be required to supplement the market income for all generators to remain viable. Support mechanisms to further foster the development of efficient renewable generation need to be considered. Work identifying the detail of transmission reinforcements must begin without delay due to the 7–10 year lead times envisaged.

6.0 The Next Term

The major wind research and development task to be undertaken in 2008 will be the pilot study for micro-generation by Sustainable Energy Ireland. Grant support to meet 50% of the start-up costs will be available in approximately 50 trial locations with an overall budget for the study of 2 million € in 2008. The initial phases of the study will concentrate on commercial installations of the technologies.

The Commission for Energy Regulation is overseeing a smart metering pilot which is due to commence towards the end of 2008. The scope of the pilot, the locations, and the technology to be piloted will be decided upon during 2008. Around the country, 25,000 meters will be installed in various locations. The Commission for Energy Regulation has stated that micro-generators will be included as a priority in the pilot as a standard facility of the smart meter will be an export capability.

For those involved on a larger scale, key policy decisions due in 2008 are the criteria for Gate 3 connection offers and the treatment of wind in the Single Electricity Market. The decisions succeeding the consultation process for both issues will be significant for the wind industry.

The All Island Grid Study has provided a platform on which further study will be based including a possible market study.

The rate of connection of wind capacity fell 75% in 2007. In 2008, capacity additions more in line with 2006 are expected.

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Author: Martin McCarthy, Sustainable Energy Ireland, Ireland.

Chapter 19
Italy

1.0 Introduction

For the Italian wind sector, 2007 was marked by three main developments. Two of these will continue to have an effect in the future, namely the introduction of a new RES incentive scheme in the 2008 Financial Law (Law 244 of 24 December 2007) and the presentation of the Italian government's Renewable Energy Position Paper, which established a maximum theoretical potential for wind energy in 2020. The third development was a new annual record for installed wind power capacity (603 MW in 2007), which brought Italy's total online capacity over the 2,500-MW target that was established for wind power in the 1999 National White Paper for Exploitation of Renewable Energy Sources (Table 1).

The Renewable Energy Position Paper (1) was presented in Brussels by the Italian government on 10 September 2007, following the adoption by the EC of the action plan "An energy policy for Europe" in spring 2007. This plan established, among other objectives, an EU target of 20% of overall primary energy consumption from RES by 2020. The Italian Position Paper included a part devoted to incentives and market design. It stressed the importance of a greater and possibly harmonized use of market-based instruments together with appropriate technology-specific incentives and a stable and simple framework to encourage investments.

Italy supports the idea of having a harmonized set of incentives across Europe and also supports market-oriented incentives for their advantages in terms of transparency, cost-based competition among sources, and cross-border trade. Technology-specific support has to be provided in this scheme by a series of measures, including so-called "technology banding." Stability in the incentive scheme is deemed necessary to give the industry a clear and long-time framework, which can in turn stimulate investments and promote technological innovation. Administrative barriers need to be removed by streamlining procedures, simplifying support schemes, and reducing requirements. However, the duration of incentives should be limited in time.

1.1 General issues for Italy

In view of the national targets that should be agreed upon on the basis of the 20% EU-wide goal mentioned above, Italy made a first, preliminary assessment of its maximum theoretical potential of energy production from RES for all uses: electricity, heating/cooling, and biofuels (1). This estimate considered: the current starting point for each renewable source; the role of climate change in renewable source availability; the physical constraints related to landscape, climate, endowment of natural resources; and a number of additional source-specific assumptions. These calculations gave a maximum theoretical RES potential of 20.97 Mtoe per year in 2020 (Table 2).

The practicability of this theoretical potential the greater diffusion of RES in Italy, is conditional upon political, institutional, economic, and technological issues. The first and perhaps most important of these issues is that all new

Table 1 Key Statistics 2007: Italy	
Total installed wind generation	2,726 MW
New wind generation installed	603 MW
Total electrical output from wind	4,074 GWh
Wind generation as % of national electric demand	1.23%
Formal wind target according to the 1999 RES White Paper:	2,500 MW or 5 TWh by 2008–2012
RES target according to Directive 2001/77/EC and Legislative Decree 387/2003:	22% (76 TWh) of gross electricity consumption from RES by 2010
Maximum wind potential according to the 2007 Position Paper of the Italian Government:	12,000 MW or 22.6 TWh by 2020

Table 2 Potentials for Annual Production of Renewable Energy				
ELECTRICITY	2005		2020	
	Power (MW)	Energy (TWh)	Power (MW)	Energy (TWh)
Hydro	17,325	36.00	20,200	43.15
Wind	1,718	2.35	12,000	22.60
Solar	34	0.04	9,500	13.20
Geothermal	711	5.32	1,300	9.73
Biomass, Landfill gas and Biological purification	1,201	6.16	2,415	14.50
Wave and tidal	0	0.00	800	1.00
TOTAL (MW/TWh)	20,989	49.87	46,215	104.18
Primary energy replaced (Mtoe) * * Using the Eurostat conversion factor	**4.29**		**8.96**	
HEATING/COOLING, BIOFUELS	2005		2020	
	Energy (TJ)	Energy (Mtoe)	Energy (TJ)	Energy (Mtoe)
Geothermal	8,916	0.21	40,193	0.96
Solar	1,300	0.03	47,000	1.12
Biomass	78,820	1.88	389,933	9.32
Total Heating/Cooling	89,036	2.12	477,126	11.40
Biofuels	12,600	0.30	25,600	0.61
TOTAL H/C+Biofuels (TJ/Mtoe)	101,636	**2.42**	502,726	**12.01**
(from the 2007 Renewable Energy Position Paper of the Italian Government)				

plants are subject to political and administrative authorizations which are, in turn, often affected by problems of acceptance by local communities. Italy has experienced frequent NIMBY (not in my back yard) problems that have produced delays and, in some cases, cancellations of infrastructure projects. Streamlining the authorization process, and, above all, improving its efficiency, will be essential for boosting the diffusion of RES plants.

This issue is linked to the reality that energy policy is subject to various levels of governance in Italy, given the very important role assigned to regions in this sector. In order to achieve an ambitious national target, better coordination will thus be necessary, both among regions and between them and the national government. Regions should also take on their own targets, and define clear and efficient roadmaps to 2020.

An evaluation of the social and economic sustainability of RES promotion policies, including incentives, will also be necessary, with special reference to possible effects of RES promotion on energy prices for consumers and businesses. Possible negative consequences in terms of competitiveness and inflation will have to be taken into consideration.

Greater diffusion of renewable energy generation plants will also require stronger investments in the electricity transmission and distribution grids, and the ability to accommodate small-scale distributed power generation resources that would need to be interconnected like an Internet network and in the form of two-way interacting infrastructures. In this sense, the guidelines provided by the SMART-

GRIDS EU Technological Platform are a useful framework.

1.2 Specific issues for wind

The main issues at stake are 1) local acceptance of the environmental impact resulting from exploitation for wind energy of progressively more valuable areas from a naturalistic or landscape point of view, and 2) the natural saturation of the locations that have more specific capability. Also for these reasons, some development of offshore plants has been envisaged. Bearing in mind both likely resources and limiting factors, the Position Paper (Table 2) set a potential electricity production in 2020 of up to 22.60 TWh from wind (with an installed capacity of up to 12 GW), compared with 2.35 TWh in 2005 and 3 TWh in 2006. Production from wind further increased in 2007, when it totaled 4,074 GWh, according to 2007 electricity statistics provided by Terna (Italian Transmission System Operator). This would mean 37% more production than in the previous year, which is a much higher growth rate than that of installed capacity. Nonetheless, installed capacity also rose by a healthy 28% and established an annual record for the number of MW installed.

As to the whole electricity system, according to Terna's provisional data, the 2007 electrical demand on the domestic grid (including both customer loads and grid losses) was 340 TWh, 0.7% more than 2006. As in previous years, imported electricity provided far-from-negligible help (the balance between import and export was nearly 46 TWh). Italy's 2007 gross domestic electricity consumption (i.e. 314 TWh of gross domestic production plus the balance between import and export) can therefore be put at about 360 TWh.

Hydropower once again supplied the largest RES contribution to gross domestic production, although its output (leaving out the production of pumped-storage plants) decreased by 10% compared to 2006, falling to about 33.5 TWh, because of less rainfall. As a consequence, despite the growing production from wind and other RES plants, total domestic production from RES in 2007 is estimated to be below the level of the previous year (52 TWh).

Wind-generated energy, as a percentage of national electricity demand, increased in 2007 to 1.23%, about 25% more than in 2006. A similar growth rate is forecast in 2008 as well.

2.0 Progress Toward National Objectives

Despite a preliminary assessment of natural RES potentials indicated in the aforementioned Position Paper, Italy has not yet formally changed its previous target for RES established in the relevant White Paper of 1999. That paper also called for total RES electricity generation of 76 TWh/year by 2010 (this target was confirmed through Legislative Decree 387 of 2003). This official target is now considered to be outdated because of the new goals recently fixed by the EC. The EC goals will have to be achieved by the member states with different contribution shares. Consequently, new formal national RES targets will shortly be set according to the final decisions about the RES quota assigned to each country.

Considering the figures of Table 2 and comparing the energy expected from wind in 2020, or 22.6 TWh, with the previous target of 5 TWh in the 1999 White Paper, the wind sector must grow by a factor of 4.5 to comply with this new possible target. This will require adding at least 9,300 MW, of which 2,000 MW will likely be offshore, in 13 years, through an average annual growth of something more than 700 MW. On the other hand, 700 MW is the minimum value that can now be anticipated for 2008.

2.1 Commercial development

With 603 MW of new generating capacity installed in 2007, which brought cumulative capacity to 2,726 MW, a new record of yearly growth was achieved, exceeding the previous one, established in 2005, of 453 MW (Figure 1). However, this 2007 result is not enough to comply with the aforementioned EC plans (20% of overall primary energy consumption from RES by 2020) and so it is necessary to increase the annual growth rate (Figure 2) through the cooperation of all the central and southern Italian regions with the best wind potentials. Only a few regions have shown a very strong commitment to the promotion of wind energy. This is the main reason why Italy did not fully achieve the result anticipated at the beginning of 2007.

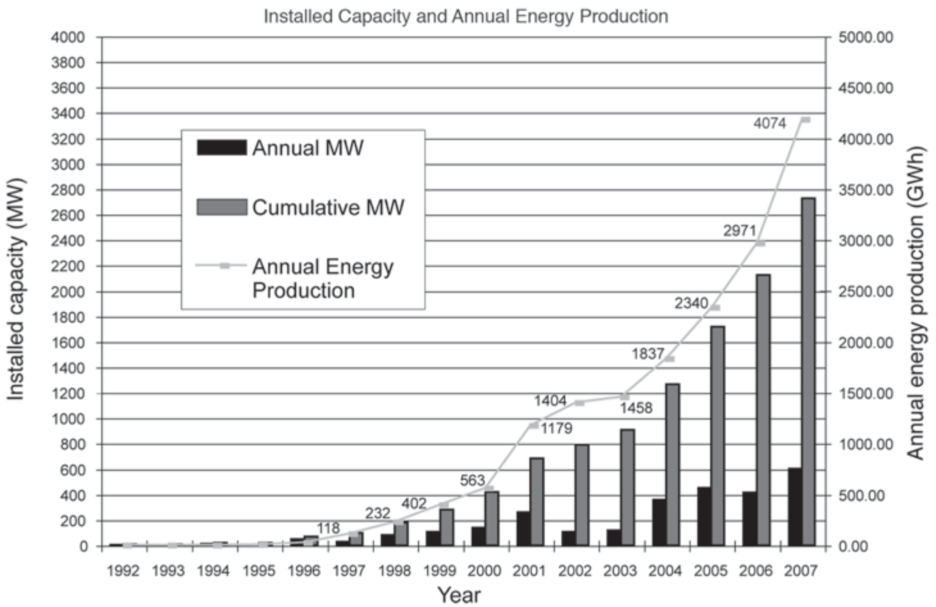


Figure 1 Trend of annual and cumulative wind turbine capacity and electricity production from wind in Italy.

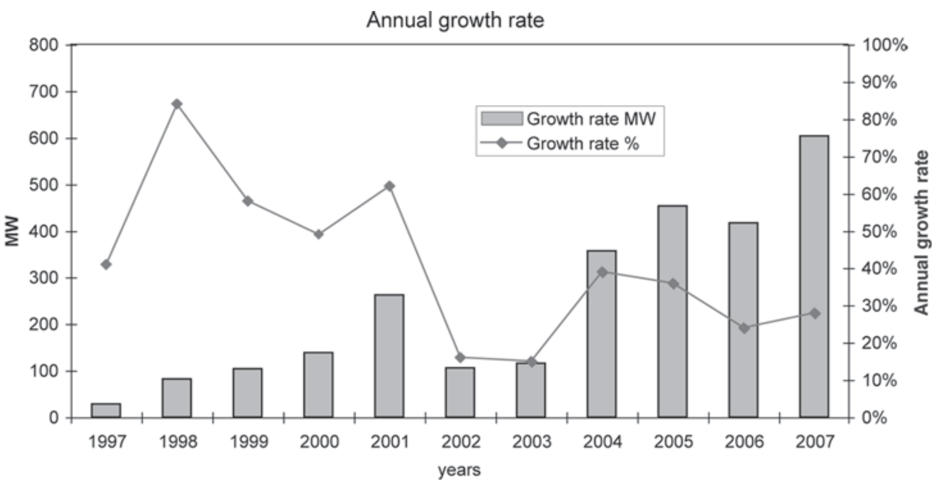


Figure 2 Trend of annual growth rate (absolute and as a percentage) of Italy's cumulative wind capacity.

In 2007, the Apulia, Sicily, and Campania regions confirmed their willingness to significantly develop wind energy (Figure 3). Apulia alone put into operation more than 200 MW in 2007. In Sicily, some 130 MW of new generating capacity brought the total in the island close to 600 MW. Significant civil-engineering work was also underway on additional wind farms developed by several old and new investors. In 2007, Calabria also provided a good contribution with around 100 MW of new installations. In 2008-2009 the same capacity or something more is expected to be added. Other regions like Abruzzo, Molise, and Basilicata have recently issued only a few permits to build new wind plants.

The major contribution to new wind capacity in 2007 came from the use of large-sized turbines in the range of 1.5 to 3 MW, which raised the average power per unit in 2007 to 1.638 MW. The total of 368 wind turbines installed in 2007 was about the same annual number of units seen since 2004, but with a significant increase in power. The cumulative number of on-line units at the end of 2007 was 2,943. Since cumulative capacity was 2,726 MW, this means a cumulative average online capacity of 926 kW per turbine (Figure 4).

In 2007, Vestas Italia, Gamesa, Enercon, and GE Wind were the most active manufacturers. Vestas alone, with some 280 MW, covered 46% of the Italian market, while the remainder was, in large part, supplied by Gamesa, totaling more than 140 MW of new plants. Gamesa was followed by Enercon, which was around 90 MW with 2-MW and 2.3-MW turbines, and GE Wind with 1.5-MW turbines. Nordex, through a wind farm made up of 1.5-MW units located in Sardinia, also entered the Italian market. The company plans to build more than 300 MW in the islands and in Calabria in the period 2008-2009. Ecotècnia plans to build two large plants totaling about 80 MW in southern Italy in 2008.

The IVPC group has long been Italy's historical leader of windfarm developers in terms of overall installed capacity record. In 2007, it added nearly 100 MW of new plants. In more recent years, however, IVPC sold 550 MW of

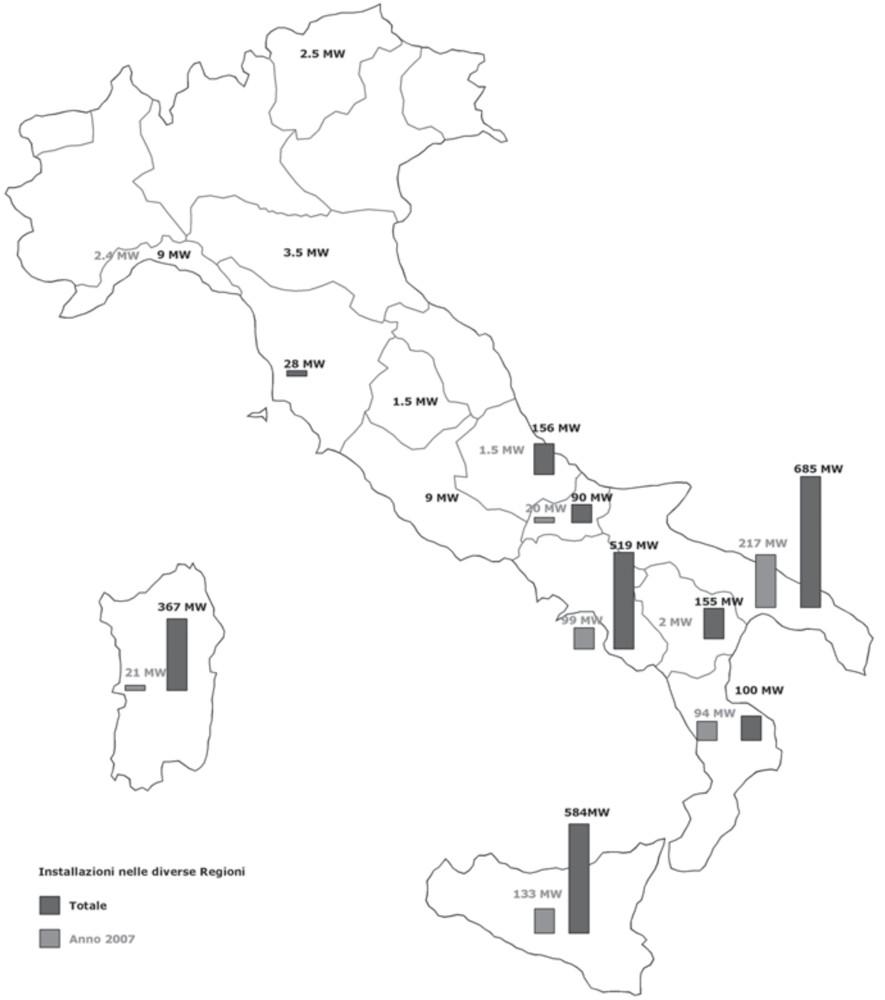


Figure 3 Wind capacity at regional level in Italy as of the end of 2007 (cumulative MW in black and 2007 MW in gray).

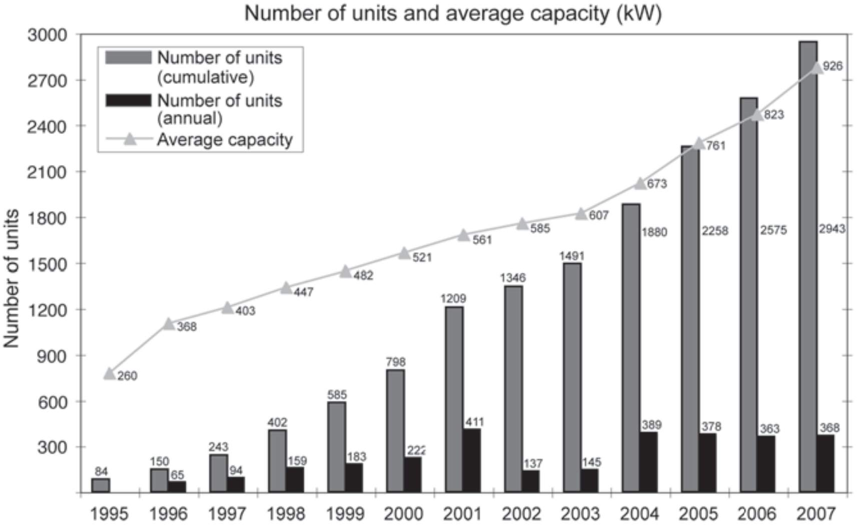


Figure 4 Trend of cumulative and yearly-added numbers of wind turbines in Italy, and average online unit capacity.

its capacity to the Trinergy group (Ireland). At present, this capacity has been acquired by International Power from the UK. As to new capacity, the 2007 leader was the utility Endesa, through 126 MW of new plants. Endesa almost doubled its 2006 market share and achieved a 9% cumulative capacity quota, very close to the large national utilities Enel and Edison. During 2007, IVPC also replaced the main components of 51 ten-year-old 600-kW turbines totaling 30.6 MW with new gearboxes, generators, etc., in order to obtain the right to get green certificates according to the Italian law. Previously these turbines had been entitled to obtain the premium feed-in tariffs granted for a period of eight years under the former RES support scheme (CIP Provision 6/92, see following section on National Incentive Programs).

Other new investors are now interested in entering the Italian wind market, but their efforts are mainly absorbed by the need to deal with complex bureaucracy. The evaluation process generally takes a long time, particularly due to the growing number of applications.

In 2007, the average capacity factor of all running plants was around 0.2, thus confirming the fact that a large number of Italian sites are endowed with rather weak wind conditions and, consequently, it is not easy for investors to find new economically exploitable sites free of constraints.

2.2 Constraints

Technical problems hampering the exploitation of potentially good sites are mainly related to the fact that most of the best wind areas are located in mountainous terrain, which obviously makes it more difficult to transport wind turbines and connect them to the grid. Other more complex barriers come from unfavorable perceptions of wind technology by some regional and central authorities, as well as by some of the environmentalist associations, particularly those active at local level. To some extent, the public may also have unfavorable perceptions of wind energy, especially when people are not appropriately informed in advance of the projects planned on their territory. In addition, even in cases of more favorable attitudes, investors have to embark on the bureaucratic procedure for permissions. As mentioned above, it generally requires a long time for a project to receive all necessary authorizations.

Regions have been called upon by Legislative Decree 387 of 29 December 2003 and by the 2008 Financial Law (Law 244 of 24 December 2007) to help fulfill the country's international environment and energy commitments, by simplifying plant authorization procedures and indicating regional targets in accordance with national ones. It will likely take time for them to give a fully satisfactory response. Nonetheless, such a sharing of national targets by local governments is of paramount importance due to the general energy situation, and particularly the shortage of domestic conventional energy resources. Italy is heavily dependent on oil and gas imports from many countries at variable and generally rising costs.

Grid connection issues are still posing problems as well. Despite the new rules issued by the Regulatory Authority for Electricity and Gas in late 2005 to streamline technical and cost aspects of the connection of generating plants to the electrical grid, investors still complain of several wind farms suffering major delays in their completion process owing to grid connection problems.

Terna (the Italian TSO), with the aim of improving wind energy penetration into the electrical system, has planned work, some currently in progress, to upgrade parts of the transmission grid in southern regions and particularly in the main islands of Sicily and Sardinia. Here, new submarine cables for connection to the mainland will substantially improve energy transfer in the next few years.

3.0 Benefits to National Economy

3.1 Market characteristics

Wind energy is the renewable source growing most rapidly in Italy and, considering its possible development in the coming years, it is very likely to contribute more substantially to a cleaner energy sector. In Italy, the economic turnover of the wind sector in 2007 was more than 1 billion €, including turbines delivered to foreign countries, up significantly from 2006. This increase has been due partly to the growth of the domestic market and partly to the increasing cost of raw materials, components, and development of projects, which together with the shortage of turbines on the market has brought about a steady rise of costs during the year. One positive consequence of the strong development of the wind market is that the total number of personnel directly and indirectly employed in the wind sector at year's end was about 10,000.

Some companies producing components such as steel and concrete towers, and small wind turbines, increased their activities in 2007, while other new ones have been set up. Prospects for newcomers have become more attractive as measures to stimulate new companies and investors in the 2008 Financial Law have come into effect.

In 2007, Trinergy sold the 550-MW windfarm capacity purchased from IVPC (see section 2.1) to International Power (UK). At year's end, International Power had thus become Italy's main windfarm owner with 20% of capacity, while IVPC held only 8% (IVPC has, however, also remained in charge of operation and maintenance of the 550 MW handed over). Other major owners, with a capacity share of around 10% each, are the utilities Enel, Edens, and Endesa.

Fri-El is a private company mostly engaged in wind, hydro, biomass, and biogas activities. The company has a good presence in the wind field and several new installations underway. In 2004 Fri-El established an important partnership with EDF Energies Nouvelles from France, one of the world's leading renewable energy companies, for the construction and operation of wind farms and the development of new renewable energy projects. In 2007, Fri-El further expanded its wind power operations through the construction of its tenth wind farm in Ricigliano, with installed capacity of 36 MW. The know-how acquired over the years has enabled Fri-El to install, in the difficult geomorphologic conditions of this area, 12 of the most powerful wind turbines operating in Italy today, with a capacity of 3 MW each and blades of 44 m. In coming years, Fri-El intends to strengthen its position in the renewable energy sector through a substantial investment plan. Investments will be made primarily in the wind sector, but Fri-El will also focus on the production of electricity from biomass and biogas, and on the production of biodiesel.

The other developers on the Italian market are private investors and small companies belonging to large industrial or commercial groups. There are some 150 companies directly involved in the wind sector and about the same number are indirectly involved with the sector including consultant firms.

Some re-powering of older plants started a few years ago, but for the time being this possibility is not yet considered by developers as a major opportunity, mainly for the lack of specific legislative measures. New measures are needed to promote this concept through a simplified authorization procedure, in order to improve energy production by encouraging the use of new, larger machines. Only IVPC in 2007, as mentioned above, refurbished 51 old wind turbines, thus obtaining access to green certificates without any need for further authorization on the sites, but maintaining the same installed capacity.

Offshore plants, too, could represent an interesting opportunity in Italy, in consideration of the very long coastline. This is true even though most of the windiest areas are located in deep waters, which makes them very difficult to exploit, at least with current offshore technologies.

3.2 Industrial development and operational experience

Among wind turbine manufacturers (Figure 5), Vestas Italia led the expansion of the Italian market in 2007, as it put into operation about 46% of annual new capacity, thus coming to hold 55% of the country's total on-line capacity. It was followed by Gamesa, which confirmed its strong presence in the country and particularly in the Calabria region. Enercon added some 90 MW to its previous capacity by installing large turbines in the Apulia region. All these manufacturers have established direct industrial activities and/or commercial agreements with Italian producers for the supply of wind turbine components.

In 2007, Vestas Italia increased the number of employees in its two factories in Taranto to 650 people. The company provides good employment prospects for coming years due to the building of a new production line for V90 3-MW turbines (Figure 6), which should be operational in early 2008. Apulia's favorable attitude to wind technology was recently confirmed by a visit of the regional official responsible for environmental issues to the Vestas factories. The regional government of Apulia has been involved in the screening and authorization process of a large number of new applications. The Vestas 850-kW units, produced only at the Taranto factories, were mainly sold and installed in Italy, while the remainder were exported abroad to Eastern Europe, Turkey and, above all, China. Vestas Italia prefers domestic and local suppliers, who have been providing a substantial part of its turbine components.

Enercon in 2007 resumed a high level of activity in Italy. As a consequence of its large number of projects underway, it decided to work jointly with IANUS, a local concrete tower production firm very close to the harbor of Bari. This is an optimal place both for its proximity to the majority of Enercon's forthcoming plants and for exporting towers overseas. Concrete towers were used for the first time in Italy to erect 13 Enercon 2-MW turbines near Alberona in autumn 2007.

Moncada Costruzioni, in its double role of plant developer and energy producer, has been looking for opportunities abroad. In Albania, it has been authorized by the local government to build and manage a 500-MW submarine high-voltage (400 kV) direct-current line between Albania and Italy. The total length of the line is 145 km, of which 130 km is undersea. The line, besides improving energy export-import between the two countries, will enable the transport of energy from a 500-MW wind farm (already authorized by the Albanian government) that Moncada intends to build with an investment of 750 million €.

The Leitner Technologies Group has continued work on the Leitwind gearless wind turbines with rated powers between 1.2 and

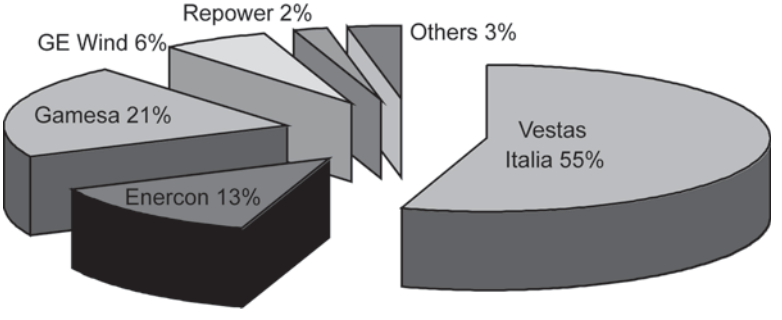


Figure 5 Market shares of wind turbine manufacturers at the end of 2007 (percentages of total online capacity).

Figure 6 Vestas V90 turbines at the 36-MW Surbo wind farm developed by Inergia in Apulia (courtesy of Vestas).

1.5 MW, featuring a 62-m-diameter rotor for wind class I as well as 70 and 77-m rotor diameters for wind classes II and III. The core of the Leitwind machines is a variable-speed generator with permanent magnets guaranteeing optimal energy yield and higher availability with less maintenance and noise emission. In 2007, the company sold its first lots of LTW 77 turbines in Austria and India. Two other units have been installed in Bulgaria at the beginning of 2008. A higher number of 1.5-MW turbines, with a rotor diameter of 70 m and 77 m, are expected to be erected in 2008. Moreover, already in 2008, Leitner will install a new model named LTW 80, a machine 80 m in tower height and rotor diameter, with new blades.

3.3 Economic details

Since 2004, the cost of installed wind turbines and other plant items has steadily been increasing. In 2007, cost increases accelerated due to the effect of the shortage of wind turbines together with higher prices of raw materials like steel, copper, and carbon. The average installed plant cost at a site of medium complexity can be up to 1,800 €/kW. This rise has partly been due to rising project development costs, which in the worst cases reached up to 500 €/kW. The purchase cost of wind turbines alone in 2007 was about 1,300 €/kW. The total cost of an average wind farm (average not only in dimensions, but also considering the complexity of the site terrain), electrical grid-connection included, could be divided as follows:

Development costs: 10%-20%
Turbines: 65%-70%
Civil-engineering works: 15%
Connection to grid: 5%

Maintenance and operational costs were also higher in 2007 than in 2006 by about 20%, with an average level of about 12-13 €/MWh.

The income wind plant owners can get by selling energy on the wholesale market or, as they generally choose, to the grid operator itself, varied through 2007 depending on many factors. The factors include the hour and area of production. On average, it could be put tentatively around 80 €/MWh.

The latest measure bearing upon the sale of wind-generated electricity was Provision 280 of 6 November 2007 issued by the Regulatory Authority for Electricity and Gas. Among other measures, this provision established Gestore dei Servizi Elettrici (GSE) (the body also in charge of managing all RES support schemes) as the sole counterpart to wind producers wishing to have their energy bought by grid operators. To make their business more profitable, wind energy producers can get additional income from RES support schemes in different ways, depending on the date when plant operation began or is going to start. The characteristics and amounts of incentives available in 2007 and recent developments affecting coming years will be explained at length in the following section.

4.0 National Incentive Programs

4.1 Major RES support instruments

In 2007, the instruments supporting electricity produced from RES were run along the same lines as previous years. It was not until the end of the year that the 2008 Financial Law

(Law 244 of 24 December 2007) introduced a number of changes, which went into effect at the beginning of 2008.

For the convenience of the reader, we briefly recall the main features of the support instruments still operating during 2007 (see also previous IEA Wind Energy Annual Reports).

Alongside the main support scheme based on tradable green certificates (TGCs), in 2007 a number of wind plants still benefited from the former system of "feed-in tariffs" granted by CIP Provision 6 of 29 April 1992. These tariffs are different for the various RES and "RES-assimilated" technologies and consist of the base price, paid over the full plant lifetime, and an incentive, available over the first eight years of plant operation only. The maximum preliminary value of the full 2007 tariff for wind-generated energy was 163.7 €/MWh in the best case, i.e. for plants feeding all their energy output to the grid.

More recent wind plants have instead been supported by the current scheme, which is based on a compulsory quota of RES electricity to be supplied, and TGCs intended to certify the fulfillment of this obligation. This scheme was first set up by Legislative Decree 79 of 16 March 1999 (restructuring the electricity market), confirmed by Legislative Decree 387 of 29 December 2003 (implementing EU Directive 2001/77/EC on RES promotion) and further adjusted by legislation in 2005 and 2006. Every year, the RES electricity quota obligation is laid on operators who, in the previous year, produced or imported electricity generated from non-renewable sources. These operators must feed into the Italian grid at least as much RES electricity as the mandatory percentage of their non-renewable electricity in the previous year. This percentage was originally fixed at 2%, but was subsequently raised by 0.35 percentage points per year. For 2007, it has become 3.05% of the energy produced from conventional sources in 2006. Imported RES-generated electricity (provided it has been certified by a Guarantee of Origin) can be taken into account in meeting the RES requirement.

Operators subject to the obligation have to prove compliance by handing in, after the end of the year, a corresponding number of TGCs granted to RES electricity by the body in charge of running support schemes (GSE). In 2007, one TGC equaled 50 MWh. TGCs can either come from one's own RES plants or be bought from other RES electricity producers. TGC-entitled RES producers (named IAFR producers) can thus have further income in addition to that from energy sales. Plants that began operating from 1 April 1999 to 31 December 2007 are given TGCs over the first 12 years (formerly 8 years). TGCs are valid for 3 years from issue.

TGCs can also be bought from GSE, at a price that is fixed every year depending, among other factors, upon CIP 6/92 feed-in tariffs. This price had been growing steadily in previous years and, for 2007 production, was set at 137.49 €/MWh. Depending on the TGC market situation, GSE certificates can either set a price cap on the TGC trading price or help sustain this price at a more rewarding level. Unlike previous years when GSE's TGCs were needed to meet demand, in 2006 and 2007 the whole TGC demand was covered by IAFR producers, mainly with hydro, wind, and geothermal plants. The ensuing competition pulled the actual TGC trading price somewhat below that of GSE's TGCs, reportedly even down to around 120 €/MWh in 2007. These poor price conditions have been blamed, among other factors, on the RES obligation percentage rising at too slow a rate, which did not allow TGC demand to grow enough. This has been seen as a particularly serious problem because Italy does not seem to be on track to meet its RES-electricity target set in EU Directive 2001/77/EC (22-25% of gross domestic consumption by 2010), at least if only domestic production is considered, neglecting RES electricity imports.

This incentive framework has been changed by the 2008 Financial Law (Law 244 of 24 December 2007). The main new features of Italy's support system can be summarized as follows:

- the yearly increase of the mandatory quota of RES-electricity has been raised from 0.35 to 0.75 percentage points in the period 2007-2012;
- the size of all TGCs has been reduced to 1 MWh from 1 January 2008 on;
- RES plants that have come online after 1 January 2008 will get TGCs for a period of 15 years (instead of 12 as older plants), in a number equaling the number of produced MWh multiplied by a coefficient, which is

specific for each technology (e.g. 1 for on-shore wind, 1.1 for offshore wind);
• RES plants not exceeding 1 MW capacity can also opt for a fixed feed-in tariff, available for a period of 15 years; specifically for wind plants below 200 kW capacity, the tariff is 300 €/MWh;
• from 2008 on, the price of TGCs bought from GSE will be calculated as the difference between 180 €/MWh and the annual average price of RES electricity sold according to article 13/3 of Legislative Decree 387/2003 (in 2007 roughly about 80 €/MWh);
• the above reference values and coefficients may be updated every three years;
• until Italy has reached its RES electricity target according to Directive 2001/77/EC, GSE shall buy all TGCs that IAFR producers have not sold to obliged operators before their expiration date, at a price equaling the average TGC price of the previous year.

It is worth recalling here that photovoltaic (PV) plants are actually outside the scope of legislation concerning TGCs, as they are the subject of dedicated measures providing them with feed-in tariffs depending on size and type (the latest provision about PV feed-in tariffs was the Ministerial Decree of 19 February 2007).

5.0 R, D&D Activities

5.1 National R, D&D efforts

In the megawatt-class turbine sector, the Leitner group, after developing the LTW 62, LTW 70, and LTW 77 (see above), is currently working on a larger 1.5-MW machine, the LTW 80. The LTW 80 has a rotor diameter of 80 m and an 80-m tower. This is an evolution of the previous models and probably will be available also with a 70-m rotor diameter for sites in class IA. As anticipated, after a testing period, the LTW 80 should become ready for sale in the second half of 2009.

As a positive consequence of recent legislative measures, a renewed interest has been shown also by manufacturers and potential customers of small wind turbines. The Bolzano-based firm Ropatec, manufacturing small-sized vertical-axis turbines (Figure 7), inaugurated its largest product, the Big Star, in the presence of the Italian Minister of the Environment. The Big Star is a 20-kW vertical-axis turbine, which was installed in a mineral water factory in the province of Trento. The main characteristics of the Big Star are: flexible use of the energy generated (connection to the grid through an inverter, battery charging and water heating), very quiet operation, and reduced maintenance.

The University of Trento has been actively operating in its wind test field in order to identify and document the characteristics of three machines in the 1.5 to 20-kW range that are currently being tested. The information collected will be posted on a web site and serve as a technical and scientific reference database of the small turbine sector. Since turbine testing began in July 2007, several turbine features have been identified for possible technological improvement.

As to offshore technology, some activities have been carried on in the academic world, particularly at the Universities of Bologna and Genoa, which are still involved in studies on offshore foundations and assessment of the

Figure 7 A Ropatec small-sized vertical-axis turbine on Monte Casale in the Italian Alps near Trento (courtesy of Ropatec).

offshore wind potential, respectively. A feasibility study on a Sicilian site started at the end of 2007 through a joint initiative between ENEA and the University of Catania.

The CESI RICERCA company, after completing its new Wind Atlas of Italy (see the *2006 IEA Wind Annual Report*), has undertaken further studies into some aspects of Italy's wind potential, particularly offshore potential. Offshore capacity could in principle supplement the limited onshore resources in meeting the country's ambitious RES targets, but still needs to be assessed more fully taking into account all factors (windiness, technology, costs, etc.) that can influence its exploitation.

Since most of the best offshore resources have turned out to be located in waters that are too deep for the current technology, in 2007 CESI RICERCA started investigating the feasibility of plants based on floating foundations, with a consultant assisting on more specific marine issues. A dynamic computational model has been under development for studying the behavior and stresses of wind turbines mounted on floating structures under normal and extreme operating conditions. The goal is to identify preliminary criteria for choosing the best promising floating structure, taking into account both technical and cost aspects.

Interest in offshore applications has also been shown by a few important industrial companies, like Enel and Gamesa, which have plant projects in the authorization process and under study. For the time being, however, their in-field activities have been limited to data acquisition.

Mention should also be made of an offshore project managed by the company Blue H. In January 2007, Blue H obtained authorization to install its floating platform prototype in waters off the Apulia coast, facing the town of Tricase. The company then applied for authorization to build a 90-MW wind farm in the same area, 20 km from shore in waters 100 – 120 m in depth. The project seems to have support from the regional government of Apulia and the local population. In December 2007, Blue H launched the prototype, with an 80-kW turbine mounted on a floating foundation called SDP (Submerged Deepwater Platform). In 2008, the prototype will be anchored in 108-m-deep waters at a distance of 10.6 nautical miles from the coastline and experimental tests will begin.

6.0 The Next Term

Considering the Position Paper presented by the Italian government in Brussels in September 2007 and the support provided by the 2008 Financial Law to renewable energy, there is some reason for optimism about the future of wind energy in Italy. Moreover, other investors, in addition to those already operating in the wind sector, have ambitious projects planned.

An important political aspect yet to be settled to achieve Italy's renewable energy targets, is to secure the strong commitment of all regions. This has been stressed in the 2008 Financial Law. In fact, Article 2/167 of this law states that the Minister of Economic Development, in agreement with the Permanent Conference for relations between the state and regions, shall establish within 90 days the minimum regional shares of increase of electricity from RES that are needed to reach Italy's current renewable energy targets as well as the new national targets that will shortly be agreed within the European Union.

Within a favorable political framework, considering the current situation of the wind sector, it would seem realistic to envisage a cumulated wind capacity of at least 5,000 MW by 2010, through an annual average growth rate of about 800 MW/year.

Reference:

(1) Energy: issues and challenges for Europe and for Italy. Position paper of the Italian Government, 10 September 2007.

Authors: Luciano Pirazzi (ENEA) and Claudio Casale (CESI RICERCA), Italy.

Chapter 20
Japan

1.0 Introduction

At the end of 2007, the total wind power capacity in Japan was 1,538 MW (1,331 turbine units) for an annual net increase of 229 MW. However, wind power development in Japan after April 2007 had little progress due to the legal reform of the Japanese Building Code. After the reform, a wind turbine is considered as a construction and its height is defined as the top height of a blade from the ground level. This has limited wind installations and Japan is only half the way to the national target of 2010.

Wind turbine damage by typhoon and lightning strikes continues in Japan. Therefore, most national wind activities are investigating or developing a J-Class Wind Turbine Guideline. Such a guideline should help achieve sounder wind turbine technology for the Japanese environment.

Another significant issue in Japan is grid connection. Compared with EU countries, Japan is very isolated, and so the influence of wind generation on grid stability is considered very large, regardless of how small the penetration ratio is. Therefore, the electric power companies generally limit new wind farm projects and often choose among the small numbers of them by drawing lots. Moving to offshore installations has not yet begun due to deep-water conditions, but a national investigation was initiated in 2007.

2.0 Progress Toward National Objectives

2.1 Strategy

At the UN Climate Change Conference in Kyoto in December 1997, the Japanese government agreed to reduce the output of greenhouse gases by 6%, compared with the 1990 level, by 2010. To attain this target, the government, in the primary energy supply plan, decided to increase "new energy" (a term similar to renewable energy) to 3% of the primary energy supply by 2010. At the time of the agreement, wind power generated 7% of the renewable energy capacity making the 2010 target for wind power generation 3,000 MW and 2.1% of the primary energy supply.

In April 2002, the Japanese government passed legislation for a Renewables Portfolio Standard (RPS) in order to realize the national target for renewables by 2010. Under the RPS, Japan's utilities are obligated to source 1.35% of total electricity supply from renewables by 2010. During the fiscal year, (from April 2007 to March 2008), wind plants supplied 2.207 TWh/yr which is 1/3 of the total supply from renewables.

To counteract natural and social obstacles to wind power development, the government has been running the following investigations and research programs:

- Field Test Program
- J-Class Wind Turbine Guideline
- Demonstration of Grid Stabilization
- New Energy Business Support Program
- Regional New Energy Development Stimulation Program
- Wind Turbine Accidents Investigation
- Wind Technology Standards (JIS/IEC).

2.2 Installed capacity and generation

Japan's cumulative wind-power capacity was 1,309 MW with 1,191 units at the end of December 2006, and 1,538 MW with 1,331

Table 1 Key Statistics 2007: Japan	
Total installed wind generation	1,538 MW*
New wind generation installed	229 MW*
Total electrical output from wind	2.207 TWh/yr**
Wind generation as % of national electric demand	0.20%**
Target:	3,000 MW by 2010

* Statistics at End December 2007
** Estimated based on Home Page Data, Japanese Renewables Portfolio Standard System, METI.

units at the end December 2007. The annual net increase was 229 MW (increase ratio: 14.9%). Figure 1 shows the history of wind-power development in Japan. Note that the statistical periods were changed from previous fiscal year to calendar year between 2007 and 2008. Wind power generation from April 2006 to March 2007 was 2.144 TWh/yr and the contribution of wind power the national energy demand accounted for 0.20%.

2.3 Rates and trends in deployment

Most commercial wind farms have been developed with governmental promotional subsidy programs, which quickly accelerated development. Figure 2 shows the history of annual increases in wind power capacity in percentages. The five-year average increase records are 47% (1993-1997), 87% (1998-2002), and 37% (2003-2007). Looking at Figure 2 together with Figure 1, the development of wind power has apparently slowed down and the tendency is not an exponential function but rather a linear function.

3.0 Benefits to National Economy

3.1 Market characteristics

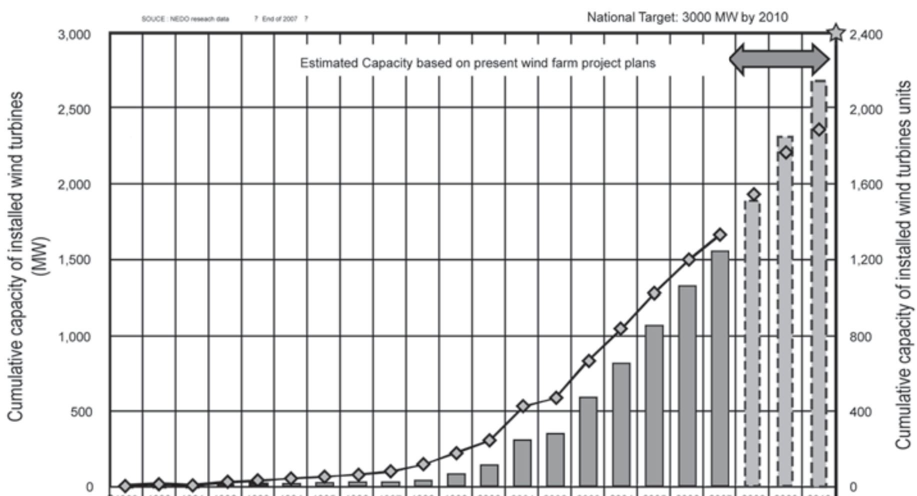
The wind power market in Japan has rapidly progressed in the past 15 years. As a result, large wind farms have been developed as shown in Figure 3. The largest wind plant generates 64 MW using 32 Enercon 2-MW turbines and was built in December 2006 relatively close to Tokyo on Nunobiki highland in Konan-machi, Fukushima Prefecture. The second largest plant was built in Wakkanai, Hokkaido in November 2005 and generates 57 MW using 57 Mitsubishi 1-MW turbines. Many entities are developing wind power: citizen groups, NPOs, third sectors, local governments, and big private companies. Most of the large wind farms are owned by big wind energy developers.

More than 80% of wind generation capacity has been supplied by foreign turbine manufacturers. As shown in Figure 4, the top supplier is Vestas (22%), followed by GE Wind (17%), Mitsubishi (17%), and Enercon (10%).

The Japanese market is deeply influenced by external conditions, both natural and grid-related. Extreme wind conditions such as tropical storms and typhoons, high turbulence due to complex terrain, and heavy lightning strikes are the most important technical issues. Isolated from foreign countries by ocean, grid connection and stability are severe barriers to development.

3.2 Industrial development and operational experience

Several wind turbine manufacturers produce turbines in Japan and the main ones are listed in Table 2. Several new turbine manufacturers have developed turbines that are very suitable for Japanese external conditions.



	?1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Capacity (MW)	1	915	883	2,624	4,924	7,315	9,471	13.24	17.04	31.91	70.15
Number?units?	4	8	6	19	30	42	51	63	77	117	177

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity (MW)	136.3	302.3	338.6	580.6	809.6	1,049	1,309	1,538	1,885	2,328	2,681
Number?units?	246	422	470	668	835	1,028	1,191	1,330	1,544	1,770	1,924

Figure 1 History of wind-power development in Japan.

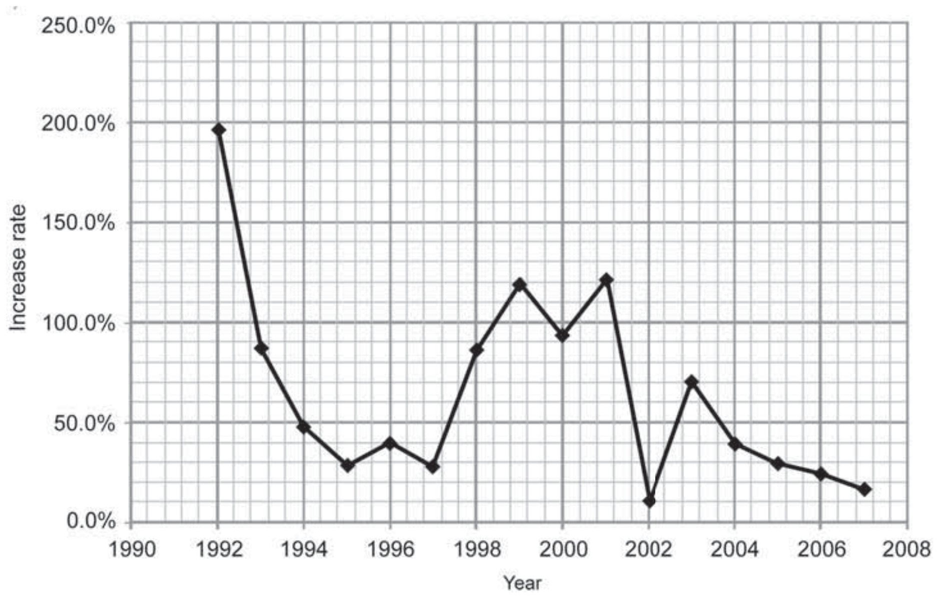


Figure 2 History of annual increase rate of wind power capacity (percent) with a fitting curve.

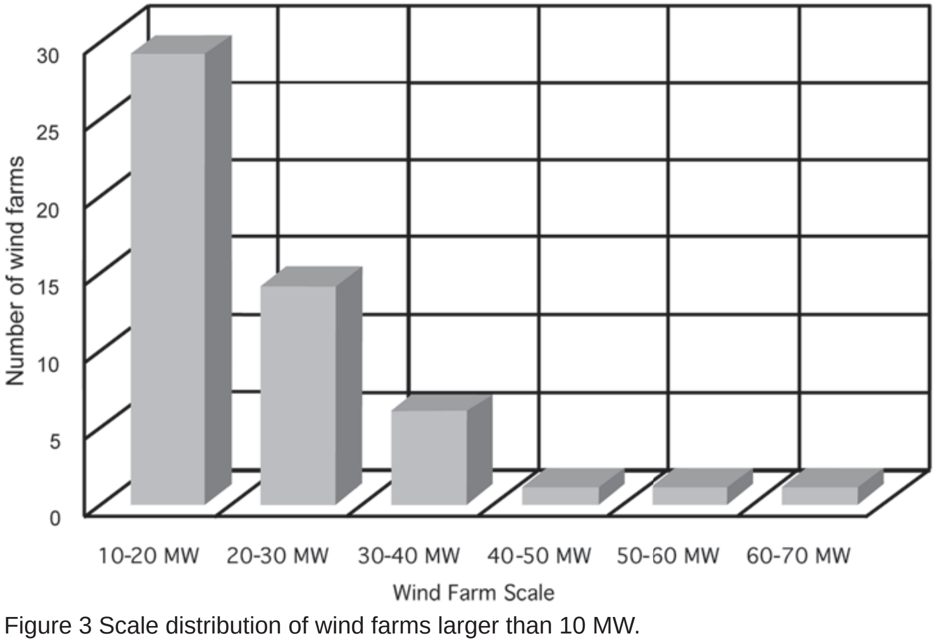


Figure 3 Scale distribution of wind farms larger than 10 MW.

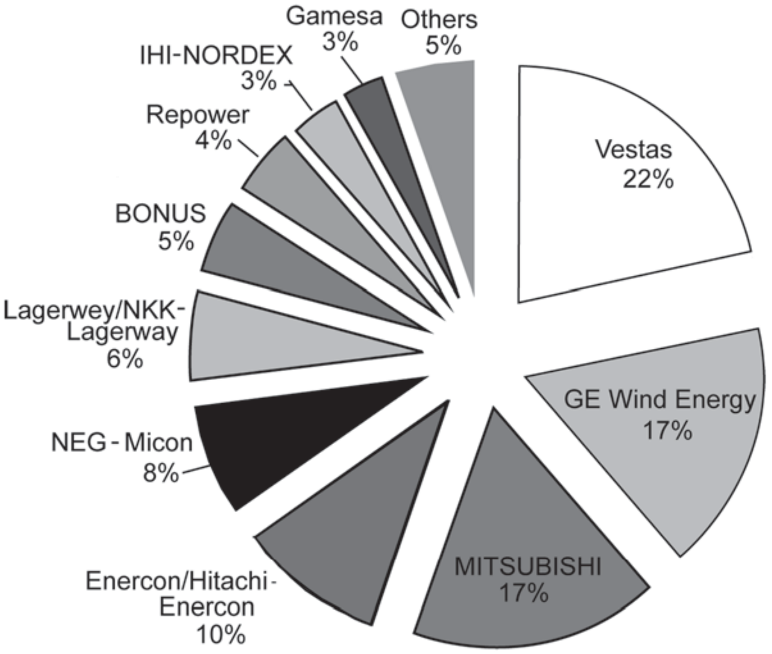


Figure 4 Share of the wind turbine manufacturers in capacity.

Figure 5 JSW' turbines J70 and J82 at Muroran.

The Japan Steel Works Co. Ltd. (JSW) has developed a new 2-MW, 82.6-m gearless wind turbine with a permanent magnet synchronous generator. The turbine began operation in September 2007 in the JSW Muroran plant, where the first 2-MW, 70.6 m wind turbine with same design has operated since June 2006 (Figure 5). These turbines were developed to be suitable for Asian/Japanese weather conditions, especially typhoons and high-energy lightning conditions. JSW plans to install more than 100 units by 2009.

Komai Tekko, Inc. has developed the KWT300 wind turbine specially designed for Japanese external conditions. The design turbulence intensity is 0.20, which is better than the IEC class I value of 0.18. The survival wind speed is 70 m/s. Therefore, the KWT300 has potential for typhoon areas, mountainous sites, or remote islands where standard turbines have had some difficulty surviving. It could also have potential overseas where the external conditions are similar to those of Japan. The prototype of the KWT300 has operated more than one year at the Futtu site facing Tokyo Bay (Figure 6). During that time, various technical measurements have been taken.

Table 2 Main Commercial Wind Turbines		
Manufacturer	Wind turbine	Technical characteristics
Mitsubishi Heavy Industries (MHI)	MWT92	P=2.4 MW, D=92/95 m, 3 bladed, Upwind Smart yaw control
Fuji Heavy Industries Ltd. (FHI)	SUBARU 80/2.0	P=2 MW, D=80 m, 3 bladed, Downwind
The Japan Steel Works, Ltd. (JSW)	J70/J82	P=2 MW, D=70.65/82.6 m, 3 bladed, Upwind
Komai Tekko Inc.	KWT300	P=300 kW, D=33 m, 3 bladed, Upwind Iref=20 %
Zephyr Corporation	Airdolphin	P=1 kW, D=1.8 m, 3 blades, Upwind Cut-in/Cut-out wind speed=2.5/50 m/s

Information regarding Mitsubishi Heavy Industries (MHI), Fuji Heavy Industries Ltd. (FHI), and Zephyr Corporation - including the technical details of MWT92, SUBARU 80/2.0 and Airdolphin - can be found in the *2006 IEA Wind Energy Annual Report*.

The Wind Power Field Test Program was carried out for 11 years from 1995 to 2005 by NEDO (New Energy and Industrial Technology Development Organization) and supported by the government. This program played an important role in introducing wind turbine generation systems into practical use at various sites all over Japan. One year of wind measurements were taken at 439 sites. Wind power plants were installed at 31 of the promising wind sites where operation tests continue. Figure 7 shows the relationship between the annual wind speed and the capacity factor at various sites analyzed by NEDO and CTC (Itochu Techno-solutions Corporation) in 2007. Each plotted mark is based on a one-year data set. Large wind farms, which are usually located at better wind sites, were not included in the Field Test Program. However, we can see that the capacity factor depends on the annual mean wind speed.

Figure 6 KWT300 Prototype at Futtu.

3.3 Economic details

In general, the cost of a wind power plant is higher in Japan than in the EU countries where wider grid systems are well developed. In Japan, additional costs for grid connection/stability are required. Several years ago, it was reported that the average cost of energy (COE) for a 25-MW wind farm was 10.20 JPY/kWh with subsidy. Generally, the COE is from 9.00 to 11.00 JPY/kWh for medium-sized wind turbines (unit capacities between 500 kW and 1,000 kW). For large-scale wind farms using wind turbines with

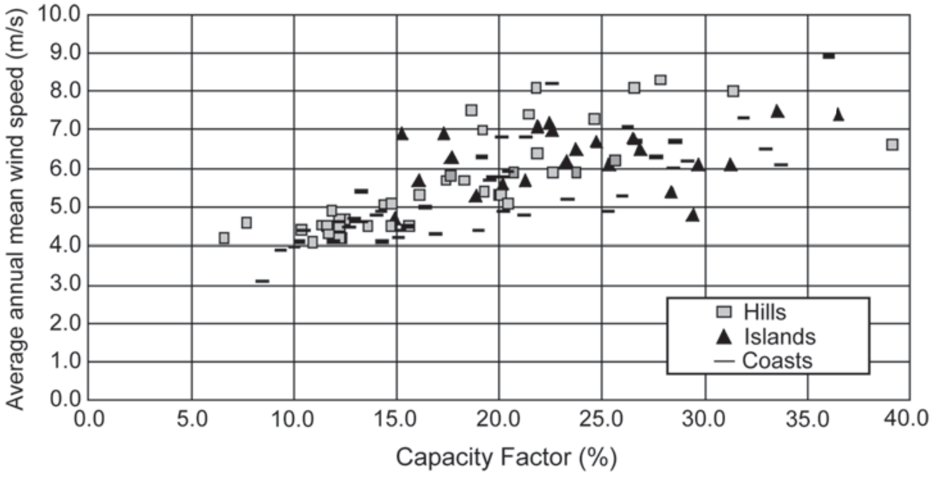


Figure 7 Statistics of operation data under field test program.

capacities of more than 1,000 kW, COE is in the range of 7.0 - 9.0 JPY/kWh.

In recent years, the cost of a wind turbine was approximately 100,000 JPY/kW and the average initial cost was estimated at 190,000 JPY/kW (2003). However, in 2007 wind turbine costs increased by approximately 80%, where 50% of the cost increase was caused by a worldwide price rise and 30% was due to a decreased exchange rate between the Euro and the Yen. This is because more than 80% of wind turbines are imported from Europe and the United States.

The electricity purchase price for private wind farm developers ranges from 7.0 JPY/kWh to 20.5 JPY/kWh. A weighted average is 11.6 JPY/kWh.

4.0 National Incentive Programs

Since national wind energy R, D&D programs were closed in fiscal year 2002, most government incentive programs for wind energy are in the form of subsidies for wind plant developments and investigations on grid issues. This resulted in a large-scale investigational program on grid issues, "Demonstration of grid stabilization with battery backup system." Meanwhile, Japan experienced much damage to wind turbines caused by typhoon winds and lightning strikes. This established the need for investigations on J-class wind turbine technology against such extremes. Therefore, technical investigations for a J-Class Wind Turbine Guideline and for offshore wind development began.

The governmental incentive programs under the Ministry of Economic Trade and Industry (METI) in fiscal year 2007 are summarized in Table 3. Budgets were 1,071.4 million JPY for R, D&D and 27,012.7 million JPY for subsidies, for a total of 28,084.1 million JPY. The main support and market stimulation incentives were mostly subsidies and were conducted by NEDO and the Japan Electrical Manufacturers Association (JEMA).

5.0 R, D&D Activities

5.1 National R, D&D efforts

The J-Class Wind Turbine Guideline is a very important research program. It aims to develop guidelines for wind turbines and their development so that they will stand against severe external conditions such as typhoons, high gusts, high turbulence, and lightning strikes. The guidelines are being developed by taking actual measurements of wind characteristics and mechanical loads of turbines at several wind plant sites over Japan with combined CFD (Computational Fluid Dynamics) work. The final report including these guidelines will be published in March 2008. These guidelines will be proposed to be incorporated into the IEC 61400-1 standards within IEC S-wind turbine class. This will make the results of the research available to regions worldwide where meteorological and topographical conditions are similar to those in Japan.

Table 3 Japanese National Incentive Programs*				
Type	Program	Purpose	Category	Budget (million JPY)
R, D&D (METI)	Field Test program	Wind resource measurements	Wind	140.8
	J-Class Wind Turbine Guideline	Develop J-Class Wind Turbine Guideline for technical measures against typhoons, gusts, high turbulence, and lightning.	Wind	124.2
	Demonstration of Grid Stabilization	Demonstrate grid stabilization technology with battery backup system at wind farms; develop new technology to predict short-term wind generation using CFD technology	Wind	201.6
Subsidy (METI)	New Energy Business Support Program	Subsidize business development of generation plant for initial cost (maximum 30%)	New energy	31,584.0
	Regional New Energy Development Stimulation Program	Subsidize local new energy development of generation plant for initial cost (maximum 30% for local authorities; 50% for nonprofit organizations)	New energy	4,465.0
	Measures for Grid Connection	Subsidize technical measures for grid connection for wind power plants	Wind	1,636.6
Committee	Wind Turbine Accident Investigation Committee	Investigate accidents, draw future load map, and discuss measures to improve availability	Wind	
	Wind Technology Standards	Develop IEC and JIS standards and investigate certification system	Wind	
	Wind turbine design; guidelines against extreme winds	Conducted by Japan Society of Civil Engineers (supported by the Ministry of Land, Infrastructure and Transport)	Wind	
*Data courtesy of METI and NEDO				

Technical developments are also proceeding with the study of a grid stabilization system with battery backup. The system is being demonstrated on a wind farm. The program will be completed in March 2008. Some priority is being given to battery-backup wind power plants in the process of granting subsidy support.

5.2 Collaborative research

Since 1988, Japan has been involved in IEC activities aimed at establishing international standards for wind turbine technology. GWEC Japan (Japanese Wind Energy Association and Japanese Wind Power Association) has been cooperating as a member of the Global Wind Energy Council (GWEC) since March 2005.

Author: Hikaru Matsumiya, National Institute of Advanced Industrial Science and Technology, Japan.

Chapter 21
Republic of Korea

1.0 Introduction

In 2007, the first domestically produced 750-kW and 1.5-MW turbines were introduced to the Korean market, while the 2- to 3-MW turbines were still under development and scheduled for field testing over the next two years. So far, progress in the Korean wind market has been a little behind schedule. At the end of 2007, the cumulative installed capacity was 193 MW (Table 1). Even though there is a national campaign with incentive programs for new and renewable energy sources, the added installation capacity of only 18 MW of wind in 2007 indicates the presence of some difficulties and barriers. These barriers include complex terrain at onshore sites and serious public acceptance issues.

The Korean wind generation capacity target of 2,250 MW by 2012 is a very ambitious goal. The local electric generating power companies that have been split from the Korea Electric Power Corporation (KEPCO) entered the wind farm market by making an agreement with the government to diversify their generating sources and include new and renewable sources. The Korean government will set the new policy by implementing the RPS and providing strong support for R, D&D into offshore sites. This is expected to accelerate growth in the future. The official data used in the following tables and this report were provided by the New and Renewable Energy Center under the Korea Energy Management Corporation (KEMCO).

2.0 Progress Toward National Objectives

At the end of 2007, there were 127 wind turbines operating in Korea. According to the 2003 government installation target as set in The Second Basic Plan for New & Renewable Energy Technology Development and Dissemination, an additional 2,057 MW of wind energy capacity is needed from 2007 to 2012 in order to reach the target. In the plan, the portion of offshore capacity is 675 MW or 30% of the total 2,250 MW by 2012.

3.0 Benefits to National Economy

3.1 Market characteristics

The second National Energy Basic Plan states that the share of new and renewable energy of primary energy consumption will be 3% in 2006 and 5% in 2011 respectively. For the electricity supply target, wind generation is expected to provide the largest contribution (up to 25% or 5.2 TWh) of the total generation 20.5 TWh by new and renewable sources in 2011. To achieve this goal, the government is providing attractive incentive programs such as the 15-year guaranteed feed-in tariff, tax incentives, and subsidies for the local wind market. Encouraged by the strong government support of R&D programs, several big companies have been participating in wind turbine development projects including component localization. In 2007, as a result of government support in previous years, 750-kW and 1.5-MW wind turbines have been successfully tested and certified by GL and DEWI-OCC respectively.

The Korean wind farm business is still behind schedule and has been slow so far for several reasons. These reasons include the complex system for approval of developments caused by the conflict among existing laws, public acceptance issues, and difficulty in getting permits for grid connection. Also sites are limited because of mountainous onshore characteristics. Coping with all these barriers, more than 550 MW of capacity is currently under development (scheduled through 2009) according to construction permit statistics at the end of 2007.

Table 1 Key Statistics 2007: Korea	
Total installed wind generation	193 MW
New wind generation installed	18 MW
Total electrical output from wind	399 GWh
Wind generation as % of national electric demand	0.1%
Target:	2,250 MW by 2012

Table 2 Total Installed Wind Capacity in Korea								
Year	~2001	2002	2003	2004	2005	2006	2007	Total
Capacity (MW)	7.9	4.7	5.4	50	30	77	18	193
Electrical Output (GWh)	32	15	21	48	130	239	399	884

The onshore wind map feasibility study performed by the Korea Institute of Energy Research (KIER) estimates the potential for wind farm development at up to 7.8 GW. In addition to this onshore possibility, the government is supportiing an offshore wind map study to determine the expansion potential and take advantage of being a peninsula country. However, offshore wind construction might be challenging due to deep-sea foundation issues, concerns over coastal fishery rights, military radar issues, and environmental issues.

3.2 Industrial development and operational experience

The Korean wind industry is still in its development stage, having only recently gained experience with wind energy – developing turbines and components, constructing wind projects, and operating wind farms. One major private developer in Korea, Unison, operates the two biggest wind farms accounting for 138.6 MW. Unison installed imported wind turbines from VESTAS and contracted for O&M with this foreign manufacturer. Unfortunately, Unison experienced a long-term shut down of several wind turbines during commissioning because defective parts had to be re-imported and delivered to the project. This kind of problem is one reason why local manufacturers and developers are accelerating their efforts to supply the local market and building up in-house technical expertise.

The Korean market was initially formed by companies such as Unison, Hajin, Doosan Heavy Industries, and Hyosung Heavy Industries. The formation of the industrial value-chain or supply-chain for the wind business has been based on the existing infrastructure of utility companies, major ship building heavy industries, and their components sub-contractors. Taewong, Pyongsan metal, and Hyunjin materials hold the biggest share of the world market for hot forging metal parts such as main shafts, tower flanges, and bearing rings. They are exporting major wind turbine components to Vestas, Enercon, Gamesa, GE Wind, and others. About a half of the world's market for wind turbine towers is also covered by the Korean companies Unison and Dongkuk S&C. Recently, new players such as Hyundai Heavy Industries, Samsung Heavy Industries, and STX engine are entering the market in Korea, with megawatt-scale wind turbines.

4.0 National Incentive Programs

According to the Korean Second Basic Plan, except for energy from wastes, wind energy will supply the biggest portion (9.8%) of the final target for new and renewable sources. In order to achieve this goal, the feed-in tariff system is the most important of the government's incentive policies. Wind generation is eligible for a 15-year feed-in tariff of 107.29 Won/kWh that is scheduled to be reduced by 2% every year after October 2009.

The government also provides subsidies up to 70% to local governments if demonstration projects or stand-alone small wind installations are less than 10 kW. For the installation of a new and renewable facility, 1/10 of the cost is deductible from income or corporation tax for the year. Also, an import tariff rate reduction is applied for stand-alone or grid-connected wind generators and blades. The government also compensates any loss to commercial banks up to a certain portion when long-term project financing to renewable energy construction is offered at lower than commercial rates. A single renewable construction facility can make a proposal to KEMCO for a maximum of 20 million USD that is payable over ten years following an initial five-year grace period.

5.0 R, D&D Activities

A strategic approach called Selection and Concentration has resulted in the selection of PV, wind power, and hydrogen/fuel cell technologies as cost-effective investments. The national goal is for wind technology to be raised from the current 60–70% level compared to the developed European countries up to about 90% by 2011.

The government's annual budget for wind R, D&D in 2007 was 17.8 million USD, and has been aimed at localizing the manufacturing of MW-size wind turbine systems and their components. Recent government research has been carried out to develop 2-MW onshore and 3-MW offshore turbine models. The research program is also running a 4-MW offshore demonstration project that will be realized in 2009.

This significant government funding has helped establish a wind generator manufacturing industry that can compete with foreign players. Unison developed a 750-kW gearless permanent-magnet generator turbine and Hyosung developed a geared doubly-fed induction generator. Hanjin took a further step by introducing a 1.5-MW wind turbine to the local market. Unison also has developed a geared 2-MW turbine adopting the permanent-magnet generator (Figure 1), while Hyosung devoted itself to a 2-MW geared doubly-fed induction generator wind turbine (Figure 2). Both 2-MW prototypes will be type tested during 2008. Doosan Heavy Industries & Construction, a giant EPC company in power and desalination plants, has been developing a 3-MW offshore model and is scheduled to fabricate the prototype by mid 2009. This type class Ia turbine adopts an integrated lightweight three-stage gearbox to reduce top head mass. It is equipped with a permanent-magnet generator. The mass production of this turbine is expected during 2010 after successful field testing.

To satisfy recent requests from the wind industry for increased research infrastructure and education programs, the government launched several sponsored programs. The Wind Turbine Technology Research Center aims to develop core technology and infrastructure with industries while training field engineers and technicians. The National Wind Research Laboratory and the Graduate School for Wind Energy are dedicated to research-oriented education programs for the next five years under an initial contract.

6.0 The Next Term

During the next few years, the government is willing to support the installation of domestically manufactured 750-kW and MW-class wind generators as demonstration projects. This support should help local manufactures to install their turbines more widely in several places. Government R, D&D support will also be focused on speeding up the localization of

Figure 1 The Prototype of Unison's 2-MW PMSG wind turbine, U88.

Figure 2 The Hyosung's HS90 2-MW wind turbine.

important turbine components like gearboxes, pitch and yaw systems, and bearings.

The Wind R, D&D Strategy for 2030 published by KEMCO in November 2007, was based on a survey of major developers. The long-term projection for installed wind generating capacity was estimated at about 2,000 MW by 2012, 8,000 MW by 2020, and 14,000 MW by 2030. These numbers comply with the government target of 2,250 MW by 2012. However, all the barriers mentioned above tend to slow down developing and planning onshore wind farms, which is forcing the Korean government also to set up new incentive programs to stimulate offshore possibility.

Authors: Jong-Deuk Ahn, Korean Energy Management Corporation and Chinwha Chung, Pohang Wind Energy Research Center, Republic of Korea.

Chapter 22
Mexico

1.0 Introduction

According to the official document, "Prospective of the Electric Sector in Mexico for the period 2007 to 2016," published by the Secretariat of Energy, by the end of 2010 the installed wind energy capacity should reach around 2.2 GW. More than a few official documents recognize that Mexico's most important wind resource would be sufficient for the installation of at least 5 GW of wind power. In a May 2005 topical workshop, the most important promoters of wind power in Mexico agreed to a shared vision of 6% of wind power penetration at the national level for the year 2030. The workshop included representatives of the secretariats of energy, environment, and economy, as well as representatives of the Federal Electricity Commission (CFE), the National Chamber of Electrical Manufacturers, the Mexican Wind Energy Association, and the major research and academic institutions.

Continuous lobbying to formalize strategic goals in both legislative and planning instruments achieved encouraging results. By the end of 2006, CFE commissioned an 83.3-MW wind power plant. For the period 2007 to 2010, CFE has programmed the construction of five wind power plants rated at 101 MW each; this additional capacity will be built in the Independent Power Producer modality. Permits, as well as electricity transmission commitments, have already been agreed upon between the public and private sectors for installing 1,583 MW of wind power capacity within the period 2007 to 2010. By mid 2007, the Spanish company Iberdrola began construction of the first privately owned wind power plant. In May 2007, the government of Mexico issued a National Strategy on Climate Action that includes a goal for installing 7 GW of electricity generation from renewable energy (not considering large hydropower plants).

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 at 30 meters above the ground. Given the favorable characteristics of this region, particularly its topography, it is estimated that more than 2,000 MW of wind power could be commercially tapped there. In fact, a 1.6-MW pilot plant located in one of the best sites in the region (La Venta), has operated for slightly more than ten years at annual average capacity factors ranging from 30% to 40%. This compares favorably with capacity factors of wind power plants located in the best inland sites in the world.

National consumption of electricity is expected to increase at an average annual rate of 4.8% for the period 2007 to 2016. This growth results in a projected requirement of 318 TWh of electricity generation for 2016, representing an increase of 110 TWh and the equivalent of around 21 GW of additional generating capacity. Of this, 5 GW are already under construction or planned, the majority using combined-cycle gas-turbine technology, in addition to several new hydro and geothermal plants. The remaining 16 GW will come from new projects. An opportunity niche therefore exists for supplying a reasonable portion of the uncommitted 16 GW of new capacity using Mexico's wind energy resource.

Table 1 Key Statistics 2006: Mexico	
Total installed wind generation	85.2 MW
New wind generation installed	0 MW
Total electrical output from wind	248 GWh
Wind generation as % of national electric demand	0.12
Target:	2.2 GW by 2010 to 2011* 6% of electric generation by 2030**
* From official projections **Shared vision from 2005 workshop	

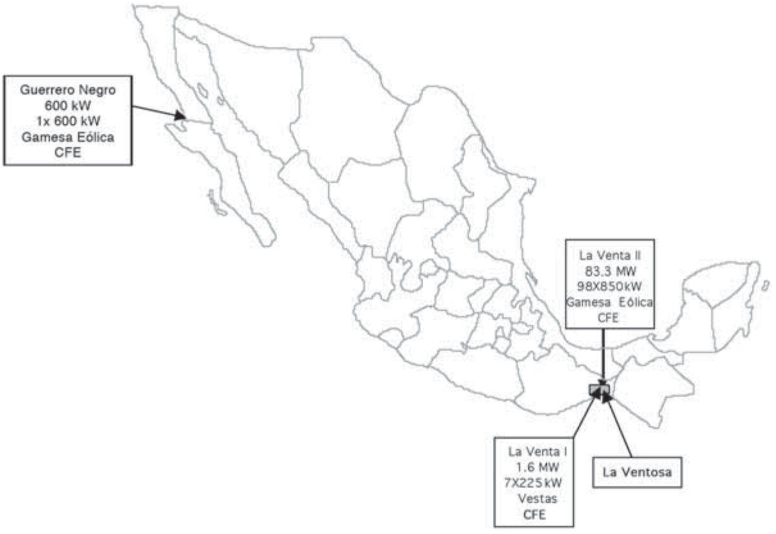


Figure 1 Location of wind turbines installed in Mexico by December 2007.

2.0 Progress Toward National Objectives

At present, it is clear that both the energy and the environmental policies in Mexico consider renewable energy to be a fitting way for diversifying energy supply within a sustainable development framework. In May 2007, the government of Mexico issued a National Strategy on Climate Change that includes a goal for installing 7 GW of electricity generation from renewable energy (not considering large hydropower plants). The National Strategy on Climate Action was prepared by a National Committee for Climate Change that included representatives of seven ministries. A recommendation of this committee was to increase the strategic goal for renewable energy generation to more than 8% of national electricity consumption.

2.1 Strategy

One of the main official instruments aimed at including renewable energy in Mexico's electricity generation mix is the initiative called the Law for the Use of Renewable Energy, approved in December 2005 by the federal congress. Unfortunately, this initiative is still pending in the senate. It includes the creation of a green fund to improve the economic feasibility of renewable energy projects under current constitutional and legislative mandates. The green fund would grant a price premium for electricity generation (kilowatt-hours) from renewable energy. The initiative obligates the national electrical system to take the electricity from renewable energy at any time of generation. A transitory article introduces a strategic goal of 8% of penetration from renewable energy for the year 2012, not including large hydropower plants. It also instructs official institutions to formulate and issue regulations, programs, methods, and any other necessary instruments.

By the end of 2003, the Electrical Research Institute (Instituto de Investigaciones Eléctricas, IIE) and the United Nations Development Program (UNDP) received sponsorship from the Global Environmental Facility (GEF) for the project Action Plan for Removing Barriers to the Full-Scale Implementation of Wind Power in Mexico. The project began in January 2004. It addresses capacity building, wide promotion of wind energy at the national and regional levels, human resource development, strategic studies (including those for supporting the recognition of the capacity credit of wind power), and assessment of the wind energy resource in promising areas. It also includes the analysis and formulation of proposals for improving the legal, regulatory, and institutional framework for the implementation of wind power. Construction of a Regional Wind Technology Center is another goal of this project. This project organized the workshop mentioned previously, during which the major promoters of wind power came to a consensus on the shared vision of the implementation of wind power for the year 2030 and the paths to reach it. The implementing agency for this project is the UNDP; the prime mover and execution agency is IIE.

By the end of 2006, GEF approved Mexico for a sponsorship for the first phase of a more extensive project originated by the Secretariat of Energy (Sener): the Large Scale Renewable Energy Development Project. The World Bank will be the implementing agency. This project focuses on launching an IPP renewable energy market by creating a transitory green fund targeted to complement regulated buyback prices for renewable energy.

2.2 Progress Toward national targets

By the end of 2006, CFE commissioned Mexico's first significant-capacity wind power plant (La Venta II) (Figure 2). It is rated at 83.3 MW and has 98 850-kW wind turbines from the Spanish manufacturer Gamesa Eólica (Table 2). The plant is owned by CFE and was constructed under the modality of financed public work. This means that a private contractor is responsible for the financing and construction of the wind power plant, and CFE pays the contractor the total amount of the contract when the plant is commissioned. After that, CFE owns and operates the plant. La Venta II will become an important project within CFE to increase knowledge about how to merge wind power technology into the national electrical system, to gain confidence on operation and maintenance issues, and to assess direct and indirect benefits.

La Venta II was constructed in one of the windier sites in the Isthmus of Tehuantepec. It is expected to operate at annual capacity factors above 40%. The estimated cost of this plant is 1,370 USD per installed kilowatt, not including the cost of the transmission line. The contract for construction was awarded to the Spanish consortium Iberdrola-Gamesa.

Another important achievement was an agreement between CFE and several private wind project developers for the future construction of a transmission line to transmit electricity from several wind power plants planned for the Isthmus of Tehuantepec. This transmission line will remove the main technical barrier for the expected installation of around 2,000 MW of wind power in that region. Together, the Secretariat of Energy and the Energy Regulatory Commission played the principal role of mediating negotiations between the parties. Furthermore, as part of the agreement, CFE will allow the interconnection of certain wind power capacity to the existing electricity transmission network in the Isthmus of Tehuantepec. In practice, this paved the way for constructing the first privately owned wind power plants.

By mid 2007, the Spanish company Iberdola began construction of the first privately owned wind power plant, rated at 79 MW. It will be built with 93 850-kW wind turbines from the Spanish manufacturer Gamesa Eolica. The wind turbines are already in Mexico; the foundations

Figure 2 La Venta II 83.3-MW windfarm on the Isthmus of Tehuantepec, Mexico.

Table 2 Wind Turbine Installations in Mexico by the End of 2007					
Location	Manufacturer	Wind turbines	Capacity (MW)	Commissioning date	Owner
La Venta, Oax.	Vestas	6 x 225 kW	1.57	1994	CFE
Guerrero Negro, B.C.S.	Gamesa Eólica	1 x 600 kW	0.60	1998	CFE
La Venta, Oax.	Gamesa Eólica	98 x 50 kW	83.3	2006	CFE
TOTAL		105	85.5		

are under construction. It is expected that the first wind turbines for this plant will be installed by mid 2008.

By mid 2007, CFE launched a call for bids to construct a 100-MW wind power plant within the Independent Power Producer modality. The bidding included a potential complement to the electricity buy-back price of around 0.015 USD/kWh that would be granted by the Global Environmental Facility, through the World Bank. Only two consortiums (both Spanish) participated in the bidding. Unfortunately, the bidding process was declared void. One of the companies was excluded during the evaluation of the technical offers while the other was excluded during the evaluation of its economic offer.

The National Commission for Energy Conservation (CONAE) issued a Guide on Official Steps for the Construction and Operation of Renewable Energy Projects, which has a specific section for wind energy. In addition, CONAE is an important stakeholder in the promotion of wind power. Within CFE, the unit New Sources of Energy has been the major promoter of wind power projects. At present, this unit is carrying out feasibility studies for evaluating new projects.

The government of the state of Oaxaca is considering the implementation of wind power in the Isthmus of Tehuantepec as a strategic project to improve regional development. To this end, since 2000, the government has organized the annual Colloquium on Opportunities for the Development of Wind Power in the Isthmus of Tehuantepec. So far, this has been the most important forum on wind energy at the national level. Governments of other states are also promoting the implementation of wind power at the local level.

The Mexican Association of Wind Power (AMDEE), constituted in 2005, became an important stakeholder in the negotiation and lobbying of legislative and regulatory instruments. All the members of this association are promoting their own wind power projects. In addition, the National Solar Energy Association (ANES) continued more than 15 years of work promoting renewable energy.

3.0 Benefits to National Economy

3.1 Market characteristics

The wind power market in Mexico is just now at its early stage, and negotiations between interested parties are still in progress. The major companies of the industrial sector are very interested in electricity self-supply projects based on wind power, and several companies are evaluating their economic feasibility. In addition, several municipal governments, as well as organizations of the trading and services sectors, are in similar positions. Indeed, several important companies have already obtained permits to build wind power projects. Simultaneously, interest is growing in the installation of manufacturing facilities for wind turbines.

3.2 Industrial development and operational experience

During 2007, 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 248 GWh. The facilities operated at an annual capacity factor of 33.4%, according to Eng. Carlos Aguilar, the manager of the wind power plants. As mentioned previously, it was expected that the capacity factor of these plants would exceed 40%; however, there were a number of constraints regarding the availability of the transmission line.

The Mexican company Fuerza Eólica is manufacturing permanent-magnet electric generators for the U.S. wind turbine manufacturer Clipper Windpower. This Mexican company is also manufacturing a 5-kW wind turbine, primarily for export markets. Several wind turbine components—including towers, generators, gears, conductors, and transformers—could all be manufactured in Mexico using existing infrastructure. Indeed, all the towers for the new La Venta II wind power plant were manufactured in Mexico. A joint venture facility is manufacturing wind turbine blades in Mexico. More than 200 Mexican companies have the capacity for manufacturing parts required for wind turbines and for 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.

3.3 Economic details

Electricity prices to consumers vary depending on the region, time of day, and voltage. For electricity billing purposes, the country is divided into eight regions. Each region has its own timetable for electric tariffs throughout the day. Table 3 shows the average price for electricity in various sectors.

In 2007, a special buyback price for wind energy had not been set in Mexico. However, according to the commitments made between private companies within the self-supply modality, it seems that some wind energy projects in the Isthmus of Tehuantepec are reaching economic feasibility. The main constraints on wind power market development in Mexico are as follows:

- Electricity for the industrial sector is subsidized.
- The methodology for computing the buy-back price for wind energy that would come from Independent Power Producers (especially from small power producers) is not fully appropriate for reaching the point of financial feasibility for the projects (including those projected at the best windy regions).
- There is a critical need to generate a confident and stable business environment that can provide appropriate guarantees to international and national financial institutions on the viability and profitability of wind power projects.
- A long-term national program for wind power deployment does not exist.

Figure 3 La Venta II wind park, commissioned in 2006.

Table 3 Electricity Prices in Mexico, September 2007	
Sector	Average price (Mexican Pesos/ kWh)
Industrial	0.90
Agricultural	0.38
Residential	0.95
Commercial	1.96
Public services	1.49

- There is a critical need to increase awareness among some decision makers and legislators of the potential benefits of wind power.
- 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.

4.0 National Incentive Programs

In September 2001, the federal government through the Energy Regulatory Commission issued the first incentive for renewable energy. Embedded in the existing legal and regulatory frameworks, this new incentive consists of a model agreement for the interconnection of renewable energy power plants to the national electrical grid. It allows self-supply generators to interchange electricity among various billing periods (e.g., base to peak). In this fashion, self-suppliers do not necessarily have to sell surplus electricity to CFE because generation delivered to the grid during certain periods can be credited to compensate for the electricity extracted from the grid during a different period. The interchange was allowed based on the ratio of the marginal costs among various billing periods; therefore, more than 1 kWh must be generated during a base period to match 1 kWh required in a peak period.

This administrative incentive was designed to improve the economic feasibility of some self-supply wind power projects, especially those for municipal public lighting, where the plants generate a considerable quantity of electricity during the daylight period when no electricity is required. Furthermore, before this incentive, electricity transmission charges for a renewable energy self-supply project were computed based on the project's rated capacity. Today, these charges are reduced to the power plant capacity factor level. However, this incentive was not effective since capacity charges were computed based on a five-minute period. This means that if a specific wind power plant for self-supply purposes does not generate any power during just five minutes over one month, then full contracted capacity is used to compute billing charges.

During 2005, Sener, CRE, and AMDEE, with the technical support of the IIE, carried out an intensive negotiation with CFE to achieve the recognition of certain capacity credit for wind power. By the end of 2005, these participants agreed on a modification of the agreement. The modification includes the recognition of capacity credit of renewable energy technologies, based on the average capacity factor computed during the system's peak hour. The modification was issued in early 2006.

A tax incentive was issued in December 2004. The federal law for income tax (Ley de Impuesto Sobre la Renta) allows accelerated depreciation of investments in renewable technologies (wind energy is specifically included). Investors may deduct 100% of the investment in a year (1 year of depreciation). Before, investors in equipment for electricity generation were allowed to deduct only 5% in one year (20 years depreciation). The equipment must operate for at least five years following the tax deduction declaration; otherwise, complementary declarations are obligatory.

5.0 R, D&D Activities

The first demonstration project, La Venta I, a 1.6-MW wind power plant sponsored by the Mexican government, was built in 1994. In 1998, a 600-kW wind turbine was installed at Guerrero Negro. CFE operates both of these projects.

With the economic support of GEF/UNDP, the IIE is working to implement a Regional Wind Technology Centre, which aims to offer the following provisions:

- Support to interested wind turbine manufacturers for the characterization of their products under the local conditions at La Ventosa

- A means to train local technicians in the operation and maintenance of wind turbines
- An easily accessible national technology display that facilitates interaction between wind turbine manufacturers and Mexican industries, thus promoting the identification of possible shared business ventures
- A modern and flexible installation that will enable researchers to obtain hard operational data on the interaction of specific types of wind turbines with the electrical system
- A means to understand international standards and certifications (issued abroad) in order to identify additional requirements to fit local conditions
- A means to increase the playing level of national research and technology development, including joint projects or specific collaboration activities with prestigious overseas R&D institutions.

Construction of the basic infrastructure of the Regional Wind Technology Center was completed in 2007. It is the first project to receive a permit to operate as a small power producer in Mexico. However, the installation of wind turbines has been delayed because of the long delivery times for machines in the wind energy market worldwide.

The wind energy resource in several promising areas of Mexico has not been evaluated in detail. Therefore, IIE's wind power action plan includes the exploration and assessment of the wind energy resource at both known and new regions. By the end of 2007, one full year of data had been collected for 20 promising new areas. Furthermore, through a contract with CFE, the IIE carried out a feasibility study for a wind power station in the state of Baja California Sur. Also, there is increasing interest by CFE in the short-term prediction of wind power output at La Venta II. CFE is preparing a Grid Code for the interconnection of new wind power plants to the national electrical system.

6.0 The Next Term

Expectations for 2008:

- CFE will issue a new call for bids to construct a La Venta III wind power plant, rated at 101 MW (IPP modality)
- Iberdrola and partners' will complete construction and commission of the first phase of 79-MW wind power plant (Self-supply modality)
- Four private consortiums will begin construction of four new wind power plants (self-supply modality).

Expectations for the year 2009:

- Two private consortiums begin construction of two new wind power plants totaling 76 MW
- Completion of a 2,000 MW transmission line for wind power from the Isthmus of Tehuantepec.

Expectations for the years 2010 to 2011:

- CFE´s wind power installed capacity: 84.6 MW
- Independent Power Producers' wind power installed capacity (for selling the electricity to CFE): 505 MW
- Privately owned wind power installed capacity (self-supply modality): 1,583 MW
- Total installed wind power capacity: 2,176 MW.

Author: Marco A. Borja, Instituto de Investigaciones Eléctricas (IIE), Mexico.

Chapter 23
The Netherlands

1 Introduction

The new installed wind capacity in the Netherlands in 2007 was 209 MW. The total installed wind capacity reached 1,745 MW. Wind power generated 3.4 TWh of electricity or 2.9% of the total electricity consumption of 117 TWh. The Netherlands government doubled its ambition from 10% to 20% renewable energy in 2020. The second offshore wind farm Q7 of 120 MW was under construction. It is unique in the world, standing in water depths of 19 to 24 m at a distance of 23 km from the coast.

2 Progress Toward National Objectives

2.1 Progress in 2007

The production of renewable electricity decreased from 6.5% of the total electricity consumption in 2006 to 6.0% in 2007. This decrease was due to a substantial decrease of the co-firing of biomass in electricity plants. The contribution of wind electricity, on the other hand, grew from 2.35% in 2006 to 2.94% of total electricity consumption (Table 2). Wind now is the main source of renewable electricity in the Netherlands.

In 2007, the co-firing of biomass decreased from 2.67 % in 2006 to 1.47 % in 2007. The reasons probably are the decrease in subsidy levels for already existing projects per 1 July 2006, increasing prices of biomass, and the public debate about the sustainability of biomass. The decision to co-fire biomass for plant owners strongly depends on these fluctuating factors.

In 2007, 117 wind turbines were installed with a total capacity of 209 MW and 62 turbines with a total capacity of 22 MW were decommissioned. The net installed capacity in 2007 was therefore 187 MW, and the total installed capacity at the end of 2006 was 1,745 MW. Of the decommissioned turbines in 2007, 17 with a total capacity of 8.4 MW were replaced with 17 turbines with a total capacity of 24.5 MW. The net repowering effect was an increase of 16 MW (2).

2.2 Government aims and objectives

The national target for electricity is 9% of total electricity consumption from renewable electricity in 2010. After the general elections of 11 November 2006, the new Government started in March 2007. The government coalition consisting of the Christian Democrats, the Social Democrats and the Christian Union stated its ambition for energy savings and renewable energy in its coalition agreement. On September 18, the new government presented its budget for 2008 and released the document New Energy for the Climate, the work program for the project Schoon en Zuinig (Clean and Efficient). It confirmed 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% compared to 1990.

Until 2011, the government expects the growth of renewable energy to come mainly from wind energy. The estimated growth for wind on land under the MEP subsidy scheme is from about 1,750 MW at the end of 2007 to about 2,100 MW in 2008. (MEP is the Dutch acronym for Environmental Quality Electricity Generation.) An additional 2,000 MW are expected under the new Stimulate Renewable Energy (SDE) subsidy scheme. The estimated growth for wind offshore under the MEP subsidy scheme is from about 110 MW at the end of 2007 to about 230 MW in 2008. An additional 450 MW are expected under the new SDE subsidy scheme. If the ambitions are fulfilled this would be a total installed capacity of 4,750 MW,

Table 1 Key Statistics 2007: The Netherlands (1)	
Total installed wind generation	1,745 MW
New wind generation installed	209 MW
Total electrical output from wind	3.4 TWh
Wind generation as % of national electric demand	2.9%
Target:	9% Renewable Electricity in 2010

Figure 1 Q7 Offshore Wind farm installation of turbines. Photo Econcern

of which 680 MW would be offshore (Table 3). The government expects to stimulate the production of renewable energy through the MEP and SDE with 900 million € in the time frame 2008-2011 to reach these ambitions.

Under the so-called Administrative Agreement National Development Wind Energy (Dutch acronym BLOW) the departments of economic affairs, spatial planning, water management, agriculture and defense, the provincial and local authorities work together to create enough available sites. At the end of 2007, about 2,600 MW of projects were in the pipeline that fit in the provincial spatial policy, of which about 1600 MW fit in the local spatial policy. Of these were 1,330 MW in the initial project planning phase, of which about 700 MW were in the building permit phase.

The government's ambition is to more than double the capacity for wind on land by 2011 and free the way to increase the capacity after 2011. On the advise of the Chief Government Landscape Architect, a new policy is in development to make a national plan 'wind energy' with all stake-holders involved. The plan has policy-priority within the Ministry of Spatial Planning through a high official steering committee with the Ministry of Economic Affairs, Ministry of Agriculture, Ministry of Water Management and Public Works. It has four policy tracks: 1) Construction of 2000 MW of extra capacity by 2011, through advancing the projects in the pipeline; 2) Removing noise bottlenecks and conflicts of interest with radar (air traffic safety and state security), because this issue is blocking several 100 MW of potential wind projects; 3) Developing a long-term siting strategy by assigning new planning areas e.g. 'designated turbine areas' and 'turbine free areas (vides)'; 4) A new program for public involvement, through communication and integrated site planning. This national plan should be implemented between mid 2008 until 2011.

3 Benefits to National Economy

3.1 Market characteristics

3.1.1 Investments in wind energy development

Total investment in wind energy installations in the Netherlands for 2007 can be estimated at 230 million €, assuming an average investment cost for land-based wind of 1,100 €/kW for the 209 MW installed. The total investments in wind energy installations from 1989 to 2007, not corrected for inflation, is estimated at some 2,200 million €. Figure 3 shows the investments per year over the period 1989 to 2007.

Table 2 Wind generated electricity, avoided fossil fuel, and national electricity consumption

	Wind generated electricity	Primary energy savings	National electricity consumption
	[GWh]	[PJ]	[GWh]
1995	317	2.79	89,058
1996	437	3.76	92,259
1997	475	3.98	95,735
1998	640	5,32	99,292
1999	645	5.34	101,508
2000	829	6.86	104,718
2001	825	6.98	107,144
2002	946	7.98	108,452
2003	1,318	11.11	109,777
2004	1,867	15.59	112,930
2005	2,067	17.22	114,700
2006	2,737	22.46	116,237
2007	3,437	28.71	116,905
CBS	Numbers CBS final		

3.1.2 Types of owners/operators

Private enterprises own 72% and energy companies own 28% of the total 1,870 MW installed capacity from 1985 up to 2007 (of which 125 MW was decommissioned leaving 1,745 MW at the end of 2007). Private enterprises are companies in agriculture and horticulture, stock breeding, food storage, general trade; companies that own projects at, or close to the company (not agricultural); developers that own several projects at sites rented or leased from third parties; and cooperatives that are associations, foundations, or companies with relatively many small shareholders. The energy companies are Nuon, Eneco, Delta, Essent, and EPZ (3). Within the category private ownership, quite a few involve joint ventures between purely private enterprises and energy companies. An example of this is the Offshore Wind Farm Egmond aan Zee (OWEZ) that is jointly owned by Shell Renewables and Nuon and the Offshore Wind Farm Q7, that is jointly owned by Eneco and Econcern.

3.1.3 New developers

Offshore wind developers that have started the process of obtaining building permits by drawing up environmental impact statements are: WEOM (on behalf of Nuon and ShellRenewables), E-Connection, Evelop, Airtricity, Raedthuijs, Arcadis, Bard Engineering Gmbh, Eolic Power Gmbh, Global Wind Support Gmbh, and Eneco Milieu BV. Up to the end of 2006, nine developers supplied 65 inception memoranda to the Ministry for a wind farm location under rules for requesting building permits for the construction of wind farms under the Public Works and Water Management Act (4). In 2007, Eneco Milieu BV supplied another seven inception memoranda for seven locations. At the 72 selected locations, the installed capacity could be between 20 GW and 30 GW. However, because of the overlap in locations this could be at the most between 10 GW and 15 GW. If realized, it could generate approximately 30 TWh to 40 TWh of electricity yearly. This is 25% to 35% of the present electricity consumption in the Netherlands.

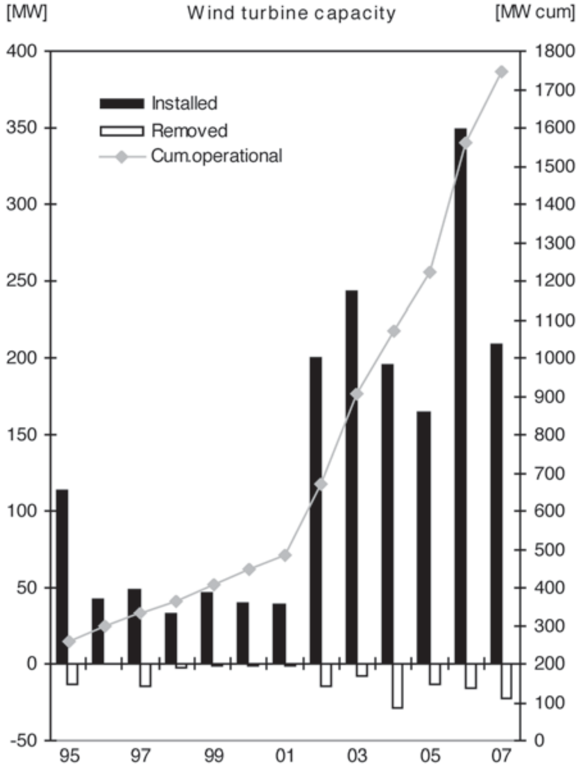


Figure 2 Installed, removed, and cumulative wind turbine capacity in the Netherlands.

Table 3 Necessary Growth of Wind Energy to Reach RE Ambitions		
Necessary growth of wind energy		Capacity
Wind on land	MEP 2007 - 2008	2,100 MW
Growth	SDE 2008 - 2011	2,000 MW
Total on land	2011	4,100 MW
Wind offshore	MEP 2007 - 2008	230 MW
Growth	SDE 2008-2011	450 MW
Total offshore	2011	680 MW
Total wind	2011	4,780 MW

In total, 15 environmental impact statements and building permits applications for offshore wind farms were supplied: two in 2005, nine in 2006, and four in 2007. In 2006, the application for a building permit for the offshore wind farm Den Haag I was declined, because of a relocation of shipping lanes foreseen by the Ministry (5). Also the applications for a building permit for the offshore wind farms Q4-WP and P12-P were declined, because the applicant supplied insufficient data for the evaluation of the application or the preparation of the permit (6). At the end of 2007, the completed environmental impact statements and building permit applications for six offshore wind farms had been open for public inspection. This implies that the Ministry will not deal with other existing or future claims of other developers for the same site,

Table 4 Ownership of Installed Wind Capacity		
Owners of installed wind capacity		
	MW	%
Agricultural companies	599	32
Companies	150	8
Developers	559	30
Co operations	46	2
NUON	222	12
Eneco	179	10
Delta	22	1
Essent	81	4
EPZ	12	1
Total	1,870	100
Private Enterprises	1,354	72
Energy companies	516	28
Total	1,870	100

unless the building permit is declined. The status of progress in applications for offshore wind farms with site rights is given in Table 5 (4).

3.2 Industrial development and operational experience

3.2.1 Manufacturing industry status

The average generation capacity per installed turbine after a sharp increase to 2,248 kW in 2006 dropped to 1,787 kW in 2007. This is mainly because fewer of the new wind farms in 2007 used 3-MW turbines compared to installations in 2006.

The average hub-height seemed to stabilize around 70 m. The installed swept area per unit of power increased again to around 2.5 m^2/kW, because only onshore turbines were installed in 2007 (Figure 5). Of the wind turbines installed in 2007, the Vestas share was 70%. Enercon's share of 36% in 2006 went down sharply to 9% in 2007. Nordex's share was 8%, Siemens 4%. Dutch company Emergya Wind Technologies came from 0% to 7% through the installation of 16 turbines of their new 900-kW 54-m diameter DIRECTWIND 900 turbines with a total capacity of 14.4 MW at Zeeland. General Electric Wind installed its prototype 2.5-MW 100 m-diameter turbine at the Energy Research Centre of the Netherlands (ECN) test site in Wieringermeer (Table 6).

Eight wind farms with an installed capacity of 10 MW or higher were installed in 2007. The largest is the wind farm in Koegorspolder at Terneuzen with 44 MW, equipped with 2-MW Vestas turbines. The second largest of 20 MW with 2-MW Vestas turbines is built along highway A27 near Almere (Table 7).

3.2.2 New products

The initial feasibility study, preliminary design, and proof of concept of an offshore access system named Ampelmann was supported by SenterNovem. The Ampelmann is a ship-based system that provides a transfer deck that stays motionless relative to the fixed world. To achieve this, the vessel is equipped with a set of motion sensors and a Stewart platform. The motions of the ship are continuously registered in all 6 degrees of freedom by the motion sensors on the deck of the vessel and instantaneously fed into a control system. The custom-made control system of the Ampelmann then calculates the required leg lengths of the six hydraulic cylinders, required to keep the top plate of the Stewart platform motionless compared to the fixed world. On this top plate, a transfer deck is installed. By extending a gangway between the transfer deck and the offshore structure, the structure can be accessed in an easy and safe way, even in high waves. On 14 December the first personnel transfer from a boat to a wind turbine took place with the Demonstrator (Figure 6). The Demonstrator project is sponsored by We@Sea, Delft University of Technology, Shell, Smit, Heerema fabrication, SMST, and Ecofys with the common goal to further develop and test its design (offshore proof), compensation performance, operational procedures and safety systems in the harsh offshore conditions of the North Sea (7).

3.2.3 Business developments

The Siemens Wind Power Division opened a knowledge centre for research and project development in The Hague on 1 October 2007. The new centre focuses on technical project

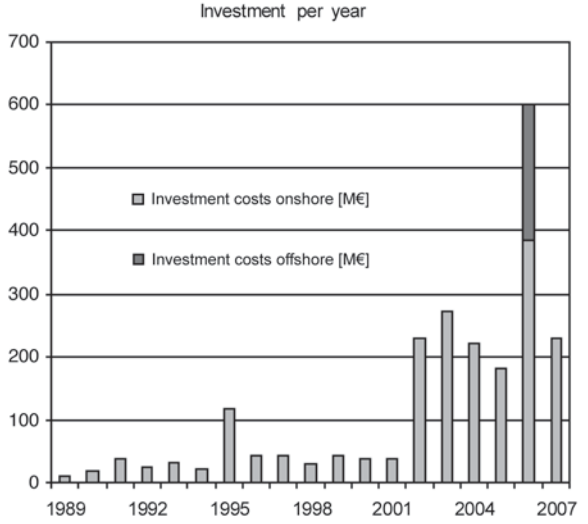


Figure 3 Investments per year over the period 1989 to 2007.

Table 5 Building Permit Applications for Offshore Wind Farms with Site Rights

Initiator	Wind farm	Area [km²]	Pmin [MW]	Pmax [MW]	Inception memo.	MER-permit app.	Inspection procedure	Draft decision
WEOM	IJmuiden	17	140	246	23-02-05	21-06-06	29-11-06	29-09-07
WEOM	Katwijk	50	400	705	23-02-05	12-05-06	29-11-06	29-09-07
WEOM	Den Haag II	43	270	480	23-02-05	22-05-06	24-01-07	29-09-07
Airtricity	West Rijn	45	250	353	23-03-05	20-05-06	29-11-06	
Evelop	Scheveningen Buiten	40	369	369	14-03-05	20-04-06	08-05-07	
Airtricity	Breeveertien II	42	300	403	07-04-05	14-11-06	12-11-07	

management of offshore wind energy projects, offshore load simulations, and installation concepts for offshore wind parks. The Hague was chosen because the Netherlands are at the centre of the European offshore wind market and because a strong knowledge base within offshore and nearshore technologies is present there. Siemens has co-operated over many years with the Delft Technical University and ECN. Siemens expects the new offshore wind energy department in The Hague to have approximately twenty employees (8).

3.2.4 New commercial applications

In September 2006, construction began on the second offshore wind farm Q7 in the Netherlands part of the North Sea. This offshore wind farm is built just outside the 12-mile zone south-west of OWEZ and has a surface area of 14 km². The 120-MW farm Q7 will consist of 60 Vestas 2-MW 80-m-diameter turbines, with a hub height of 59 m. The turbines are positioned 550 m apart. The owners of Q7 are Econcern BV and ENECO Holding NV. Investment costs are 383 million €. The electricity production will be about 435 GWh per year and will be bought by ENECO Energy Trade B.V. The farm is built by Vestas Wind Systems A/S and Van Oord Dredging and Marine Contractors BV ("Van Oord") under separate construction contracts. Initially, it will be operated by Vestas Offshore. Van Oord's installation ship Jumping Jack started piling the monopile foundations in

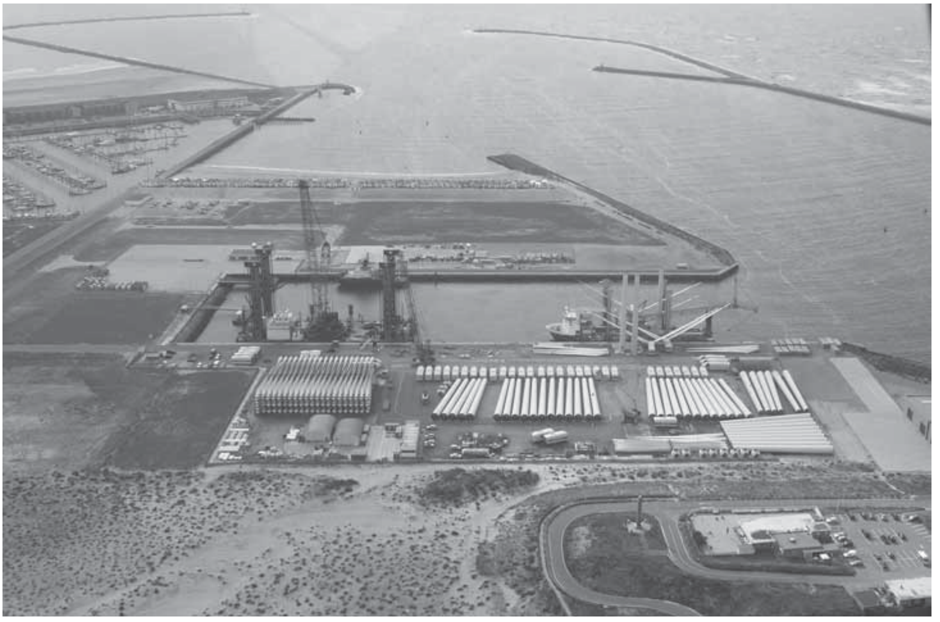


Figure 4 Q7 construction yard at IJmuiden Harbour on 27 July 2007, towers, blades, and nacelles. Photo: Jaap 't Hooft, SenterNovem.

Table 6 New Wind Turbines by Manufacturer in 2007

Manufacturer	Turbines	Installed		Rotorarea
	[-]	[MW]	[%]	[m²]
Vestas	69	146.3	70%	341,158
Enercon	15	18.9	9%	37,892
Nordex	7	17.5	8%	41,862
Siemens	7	9.1	4%	21,133
Emergya WT	16	14.4	7%	36,644
Others	3	2.8	1%	36,644
Total	117	209.0	100%	515,332

September 2006. The last pile was driven about 30 m into the sea bed early May 2007. In January 2007, the Jumping Jack was sold to A2SEA and renamed the Sea Jack. The Sea Jack placed the 22-kV/150-kV transformer station on a separate monopile on 5 May 2007 (Figure 7).

From June 2007 to September 2007 installation took place of the 22-kV sea cables for the connection of the turbines with the high-voltage substation. Also installed was the 150-kV deep sea cable with a length of 28 km that connects the substation with the shore. The sea cables include three 1-phase cables and a fibre-optic cable, which are bundled into a single, thick cable, wrapped with steel wire. The 7-km export cable on land contains three single-core cables. The export cable connects to the 150-kV distribution station of NUON's energy plant in Velzen-Noord. Of the 30 turbines that had been fully installed on 21 December 2007, seven started to deliver electricity to the Dutch national electricity grid. All 60 turbines are expected to be connected to the grid at the end of the first quarter of 2008.

Q7's financing is probably the first non recourse financing for an offshore wind farm (9). It won two awards in 2007 for its financial engineering (10).

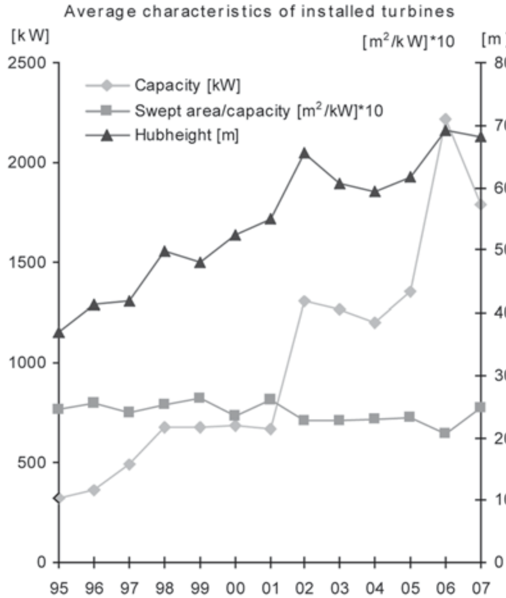


Figure 5 Annual average characteristics of installed turbines in the Netherlands.

3.3 Economic details assessed

The Ministry of Economic Affairs contracted ECN and KEMA to further assess the financial viability of the different renewable electricity production technologies. This assessment is part of an advice on the subsidy base for the new feed-in support scheme SDE as successor of the MEP. The Ministry intends to use this assessment to decide on the level of the SDE tariffs required to bridge the difference between cost and market prices (unprofitable top) for each renewable electricity source and technology for 2008. The draft assessment of ECN and KEMA on the costs for projects in the Netherlands aimed at realization in 2008 and 2009 was published in November 2007 (11). It is an update of the report from 2006 (9). The general financial and economic assumptions for the calculation in this report are given in Table 8.

In Table 8, EIA stands for the energy investment deduction scheme. Under this scheme a company is entitled to a deduction of 44% of the investment in a wind farm before fiscal profit for a maximum investment of 110 million €. The percentage of 85% for wind onshore means that it is assumed that the deduction is limited because of a limited amount of fiscal profit.

3.3.1Wind on land

Investment costs in the assessment are based on a reference case of large orders for 3-MW wind turbines. The O&M costs are seen as representative for 3-MW turbines. The imbalance costs lie around 10% to 15% of the Amsterdam Power Exchange (APX) day-ahead market prices based on a long-term electricity price of 50 to 60 €/MWh.

The maximum amount of full load hours that is eligible for subsidy is part of the SDE-scheme. The maximum of 2,200 hours is assumed, because in the past years most wind turbine projects are realized in the wind-rich parts of the country and the specific swept area per unit of capacity (m^2/kW) and hub heights have increased.

For both wind on land and offshore the ECN/KEMA report expects the electricity market price to rise from 37 €/MWh to 56 €/MWh. The calculation then leads to a base tariff of 71 €/MWh. The values are summarized in Table 9.

3.3.2 Wind offshore

The main element in this update of the 2006 report is the distinction between offshore

Table 7 Size of Wind Plants Installed in 2007						
Wind farms > 5MW	Manufacturer	Turbines	Height	Diameter	Capacity	Swept area
		[-]	[m]	[m]	[MW]	[m^2]
Terneuzen	Vestas	22	78	80	44.0	110,584
Almere-A27	Vestas	10	70	80	20.0	50,265
Amsterdam-Westpoort	Vestas	5	68	90	15.0	31,809
Sint Annaland-Tholen	Vestas	5	80	90	15.0	31,809
Rotterdam-Rozenburg	Vestas	10	78	64	14.9	32,170
Rilland	Emergya WT	16	75	54	14.4	36,644
Noord-Beveland-Rippolder	Nordex	5	80	90	12.5	31,809
Hazerswoude-Rijndijk	Vestas	4	80	90	12.0	25,447
Kats	Vestas	3	80	90	9.0	19,085
Tjerkwerd	Siemens	6	60	62	7.8	18,114
Biddinghuizen / Zeebiestocht	Enercon	3	70	71	6.9	11,878
Lopik	Vestas	3	80	80	6.0	15,080
Rotterdam-Distripark	Nordex	2	78	80	5.0	10,053
Various < 5MW	Others	-	-	-	27.2	62,692
Total					209.7	487,437

wind farms at 20 km and 40 km from shore. Regarding turbine costs, for wind farms 20-40 km offshore the ECN/KEMA report recommends a reference price of 2,200 €/kW for 2008. For wind farms at 40 km, the assumed reference price is 2,500 €/kW. Regarding O&M costs, the report recommends 80 €/kW at 40 km and 60 €/kW for a farm just outside of the 20-km zone. The full load hours depend on wind regime, rotor diameter, hub-height, and technical availability of the wind farm. For wind farms outside 20-km zone, 3,650 full-load hours is used. At 40 km, it is expected that during maintenance wind turbines will be out of operation longer, hence the full load hours will be 3,350. More full-load hours lead to lower imbalance costs. The ECN/KEMA report recommends documenting investment and operational costs at a later date. The values are summarized in Table 10. The calculations of the assessment leads to a base tariff of 107 €/MWh for wind farms at 20 km and 136 €/MWh at 40 km distance from shore.

4 National Incentive Programs

4.1 Changes in incentives programs

For the basic description of support initiatives and market stimulation instruments in the Netherlands, please refer to the *2004 IEA Wind Energy Annual Report* (12). For the update on the MEP subsidy scheme, refer to pages 185 and 186, *2006 IEA Wind Energy Annual Report* (9).

The feed-in support scheme SDE is the successor of the MEP scheme and was published

Figure 6 First personnel transfer with Ampelmann Demonstrator onto turbine of OWEZ.
Photo: Jos Beurskens, We@Sea.

Figure 7 Q7 Wind Farm turbines and transformer station on monopile.
Photo: Econcern.

by Royal Decree on 28 October (13). The SDE scheme is a flexible instrument to support the production of all kinds of renewable energy. It gives the government the ability to determine different support levels for different production technologies, e.g. wind onshore, wind offshore from 20-40 km, and wind offshore farther than 40 km. It contains provisions to allocate a maximum budget per year for each separate category. Another possibility is to issue tenders or use a 'first come first serve' basis for a separate technology. For instance the SDE scheme will make it possible to tender wind projects for a requested level of production subsidy and to evaluate projects on innovative aspects and learning effects.

In the SDE scheme, a base support level per category (renewable technology) is determined

Table 8 Financial and Economic Assumptions for Calculation Base Tariff				
Wind energy		On shore	Offshore	
			20-40 km	> 40 km
Equity share	[%]	10	50	50
Interest rate	[%]	5	5	5
Return on equity	[%]	15	15	15
Project return	[%]	6	11	11
Term of loan	[year]	15	15	15
Economic lifetime	[year]	15	15	15
Company tax	[%]	25.5	25.5	25.5
EIA	[%]	85	100	90

on the basis of average production costs. The amount of support per kWh which a producer receives varies yearly by decreasing the base support with a correction. This correction is based on the monetary value per kWh, determined yearly, based on the revenue per unit of production (e.g. average market price of electricity, guarantees of origin, and CO_2 emission rights) and the base electricity price per kWh determined by the Ministry. Like in the MEP scheme the amount of subsidy in the SDE is determined on the basis of the difference between costs and yields (unprofitable top). The main difference is that in the MEP scheme the in-advance expected unprofitable top applies, whereas in the SDE scheme, the subsidy base consists of the afterward-realized unprofitable top. This is illustrated in Figure 8.

We assume that the base tariff for wind on land is 71 €/MWh and that the average market price of electricity varies throughout the 15-year subsidy period according to the curved line. Further we assume that the base electricity price is determined at 50 €/MWh. The subsidy tariff in a given year is then the base tariff decreased with the average market price of electricity e.g. in the year 2011 it would be 15 €/MWh. During years with average market prices lower than the base electricity price the subsidy tariff is the base tariff decreased with the base electricity price, e.g in the years 2013 to 2015 it would be 21 €/MWh. During years with average market prices higher than the base tariff, the subsidy tariff is zero.

At the end of 2007 the market was anxiously waiting for the publication of the final subsidy levels and other details of the SDE in Ministerial executive regulations.

4.2 Impacts of incentive programs

The effect of the announcement of change in the MEP tariffs in the beginning of 2006 was that many developers hurried to file applications before 1 July 2006, and this resulted in a large number of wind projects in the pipeline to be installed by the end of 2008. From this pipeline the effect in 2007 was that 209 MW of wind capacity was installed under the MEP scheme.

5 R, R&D Activities

5.1 National R&D efforts

5.1.1 RD&D priorities

The EOS-LT R&D program aims at research that strengthens the Netherlands' knowledge position and clears the way for the introduction of innovative energy technologies. For wind offshore, it concentrates on two things: generating knowledge for design of wind conversion systems to make offshore wind electricity competitive with fossil fuel based electricity in 2020 and integrating 6,000 MW of offshore wind capacity in the Netherlands electricity grid in an economic, reliable, and stable manner.

The ECN wind research program concentrates on the research areas of aero elasticity; condition monitoring and measurement techniques; control technology; wind farm aerodynamics; and decision support models for maintenance and operation.

The Consortium We@Sea develops knowledge and skills to built, exploit, and decommission large-scale offshore wind farms. The

Table 9 Technical and Financial Parameters for Wind Onshore		
Wind onshore		2008-2009
Investment costs	[€/kW]	1100
Full load hours	[h/yr]	2200
Fixed O&M costs	[€/kW]	39
Electricity price	[€/MWh]	56
Imbalance costs	[€/MWh]	6
Base tariff	[€/MWh]	71

Table 10 Technical and Financial Parameters of Wind Offshore			
Wind offshore		2008-2009	2008-2009
		20-40 km	40 km
Investment costs	[€/kW]	2200	2500
Full load hours	[h/yr]	3650	3350
Fixed O&M costs	[€/kW]	60	80
Electricity price	[€/MWh]	56	56
Imbalance costs	[€/MWh]	4	4
Base tariff	[€/MWh]	107	136

research lines include: offshore wind power generation; spatial planning and environmental aspects; energy transport and distribution; energy market and finance; installation, operation, maintenance, and dismantling; education, training, and knowledge dissemination; and the PhD@Sea project.

For a complete description of the Netherlands research priorities refer to *2006 IEA Wind Energy Annual Report* (9).

5.1.2 Interesting new research efforts

Smart Rotors

About four years ago, Delft Technical University (DTU) started preliminary research work on smart rotors. The successor of this work is now part of the Dutch INNWIND and the EC UPWIND projects. The research work was discussed extensively during the IEA Wind Task 11 Expert Meeting at DTU in December 2006. The objective of smart structures for rotor blades is to alleviate significant blade loads by applying spanwise-distributed load control devices without incurring lower reliability or higher maintenance. DTU concentrates on the investigation of concepts, feasibility, and integrated design; aerodynamics; structural integration; control, identification, and experimental investigation of developed models. In summer 2007, DTU proved the concept in their wind tunnel. Figure 9 shows the model blade with a pitch actuator at the top and two trailing edge flaps actuated by piezoelectric actuators. The blade is pitched in various modes, and the flaps are activated by the controller to keep blade root bending moment constant. Researchers observed load reductions between 70% and 90% and concluded that up to 60% of fatigue blade load alleviation is possible (14). In the spring of 2008 DTU will carry out a rotating experiment with a 2 meter diameter wind tunnel model in their new Open Jet Facility. 'Smart rotors' is one of the most exiting research lines in wind energy nowadays.

Materials/Soft plastics

Another research line at DTU is the development of sustainable vacuum infused thermoplastic composites for MW-size wind turbine blades. In a paper (16) on the Preliminary Design and Manufacturing Issues, DTU addressed the feasibility of using innovative vacuum infused anionic polyamide-6 (PA-6) thermoplastic

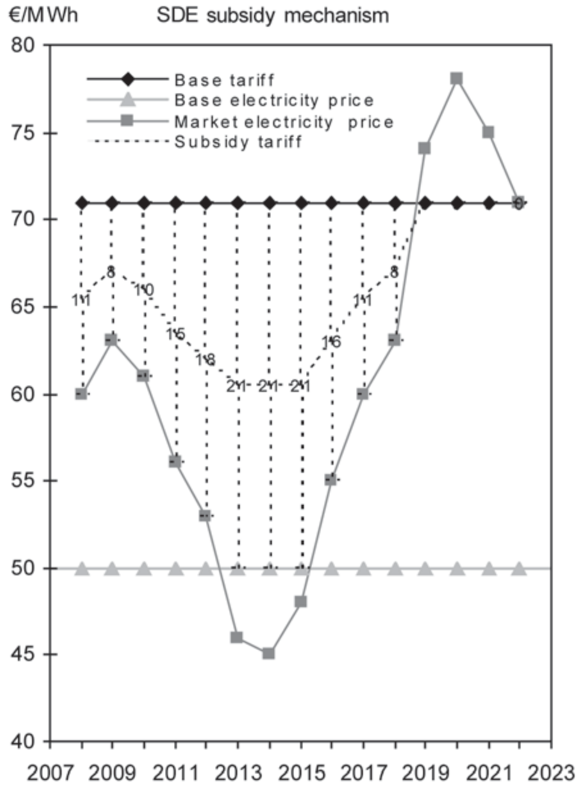


Figure 8 Example of SDE subsidy mechanism.

composites for MW-size wind turbine blade structures. They compared the performance of this recyclable material against commonly used thermoset blade materials in a baseline structural MW-size blade configuration (box-spar/skins). Four different blade composite material options were investigated: glass/epoxy, carbon/epoxy, glass/PA-6, and carbon/PA-6. Blade characteristics such as weight, cost, and natural frequencies were compared for rotor blades ranging between 32.5 and 75 m in length; the blades were designed according to both stress and tip deflection criteria. Results showed that the PA-6 blades have similar weights and natural frequencies when compared to their epoxy counterpart. For glass fibre blades, a 10% reduction in material cost can be expected when using PA-6 rather than epoxy, while carbon fibre blades costs were found to be similar. Regarding manufacturing, processing temperatures of PA-6 are significantly higher than for epoxy systems; however, the associated cost increase is expected to be compensated for by a reduction in infusion and curing time.

5.1.3 Interesting completed research

5.1.3.1 Results of the ECN program.

MEXICO

On 13 December 2006, researchers tracked wind turbine vortices in the Dutch German wind tunnel. The measurements on the 5-m model were done by researchers from ECN, DTU, the Swedish Defence Organisation (FOI), and the KTH of Sweden as part of the EC MEXICO project, for which ECN was the coordinator. They measured precise pressure distributions and air flows around the blades. They also measured the precise location of vortices and their size and speed with Particle Image Velocity techniques. A clear picture of the flow structure in the direct neighbourhood of a vortex is taken from the final report and shown in Figure 10. The horizontal projections of the streamlines are shown. The vortex position shown is at approximately 0.12 D behind the rotor. In the graph, the colours map the values of the axial velocity component. Its values are close to 15 m/s in the

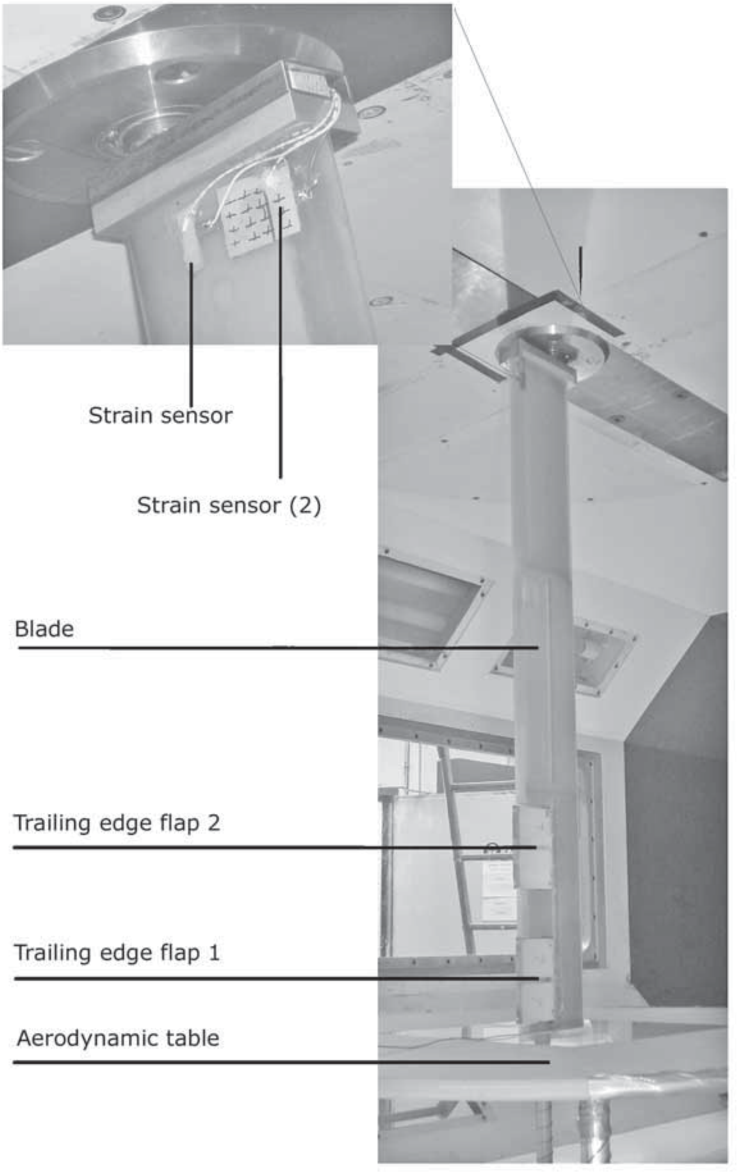


Figure 9 'Smart' blade in wind tunnel with trailing edge flaps, strain sensors and pitch actuator (15).

bottom of the graph (outer flow) and about 10 m/s in the top part (wake flow).

The most important results from the project include: an extensively instrumented wind turbine model, which can be used for future wind tunnel experiments and/or field experiments; a 100-Gigabyte database of unique detailed aerodynamic measurements on a representative wind turbine model; and important new insights on the flow field around the rotor which will help to validate and improve aerodynamic wind turbine models. The PIV traverses in axial direction allowed a detailed appraisal of the development of the induction upstream and downstream of the rotor. For the report refer to the website of ECN (17).

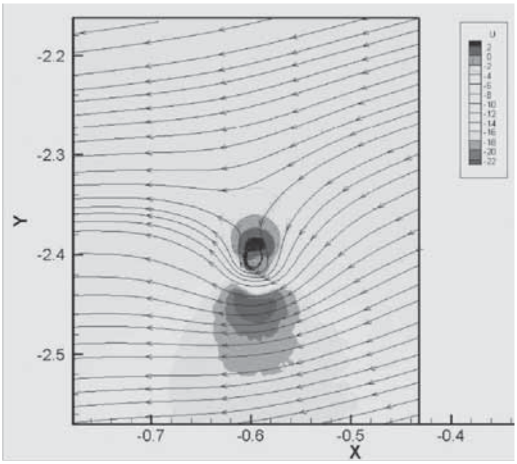


Figure 10 Flow structure of a vortex in direct neighbourhood of a blade.

SIROCCO

The principal objective of the EC SIROCCO project, for which ECN was the coordinator, was to obtain a significant noise reduction on full-scale wind turbines, without a reduction in power performance. This would be accomplished by improving the aerodynamic flow through low noise acoustic airfoils, serrations, and brushes at the trailing edge of wind turbine blades. The most important results/conclusions are as follows. Low noise airfoils were designed for the outer part of two existing wind turbines with a combined (2D) aerodynamic/aero-acoustic model. The behaviour of the acoustic airfoils were verified by means of 2D wind tunnel measurements. These measurements showed noise reductions of 1-1.5 dB(A) and 2-3 dB(A) respectively, with the same or better aerodynamic performance and very good quantitative agreement between prediction and measurement. Field measurements showed the noise reduction from these airfoils to be in the order of 0.5 dB(A) with the same aerodynamic performance, while the addition of serrations or brushes to the trailing edge of a wind turbine blade, led to an additional noise reduction of more than 3dB(A). For the report refer to the website of ECN (18).

ERAO-3

The project Validation of dynamic models of wind farms (ERAO-3) is the Netherlands' contribution to the IEA Wind Task 21: Dynamic models of wind farms for power system studies. Three validation exercises have been executed. The first validation compares models of different project partners with regard to a voltage dip in a hypothetical benchmark system. The second validates the Constant Speed Stall wind farm model using measurements on the Alsvik wind farm. The third validates the Variable Speed Pitch model using measurements on the JWT wind turbine. The three validation exercises showed different levels of success. The results of the first validation showed only minor deviations from the results of others and these could be explained by small differences between the models. In the second validation, detailed turbine data were available and the model predictions were quite accurate. In the third validation, the similarity between measurements and simulations was limited. The unavailability of detailed data on the system used for this validation played an important role with regard to the accuracy. To increase confidence in the dynamic wind turbine and wind farm models, additional validation work is still required. For the report refer to the website of ECN (19).

CONMOW

The EC CONMOW project, for which ECN was the coordinator, investigated whether online condition monitoring (CM) techniques are valuable for optimizing O&M strategies of large offshore wind farms and how these techniques can be improved. Analyses of suitable state-of-the-art CM-techniques and a failure mode and effect analysis were used to select meaningful condition monitoring systems and to identify useful developments. Then a measurement campaign was carried out on a GE 1.5S turbine and on five Nordex N80 2.5-MW turbines. Results from five different drive train vibration monitoring systems were analyzed in combination with high-frequency data from "traditional" measurement systems and from the turbine PLC. By analyzing the high-frequency electric power signal using wavelet transformations, a shaft misalignment could be detected. This was confirmed by vibration measurements, which provided more detailed information on the origin and the effects of these vibrations.

Large amounts of SCADA statistical data and inspection reports were analyzed. Several methods to process and present these data resulted in a simple and orderly presentation to the operator. This contributes to early failure detection. Because of the limited measurement time, during which no failures occurred in the turbines, no proof that the methods indeed are useful to determine failures at an early stage was found.

The drive train monitoring systems performed well and were reliable. They detected component errors at an early stage as well as during off-design conditions. However, as yet insufficient knowledge is available to predict how the failures will develop in order to change from calendar-based maintenance to condition-based maintenance. Such knowledge can only be obtained from a larger population of identical wind turbines and longer measurement periods during which faults occur.

Several improvements have been implemented in the vibration monitoring systems. Simulations with GH Bladed showed that in some cases fault conditions and off-design conditions can be detected from measurements with the wind farm SCADA system. A cost sensitivity study with the ECN and Risø cost models, clearly showed that significant cost benefits are possible when suitable CM-techniques are applied.

Real-time Process Simulator

In the project Real-time Process Simulator for Evaluation of Wind Turbine Control Systems, ECN developed a real-time simulator for a complete wind turbine system for the evaluation of the overall control system. The software was developed in Matlab/Simulink and supports automated real-time compilation to a real-time code for use at a hardware platform. The program modules developed and implemented include: efficient integrated linear structural models for the rotor, drive-train, and support structure in a working point range; an interpolation method between these models; non-linear aerodynamic (BEM) and hydrodynamic (Morison) conversion models; a blade effective wind speed model, which accounts for the rotational sampling of spatial turbulence, for tower shadow and wind shear, and for oblique inflow; a wave generation model in order to cope with offshore situations; an electric system model in a rotating reference frame consisting of a doubly-fed induction generator, converter, transformer and cabling; quasi-steady and easy to parameterize models for turbine specific peripheral devices like pumps, motors, valves, brakes, heat exchangers; models of peripheral devices which comprise discontinuous behaviour such as switching and Coulomb friction; and generic models for the thermic behaviour of the heat generating systems like gearbox, brake and generator. These subsystem models were integrated in an overall Simulink scheme for time-domain simulation and compilation to real-time code.

5.1.3.2 Results of OWEZ

Further results of the Monitoring and Evaluation program of the offshore wind farm OWEZ, formerly know as NSW became available in 2007.

Wind Climate

Available are 10-min average wind measurements of the site at three heights of the meteorological mast. Data from July 2005 to June 2006 comprise one year in an 'undisturbed' situation prior to construction of the NSW. Data from July 2006 to March 2007, includes the period until December 2006 during which the wind turbines were erected and the first three

Figure 11 Picture of test set-up for acoustic measurements on the GE baseline turbine. The distribution of noise sources in the rotor plane is projected onto the picture.

months of full operation. The formal start of the technical effect measurements was April 1, 2007.

During construction of the wind farm in the second half of 2006, the met mast wind measurements gradually got disturbed by the erected wind turbines. On the 29th of September 2006 the first wind turbines surrounding the meteorological mast made their trial runs. The document 'Surrounding obstacles influencing the OWEZ meteo mast measurements' gives the significant disturbed wind direction sectors.

NoordzeeWind supplied half year reports with analyses of the meteorological measurements at the 116-m high meteorological mast at the location of the wind farm. The reports give the availability, quality and consistency assessment of raw measurement series as well as graphical and tabular presentations of wind speed frequency distributions, turbulence intensity, vertical profile of turbulence intensity and wind speed profiles. The data can be downloaded from the SenterNovem web page on wind climate (20).

Wind Forecasting

The objective of wind forecasting under the program is to get insight into the possibilities of short-term forecast systems for the farm capacity (potential economic value, reliability). For this subject, Noordzeewind delivered the report 'Short-term output prediction OWEZ, Wind forecasting Reporting period 2004-06-01 – 2006-05-31'. Data from the meteorological mast of the undisturbed wind conditions were used for a first assessment of wind forecasting at the OWEZ site. The report describes the ECN wind power forecasting method AVDE that was used to create the wind forecasts and that will be used to create the power forecasts. The accuracy of wind forecasting with AVDE is based on on-site data in the period from June 2004 to May 2006. The report can be downloaded from the SenterNovem web page on power forecasting (21).

Licensing

On licensing, NoordzeeWind delivered one report: 'Rapportage Proces Vergunningverlening Offshore Windpark Egmond aan Zee.' This report describes the policy, strategy, and acquisition of the permits (environmental and building) for the NSW wind farm. It contains conclusions and recommendations that are useful for the development of other offshore wind farms in the future. The report is available in Dutch only (22).

5.1.3.3 Results of the We@Sea program

The results of the We@Sea program 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 can be found on their website (23).

5.1.3.4 Collaborative research

Various Netherlands organisations participate in IEA Wind Tasks 11, 20, 21, 23 and 25. The participation benefits the Netherlands R&D in various ways. The reasons for participation in these Tasks were given in the 2006 IEA Wind Energy Annual Report (9).

As of 2007, the Netherlands also participates in the Task 26 Cost of Wind Energy. The Netherlands participation in this task is important because it locks in with the Egmond-Copenhage-Berlijn process. It will give insight into international cost data for offshore wind energy that can be used for policy decisions.

Participation in the IEA Wind tasks is a cost-effective way to conduct research. On average, each euro spend in our country on research gives access to five euros value of research spend in the other participating countries.

Netherlands research institutes also participated in the EC projects Mexico, Optimat Blades, Accuwind, Sirocco and Conmow. At present they participate in the EC project Upwind which is closely interlinked with the Netherlands Innwind project.

6 The Next Term

6.1 Policy developments in 2008

The following policy developments in 2008 are expected. The publication of the final subsidy levels and other details of the SDE scheme in Ministerial executive regulations. The start of the implementation of the national plan 'wind energy' in mid 2008.

6.2 Wind capacity expected in 2008

Projects under construction to be completed in 2008 are given in Table 11. Two projects at Eemshaven in the province of Groningen will have a total capacity of 204 MW. Eemshaven

Table 11 Turbines under Construction to be Completed in 2008 (2)						
	Manufacturer	Rotor diameter	P	Turbines	Height	Capacity
		[m]	[kW]	[-]	[m]	[MW]
Marrum (Fryslân)	Vestas	48	750	7	40	5.3
Eemshaven	Vestas	90	3,000	21	100	63.0
Noordzee Q7	Vestas	80	2,000	60	57	120.0
Franeker	Vestas	52	900	1	70	0.9
Middelburg-Borssele	Vestas	52	900	12	70	10.8
Aalten (Gld)	Enercon	82	2,000	8	98	16.0
Eemshaven	Enercon	82	3,000	47	100	141.0
Echteld - A 15	Enercon	82	2,000	4	78	8.0
Amsterdam Afrikahaven	Vestas	90	3,000	9	80	27.0
Total				169		392.0

harbour area will then be the home of the largest wind farms in the Netherlands. With total of 169 turbines and an expected capacity of 392 MW the year 2008 looks to be a record year. The average capacity of these turbines is 2.3 MW, turbine height 97 m; 76 of these turbines will have a hub height of 100 m. This will make them the tallest in our country.

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(1) Source CBS, http://www.cbs.nl/nl-NL/menu/themas/industrie-energie/publicaties/artikelen/archief/2008/2008-2394-wm.htm

(2) Wind Service Holland, http://home.wxs.nl/~windsh/statistiek.html

(3) Wind Service Holland report to SenterNovem, January 2008.

(4) For a complete updated list see http://www.senternovem.nl/Offshore_Wind_Energy/locations_and_licences/licence_system.asp .

(5) Afwijzing aanvraag vergunning Windpark Den Haag I, http://www.senternovem.nl/offshore_windenergie/nieuws/afwijzing_aanvraag_vergunning_windpark_den_haag_i.asp

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(7) See for more information on the Ampelmann http://www.ampelmann.nl/index.php?id=28

(8) Siemens Wind Power press release http://www.siemens.nl/persinfo/pressinfo.asp?id=1392 .

(9) For more details please refer to Netherlands chapter of the 2006 IEA Wind Energy Annual Report.

(10) Q7 wind farm wins Euromoney Deal of the Year Award http://www.q7wind.nl/en/nieuwsarchief05.asp .

(11) Technisch-economische parameters van duurzame elektriciteitsopties in 2008-2009, Conceptadvies basisbedragen voor de SDE-regeling, ECN-E--07-069 - Versie 2 November 2007. http://www.ecn.nl/publicaties/default.aspx?nr=ECN-E--07-069

(12) Please refer to pages 162 and 163, of reference (9) for a basic explanation of MEP-tariffs, www.ieawind.org.

(13) Staatsblad van het Koninkrijk der Nederlanden, Jaargang 2007, 410, Besluit van 16 oktober 2007, houdende regels inzake de verstrekking van subsidies ten behoeve van de productie van hernieuwbare elektriciteit, hernieuwbaar gas en elektriciteit opgewekt door middel van warmtekrachtkoppeling (Besluit stimulering duurzame energieproductie)

(14) "Proof of concept of a 'Smart' wind turbine rotor blade for load alleviation," J.W. van Wingerdena, A. W. Hulskamp, T. Barlas, B. Marrant, G. A. M. van Kuik, D-P. Molenaar and M.Verhaegen, Delft University of Technology,

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(15) Photo: Delft Technical University, recreated in color by E. Jührend.

(16) See http://pdf.aiaa.org/preview/CDReadyMASM05_666/PV2005_198.pdf

(17) Download the MEXICO report http://www.ecn.nl/fileadmin/ecn/units/wind/docs/Mexico.pdf

(18) Sirocco http://www.ecn.nl/en/wind/additional/special-projects/sirocco/

(19) Download the ERAO-3 report http://www.ecn.nl/publications/default.aspx?nr=ECN-E--07-006

(20) Download data wind climate from http://www.senternovem.nl/Offshore_Wind_Energy/technology/monitoring_mep-nsw/wind_climate.asp

(21) Download report power forecasting from http://www.senternovem.nl/offshorewindenergy/technology_nsw/monitoring_mep-nsw/power_forecast.asp

(22) Download the report on licensing from http://www.senternovem.nl/offshorewindenergy/technology_nsw/monitoring_mep-nsw/licensing.asp

(23) View the research publications of We@sea at http://www.we-at-sea.org/index.php?keuze=r0

Author: Jaap L. ’t Hooft, SenterNovem, Netherlands agency for innovation and sustainability, the Netherlands.

Chapter 24
Norway

1.0 Introduction

Electric energy in Norway is generated using a very high share of renewables. The dominating 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 hydropower, mostly small-scale hydropower.

The wind energy potential is located mostly on west coastal areas. Norway has a long coastline and the offshore potential is also huge even though most of the offshore areas are deep water or protected marine zones. More than 50,000 MW of wind power potential has been identified as possible areas for developing wind power.

In 2007, the installed wind power capacity in Norway increased from 325 MW to 385 MW. By the end of 2007, there were project plans for over 15,000 MW in Norway. However, financing and public acceptance remain substantial hurdles to overcome for the installation of wind turbines. Although the price for long-term future electricity has risen during past years, it is still not a strong enough incentive to spur new investments in wind energy.

2.0 Progress Toward National Objectives

2.1 Strategy

Norway's national goal for renewable energy production and energy savings in 2010 is 12 TWh above the 2001 level. At least 3 TWh of this production will be achieved from wind power and 4 TWh from water-based central heating systems. 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. To help achieve this goal, the Energy Fund, administered by the state-owned agency Enova, gives grants to energy saving and renewable energy production projects. Financed by a levy on the transmission tariff, the Energy Fund contained approximately 88 million € in 2006.

To strengthen efforts to increase the production and use of renewable energy and to improve energy efficiency, the Norwegian government in October 2006 proposed allocating 20 billion Norwegian Kroner (NOK) (approximately 2.3 billion €) to a new fund. The first 10 billion NOK were allocated to the state budget for 2008. Another 10 billion NOK will be proposed to be allocated to this Basic Fund in the 2009 state budget. When the Energy Fund reaches its full size of 20 billion NOK, the yield from the new Basic Fund is estimated to be about 880 million NOK (approximately 100 million €) annually. This amount will more than double today's level of support. The state-owned agency Enova will administer the yield from the Basic Fund.

In 2007, renewable sources of electricity contributed 107% of national electrical demand. About 0.7% of the renewable supply comes from wind power. Since electricity production in Norway mainly comes from hydropower, the share of renewable energy varies considerably from one year to the next. It turns out that 2007 was a rather wet year resulting in an excess power production for export. For 2010, the target set by the government for the renewable share of electricity consumption is 90%. According to a government statement, this target

Table 1 Key Statistics 2007: Norway	
Total installed wind generation	385 MW
New wind generation installed	60 MW
Total electrical output from wind	0.899 TWh
Wind generation as % of national electric demand	0.7 %
Target	3 TWh in 2010

corresponds approximately with the 6 to 7 TWh new production capacity of electricity from renewable energy sources being introduced from 1997 to 2010.

2.2 Progress toward the wind target

Interest in wind power is high, and several projects have been submitted for approval. Projects totalling 5,400 MW have applied for concession (approval). More than 1,400 MW have received approval; however, very few projects are under way. This indicates that the economic incentives are not yet sufficient. There is an expectation, however, that the economic conditions will be improved in the future. In addition, projects totalling an annual production of 30 TWh have been proposed, including offshore wind power projects totalling 2,400 MW (7 TWh/yr).

Enova provided a grant to one wind power project in 2007. Jæren Energi AS received 218 million NOK in an investment grant to fund a new wind park in Rogaland, with an annual production of 260 GWh.

The target for wind power of 3 TWh of generation by 2010 represents approximately 1,000 MW installed capacity at the most favorable sites. Since 2001, Enova has signed contracts with energy utilities for 13 wind power projects. The projects represent an estimated 1.8 TWh/yr of energy production. There is no indication that the 3 TWh target can be reached by 2010 (Figure 1).

3.0 Benefits To National Economy

3.1 Market characteristics

Production of wind power is dispersed among seven energy companies, some of which are small local utilities. The largest wind power projects are operated by big national energy companies that also own power stations in foreign countries. So far there is no significant wind turbine manufacturing industry in Norway.

3.2 Industrial development and operational experience

ScanWind Group AS is a new Norwegian-based manufacturer of large wind turbines (3.5 MW) for use in Class 1 wind areas. The design consists of a directly-driven, variable-speed turbine with a permanent-magnet generator. They aim to be a supplier of wind turbines and services for the coastal onshore and the offshore market.

Some of the Norwegian industry takes part in component production for wind energy systems, e.g. wind turbine blades and nacelles. Aker Kvaerner was awarded a contract in 2007 by Multibrid Entwicklungsgesellschaft for 13 jackets for offshore wind projects in Germany and France. This represented the first contract for the company on wind turbine substructures. Earlier, Owec Tower AS, a Norwegian-based company, delivered two substructures to the DOWNVind project (Beatrice).

A new initiative has begun to develop a new weight-reduced generator for wind power applications. The main objective of this project is to develop a new permanent-magnet generation system that reduces the generator mass by at least 25%.

3.3 Economic details

Due to the low investment activity in Norway in 2007, relevant average economic figures are not available.

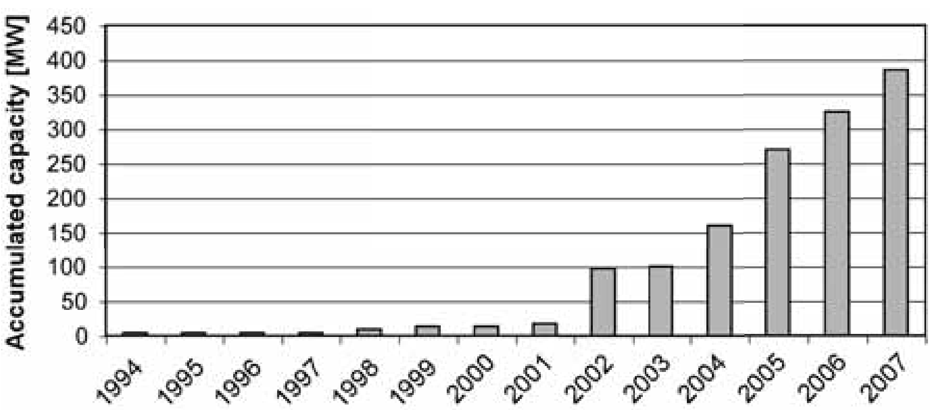

Figure 1 Installed wind power capacity in Norway.

In some remote areas having favorable wind conditions, the cost of grid connection is too high to make the development of wind energy economical. In addition, the capacity of the existing grid is a limiting factor in many places and restricts the size of the wind farms being constructed. Most new wind farms are designed taking into account the limitation of the capacity of the grid. An increase of the grid capacity can be an option in some areas. Generally, areas with the best wind conditions are located in the northern part of the country, but these areas are too far from the consumer. Constructing new transmission lines has been considered, but so far the lower cost for generating in the north, where wind conditions are more favorable, does not make up for the additional cost of building new lines.

Estimates of production costs from sites with good wind conditions suggest a production cost of about 420 NOK/MWh (53 €/MWh), including capital costs (discount rate 6.5%, 20-year period) and operation and maintenance. During the last year, the spot market electricity price on the Nord Pool (Nordic electricity market place) has increased noticeably leading to the forward price to be about 420 NOK/MWh (53 €/MWh).

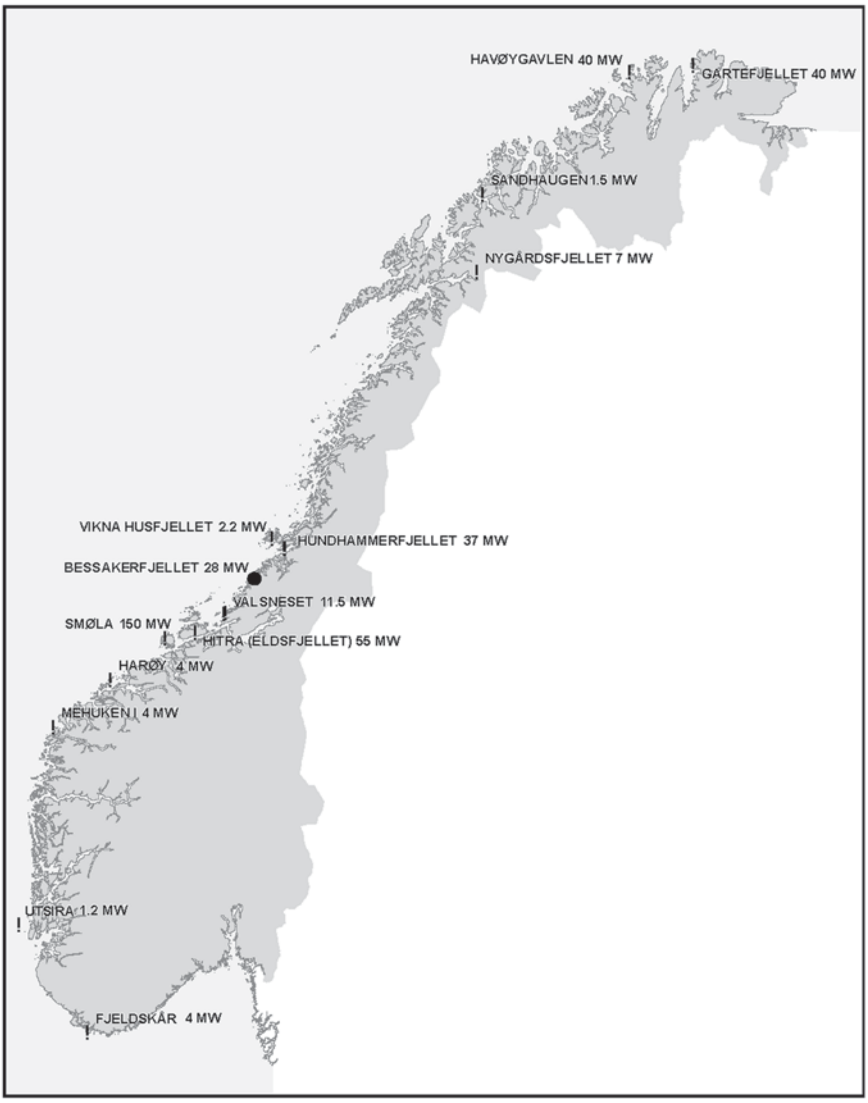

Figure 2 Location of wind installations in Norway.

Table 2 Government Support Per Kilowatt-Hour	
Type of production	Government contribution Euro/kWh (NOK/kWh)
Hydropower production representing the first 3 MW of installed capacity	0.005 (0.04)
Wind-power production	0.010 (0.08)
Power production from biofuels and immature technologies	0.0125 (0.10)

Nord Pool is wind energy competitive with the price of many new hydropower projects, which still is an option for new green power. Even though both wind and hydro resources are large, the development of hydropower is more controversial than wind power.

4.0 National Incentive Programs

For renewable power production, the government plans to establish a feed-in system in which accepted projects will achieve a fixed support per kWh in 15 years. The support level is proposed as shown below (Table 2).

It is questionable whether the support level is enough to spur new investment in wind energy. The power industry has refused to accept the new terms and plans to go abroad. For the time being, there is hardly any wind development activity in Norway. Moreover the support scheme should have been implemented at the turn of the year, but due to administrative problems the implementation has been postponed.

Viewed in this light the government has decided, as an option, to reopen negotiation with the Swedish government in a new attempt to come to an agreement of a common scheme for a green electricity market. If an agreement is not achieved the government has committed itself to propose a new support scheme for renewable power production. In the mean time, the present levels of investment grants will be continued and reinforced with increased support to a level necessary to trigger new projects.

5.0 R, D&D Activities

In February 2007, the Ministry of Petroleum and Energy established a task force with a mandate to propose a new national renewable technology development (RTD) strategy for the Norwegian energy sector. A new RTD strategy will be developed by February 2008 in cooperation between industry, research institutes, and governmental bodies.

The governmental research program for sustainable energy is called RENERGI. Its budget for wind energy R&D in 2007 was 20.3 million NOK (2.5 million €). The following wind energy R&D projects have been approved for funding:

- A pilot project demonstrating hydraulic transmission of wind power will be conducted on a 225-kW wind turbine at VIVA AS test facility
- Two concepts for floating wind turbines are under development. The systems are designed to operate in areas of deep water (200 m to 800 m). A prototype is expected to be in operation during 2009. One of the concepts is the demonstration project Hywind. Hywind is a demonstration project in which StatoilHydro will use floating constructions familiar from the offshore industry as foundations for the offshore wind turbines. Hywind received a 59 million NOK (7.08 million €) investment grant from Enova in 2007.
- Several projects dealing with wind resource mapping and micrositing in complex terrain have been approved.
- 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 in Trondheim (NTNU) took a joint initiative to develop a test station for wind turbines on the midwestern coast of Norway. The test site was opened summer 2005 and is now operating. For more information : www.viva-test.no
- The wind/hydrogen demonstration project at Utsira has now been in operation for two years. The purpose of the project is to demonstrate how renewable energy can provide safe and efficient energy supply to

isolated areas. The system is based on wind energy as the only energy source. Excess power is used to produce hydrogen which is to be used later in a fuel cell. The system was developed and is operated by Norsk Hydro ASA.

The Norwegian Water Resources and Energy Directorate (NVE) and Enova SF have conducted studies on the resource potential for offshore wind off the coast of Norway. The studies show a total theoretical potential annual wind resource of 14,000 TWh along the Norwegian coast. Only sea areas from the shore line up to water depth less than 300 meters are included in this potential. The studies document resource variation geographically along the coast line as well as seasonal variation of the wind speed over the year.

A computer based dataset representing the wind regime during the past 30 years has been developed. The data will be compared with the hydrologic data to study integration of wind power and hydropower. The Norwegian energy supply system is largely dependent on hydropower, however, this hydropower system, which generates approximately 122 TWh annually, has a reservoir capacity of approximately 87 TWh. Nevertheless, the system is vulnerable to annual variations in precipitation and to prolonged droughts. An increasing share of wind power promotes interest in the integration of wind power and hydropower, because both resources are naturally intermittent. The question is whether the two can be complementary and improve overall performance, or whether, when combined, they tend to increase the problems of energy supply. The latter eventuality can be the case if drought years generally coincide with periods of low mean wind speed. Wind power development has been slowed in Norway recently due to low electricity prices, low support system, and increasing construction costs. As a result, pressure to highlight large-scale integration of wind and hydro has been low. With a new strategy for large-scale wind development, the wind-hydro integration study will be more important to implement. We therefore expect the activities to grow in 2008.

6.0 The Next Term

By the end of 2007, project plans for 80 MW of new wind capacity were under way and more than 1,400 MW had received permission/approval. However, the availability of financing and public acceptance of projects will determine how many turbines are installed in the coming term.

Author: Knut Hofstad, NVE, Norway.

Chapter 25
Portugal

1.0 Introduction

Portugal has its most valuable energy asset in renewable energy resources. It is one of the countries of Europe with a high level of sun radiation, considerable vegetable and animal biomass potential, and a good wind resource. Portugal also has available hydro resources and possibilities for ocean energy (when that technology reaches maturity). Although Portugal still depends largely on foreign countries for oil, gas, and coal, especially for the transportation sector, in recent years the country has taken a clear path towards a sustainable, renewable-based, electricity generation. The energy contribution and the investments in the renewable energies are becoming more relevant every year as a strategically sector for the development of the country's economy.

By the end of 2007, Portugal had installed 7,409 MW (1) of renewable-based power plants. That capacity has generated an estimated 18, 207 GWh (2) during 2007. Renewable sources have contributed an estimated 36.4% of the total electricity demand, one of the highest percentages in Europe. The goals defined for 2010 and 2013 of 39% and 45% of the national electricity demand generated from RES, respectively are within reach.

In 2007, fewer wind parks were installed than in previous years. However, the second phase of the public call for grid connection of wind power capacity, started in 2005 was concluded in August 2007. As a result, 400 MW were added to the 1,200 MW attributed in 2006. It is expected that wind energy capacity growth will increase again in the next few years.

2.0 Progress Toward National Objectives

The wind and hydro resources are considered the most valuable energy resources in Portugal, and the ones that will have a higher contribution to the national and European targets, both for 2010 and 2020. Until 2006, the successive Portuguese governments set up ambitious targets stating that 5,100 MW of wind capacity should be installed in Portugal by 2013 (RCM 169/2005). If this elevated goal is achieved, the Portuguese electrical sector will be among the top three power systems in the world with a high wind energy penetration (approximately 20% of total consumption).

The high wind energy penetration forecast will require careful design of the Portuguese system. This will be especially important because of the peripheral location of Portugal and the much less interconnected network relative to the central European countries.

With that in mind, the Portuguese government sponsored studies which indicated that added reversible hydropower capacity would not only contribute to the national renewable energies goals, but would also enable easy wind power integration (Figure 1 and 2). In Portugal there is currently 4,945 MW of hydropower capacity. To fulfill the 2020 targets another 2,055 MW are needed to total 7,000 MW. At least 5,354 MW of hydropower capacity are needed by 2011. The study – "Plano Nacional de Barragens de Elevado Potencial Hidroeléctrico (PNBEPH)" – was published in September 2007 by the Portuguese Government and resulted in the definition of ten new hydroelectric power plants for deployment. These are Almourol,

Table 1 Key Statistics 2007: Portugal	
Total installed wind generation	2,125 MW
New wind generation installed	427 MW
Total electrical output from wind	4.036 TWh
Wind generation as % of national electric demand	8%
Target:	3,750 MW by 2010 5,100 MW by 2013

Alvito, Daivões e Foz Tua, Fridão Girabolhos e Gouvães e Padroselos, Pinhosão e Vidago) totaling approximately 1,100 MW and having an estimated yearly production of 1,630 GWh/y. It is of notice that seven of them with installed capacity of 807 MW will be reversible.

The hydroelectric power plants already in the project or construction phase are: Picote II with 231 MW; Bemposta in Douro river with 409 MW; Ribeiradio in Vouga river with 70 MW; Baixo Sabor in Sabor river with 170 MW (reversible); and Alqueva II in Guadiana river with 260 MW. This later is of special notice since two reversible groups to support the high wind penetration and having a pumping equivalent capacity of 2,110 MW will be available in 2011.

Figures 1 and 2 illustrate the natural compatibility between the wind generation - that will exceed the consumption both in wet and dry windy days in 2011 - and the reversible hydro power stations. With these new hydropower stations, Portugal is preparing for the penetration close to 20% expected in 2013.

In 2007, the amount of new wind capacity installed in Portugal was slightly lower than in previous years. According to the national Directorate for Energy and Geology (DGEG), 427 MW of capacity, corresponding to a growth rate of 25%, was installed and commissioned during 2007. By the end of 2007, 2,108 MW were installed in mainland Portugal, and 17 MW were installed in the archipelagos of Madeira and Azores. These values correspond to 2,125 MW

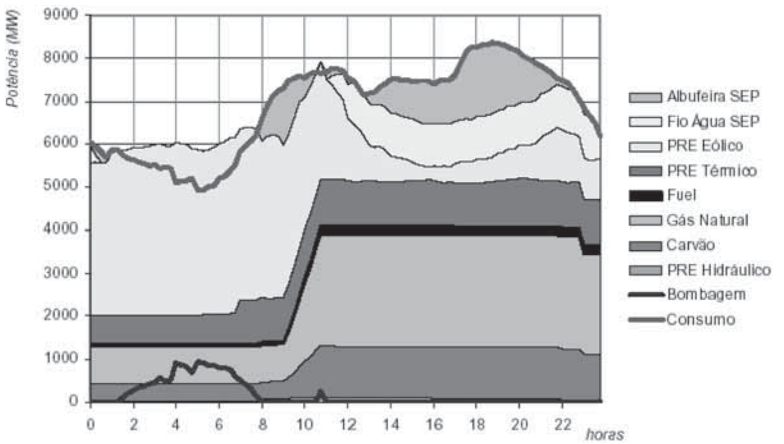

Figure 1 Scenario of generation profile for a dry windy day in 2011.

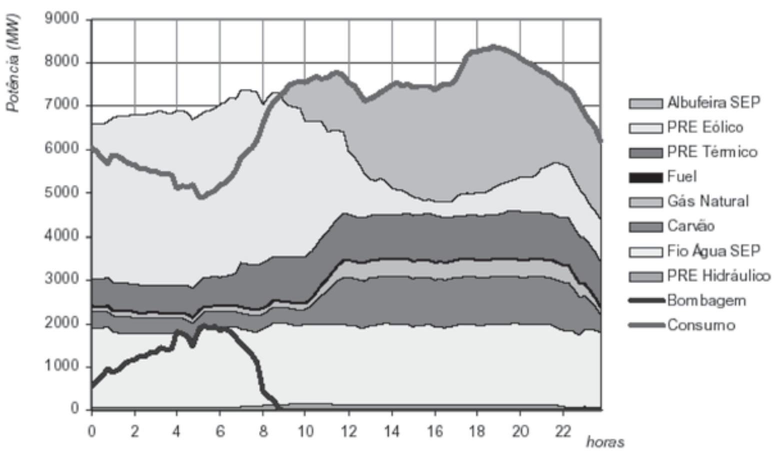

Figure 2 Scenario of generation profile for a wet windy day in 2011.

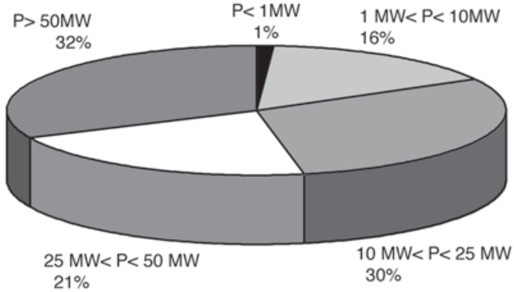

Figure 3 Wind parks capacity classification.

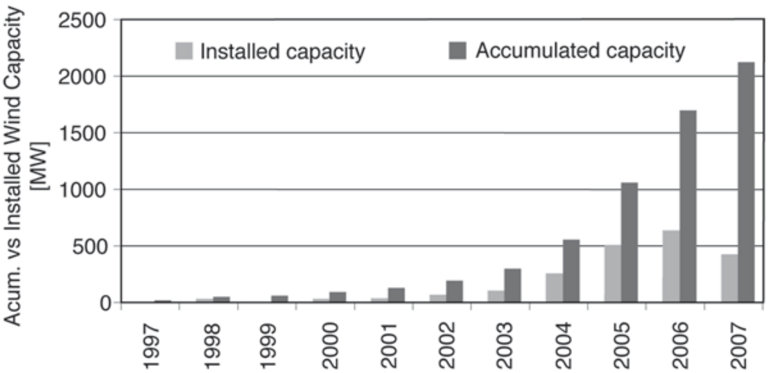

Figure 4 Accumulated vs. installed wind capacity.

in the whole territory, representing already 56% of the 2010 goal.

The wind parks installed in 2007 are characterized by large nominal power – 32% of them being above 50 MW, as shown in Figure 3. The wind capacity installed and accumulated is presented in Figure 4.

The electric energy generated from the wind capacity installed through the end of 2007, was 4,036 MWh. That represented, approximately, 8% of the national demand, the highest energy penetration experienced by the country so far. Figure 5 depicts the wind capacity installation trend through 2010 that will fulfill the Portuguese wind power goals under the 77/2001/EC Directive for Renewable Energies. Figure 6 shows the wind energy generation until the end of 2007.

Assuming an annual rate of capacity growth of approximately 20% through 2010, and grid capacity allocated for wind park development, there is not much doubt that the goals established for this sector will be achieved.

The wind capacity is not evenly distributed in the Portuguese mainland territory. By analyzing Figure 7, one can see that the northern and coastal areas have more wind parks. This is because of the wind potential of these areas and also due to the availability of the transmission lines to collect the generated energy.

3.0 Benefits to National Economy

3.1 Market characteristics

During 2007, the unit cost of wind turbines was estimated to be in the range of 950 to 1,110 €/kW. Cost depends on the turbines' characteristics and/or the origin country of manufacturer. Contracted O&M has averaged approximately 13% or 15% of the investment cost, for the last decade of the wind power plant operation.

A new line of manufacturers is now entering the wind energy market and there is growing interest by developers to invest in other "niches" of this renewable energy sector. One of these is the micro-turbines market for the urban and built environment which has gained interest with the publication of new legislation at the end of 2007 (Dec. Law 363-2007, 2nd November). This Dec.-Law regulates the capacity of domestic renewable projects to connect to the electric grid, as well as the tariffs that apply to each renewable source. The legislation has as

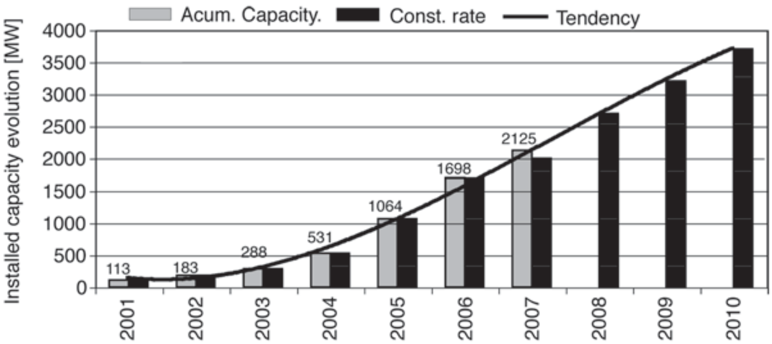

Figure 5 Wind capacity trend (2001-2010).

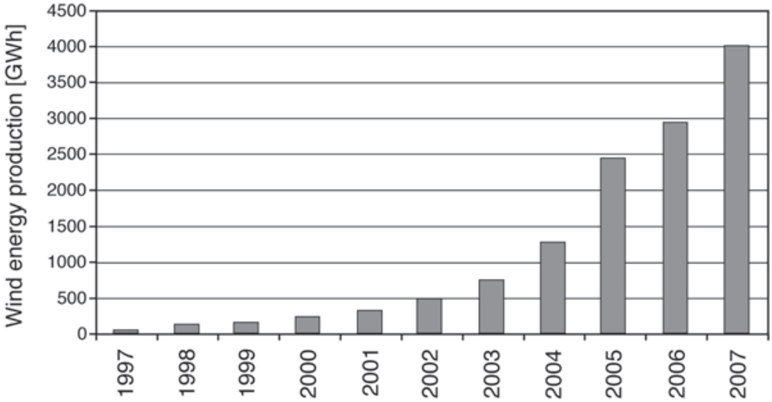

Figure 6 Wind energy production.

main objective to simplify the licensing process for potential producers/consumers by using Internet registration and licensing. This Dec.-Law has several positives aspects while it encourages the public in general to become an electricity producer, it simplifies the permitting process and contributes to unloading both the distribution and transmission grids.

Since Portugal is part of the Iberian Peninsula, the economic relevance of the sea is very high. It is thus natural to think of offshore wind development as the next step for the wind energy sector in this country. In 2007, a few developers and utilities started to investigate the feasibility (energetic and economic) of performing measurement campaigns and installing offshore wind parks. Some demonstration projects, both national and European, are about to start, mainly in the area of wind resource assessment, detailed bathymetry, and sea bed characterizations.

3.2 Industrial development and operational experience

During 2007, more than 200 wind turbines were installed, with average nominal power of 2.6 MW (source DGEG). The distribution in the Portuguese market of the different manufacturers was not as varied as in the previous year. The largest share was attributed to ENERCON, the first wind turbine manufacturer to set up an organization and produce relevant components of wind turbines in this country. This new industrial capability of the country is an outcome of the public call opened in July 2005, where gaining access to the transmission network was dependent on (among other factors) the investment and creation of jobs in deprived regions. The distribution of installed capacity by the manufacturer is shown in Figure 8.

Early in 2007, a national project to develop a small wind turbine was started. In this project the turbine design was developed by the

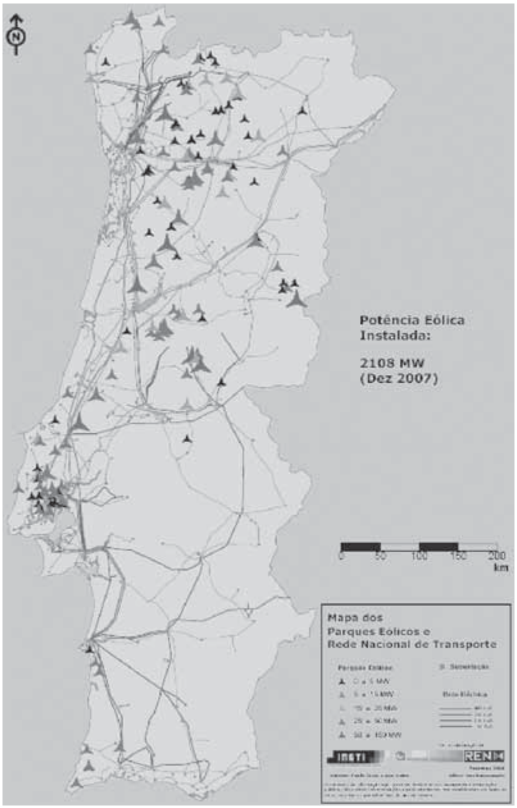

Figure 7 Wind capacity installed in mainland Portugal with the wind parks' location and the transmission network.

National Institute for Engineering, Technology and Innovation I.P. (INETI) and the manufacture of the components was contributed by the Portuguese industry. This project named TUR-Ban is the result of the national government policy and strategy to encourage the micro-generation of electricity by renewable sources in Portugal, the already mentioned Dec.-Law nº363/2007.

Another result of the public call for wind capacity was the strong interest showed by some foreign industries to establish production facilities in Portugal in the near future. In November 2007, a technological complex from the German company Enercon GmbH began activity in Viana do Castelo, (Figure 9) a city in the northern part of Portugal. This complex manufactures most of the wind turbine's components, both for the national market and for export. The complex also integrates with other Portuguese companies already established in the wind sector, namely the high-quality tower manufacturers and the specialized construction and electrical components companies.

Also during 2007, wind energy international consultancy companies and wind energy developers, as Garrad Hassan and Partners and Airtricity have started their activity in Portugal.

All the existing and planned facilities, both in the industrial and the consultancy sector, will benefit from experienced Portuguese workers, because wind power has been a relevant sector

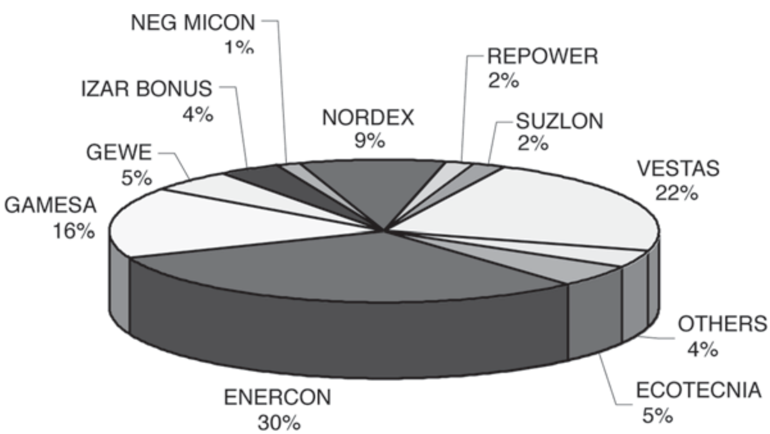

Figure 8 Distribution of the installed wind capacity by manufacturer.

in the economy for a number of years. These facilities promise continued job creation in interior remote areas. As has already been reported in most European countries with large wind development, specialized workers such as engineers for new developments are becoming hard to find.

3.3 Economic details

In Portugal, the environmental regulators are very rigid about wind energy, and prefer large wind turbines (> 1,500 MW) over the smaller ones. Also the very complex orography that characterizes mainland Portugal and the fact that most of the suitable sites for wind energy exploitation are already taken and/or under project leads to the installation of turbines with high rated capacity.

The total wind farm installation costs are estimated to be between 1200 to 1400 €/kW, and annual maintenance is about 15% of annual income.

Concerning renewable energies tariffs, in 2007 no new legislation was published regarding conventional wind parks. The Dec. Law 33 – A/05, is used to define which tariffs to apply in the operating projects. Also the price for energy remains unchanged since 2006 (Figure 10), for wind parks with connection permits granted before 2005.

For micro-generation, the actual tariff for wind energy production established in the recent legislation is 455 €/MWh, corresponding to 70% of the overall tariff (650 €/MWh) applicable to PV systems.

4.0 National Incentive Programs

During 2007, a call in the form of a QREN program was opened on 15 November with the final date for participants to present their projects at the end of February 2008. This program was not specifically directed to the wind energy sector, but during this year was the only national program to support R,D&D in Portugal. Besides this, a call in the European Union Seventh Framework Programme (FP7) was opened for the wind energy sector. Portuguese institutions are participating in relevant projects namely the five-year project Norsewind (EC FP7-2008) to run from 2008 to 2013 where INETI is participating. Another relevant governmental financing program, PRIME/MAPE, was released in 2007 with funds covering 110 wind energy projects.

Figure 9 Technological complex in Viana do Castelo.

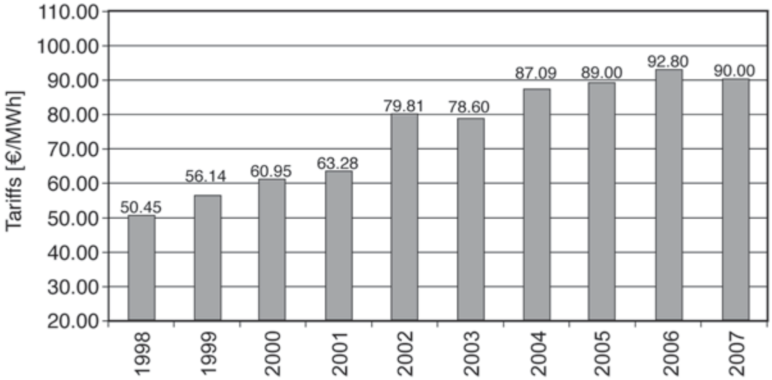

Figure 10 Evolution of wind energy tariffs in the period 1998–2007.

5.0 R, D&D Activities

5.1 National R, D&D efforts

In Portugal, the R, D&D activities related to wind energy are located mostly in Lisbon and Oporto. In 2007, Oporto gained the Garrad Hassan group, a consultancy company with some activity in the wind energy market and in R, D&D. The majority of R,D&D groups are in academic and/or research institutes. Most of this work is financed by their own research projects, which are usually included in international, European, and national programs, as the mentioned above. Wind energy developers and consultancy entities also participate in academic projects mainly in those concerning doctoral and post-doctoral projects, contributing to R, D&D development in a small way.

INETI, a part of the Ministry of Economy and Innovation, is one of the most active public R, D&D organizations in wind energy research and technology. Its activities are partially financed by the national government and by wind energy companies (consultancy contracts).

In the north of Portugal, the main institutes dedicated to R, D&D are the Faculty of Engineering of the University of Porto (FEUP) through the Research Centre for Wind Energy and Atmospheric Flows (RCWEAF) and the associated laboratory INESC-Porto (Computers and Systems Engineering Institute of Porto), which is part of the research network established by the Portuguese Foundation for Science and Technology (FCT).

The main R, D&D projects underway in Portugal include the following:

- ANEMOS plus (EC) – INESC Porto:
- Cup anemometer correlation with wind satellite data for offshore purposes (input to NORSEWind, EC FP7-2008) – INETI;
- Applying research on the use of hydro storage as regulation for excess wind production; – INESC Porto;
- Remote control of wind park clusters using DSO by TSO request – Several wind energy developers;
- Using wind turbine as FACTS – INESC Porto;
- TURBan 2.5-kW small wind turbine project. A national project financed by DEMTEC (70/0201) that consists in the development of two prototypes of small and low-cost turbines for urban use – INETI.

5.2 Collaborative research

In the TURBan project, a prototype small (2.5-kW) wind turbine with horizontal axis is in the test phase. This turbine has a 2.3-m rotor diameter and is designed for a 10 to 15 m high tower (Figure 11).

Also the wind offshore atlas project is under way. Its offshore measurement campaign has been going on in Berlenga Island, since November 2006. New sites for offshore measurements are also under study along the Portuguese coast.

6.0 The Next Term

During 2008, the Portuguese Wind Atlases (Onshore and Offshore) will be further developed and updated. The Portuguese Wind Atlas

Figure 11 The TURBan 2.5-kW horizontal axis prototype, developed by INETI and installed in the Gardens of S. Bento Palace, the official residence of the Portuguese Prime Minister.

(onshore) will incorporate detailed data at the municipality scale and apply methodology applicable to several foreign countries, especially from Africa and Eastern Europe. Also the offshore wind atlas project will be continued. It will include the data obtained in the measurements campaign of 2007 and will study new methodologies for offshore resource assessment.

The urban wind energy sector is now a high priority, representing a new business opportunity for the wind energy sector. This opportunity demands new methodologies for urban wind resource assessment. It also requires continued development of simple methods to reliably estimate wind energy production in very complex terrain. These are good prospects for R, D&D during 2008.

It is expected that 2008 will be the year when the offshore wind feasibility studies will begin with measurements over the sea along the Portuguese Atlantic coast.

References:

(1) Source General Directorate for Geology and Energy (DGGE).

(2) Source REN – Rede Eléctrica Nacional.

Author: Teresa Simoes, Liliana Madeira and Ana Estanqueiro, Department of Renewable Energies, INETI – Instituto Nacional de Engenharia, Tecnologia e Inovação.

Chapter 26
Spain

1.0 Introduction

Wind energy installations in Spain reached a new record during 2007. Capacity installed in 2007 was 3,522 MW, twice the 1,524 MW installed in 2006. The capacity installed in 2007 is even greater than the previous record during the year 2004. The growth of wind power in Spain in 2007 has been the second largest in the world market.

By January 2008, the total capacity was 15,145 MW according to the Wind Power Observatory that includes the data supplied by promoters and manufacturers (1).

In relative terms the new capacity put into the system during the last year means a growth of 30% of the total capacity, in comparison with the 18% corresponding to the year 2005 or the 16% during the year 2006. This strong performance is a key step to achieve the objectives of the Spanish Renewable Energies Plan (PER) which expects to reach 20,155 MW of wind energy at the end of 2010 (2).

One explanation for this strong growth is the new favorable regulations for wind farms put in operation before 2008. For instance, after 2008 wind farms must satisfy the new grid code PO.12.3 referring the behavior of wind turbines during voltage drops.

The Spanish demand for electric power reached 260,838 GWh, which represents a growth of 4% over 2006. Wind energy met 10% of this demand and was the fourth largest contributing technology in the generation system, besting hydropower (9% of demand). The other contributors to the system were coal power plants (25% of demand), natural gas (24%), and nuclear energy (20%) (3). Figure 1 shows the structure of the electricity system in Spain during 2007.

During 2007, the demand for power and energy reached new highs in Spain and wind energy made significant contributions to supply. The average hourly demand for power rose to 45 GW on December 18, and on that day wind energy supplied up to 6 GW. On several occasions wind energy has covered 30% of the hourly demand, and for several days supplied more than 20% of the daily demand for electricity. For instance, on March 19, wind energy supplied a record 23.2% of the demand for the day.

Wind energy in Spain has also emerged as a driving force for industrial development. In 2007, investment was more than 5,000 million €, and around 50% of the Spanish wind energy equipment production is dedicated to the export market. Jobs resulting from wind power reached 45,000 in 2007. Of this total, direct jobs in operation and maintenance of wind farms, manufacturing, assembly, research, and development is estimated at more than 18,000, while indirect jobs linked mainly to components is estimated to be more than 27,000.

Finally it is important to point out the important 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 regulation systems have been able to regulate and optimize system management with very low costs.

2.0 Progress Toward National Objectives

The present objectives for 2010 for the promotion of renewable energies are contained in the Plan of Renewable Energies (PER) 2005-2010 "Spanish Renewable Energy Plan" (2). This plan is a revision of the previous one (the last revision was completed in 2002). The aim of

Table 1 Key Statistics 2007: Spain	
Total installed wind generation	15,145 MW
New wind generation installed	3,522 MW
Total electrical output from wind	27.026 TWh
Wind generation as % of national electric demand	9.8%
Target:	20,155 MW by 2010

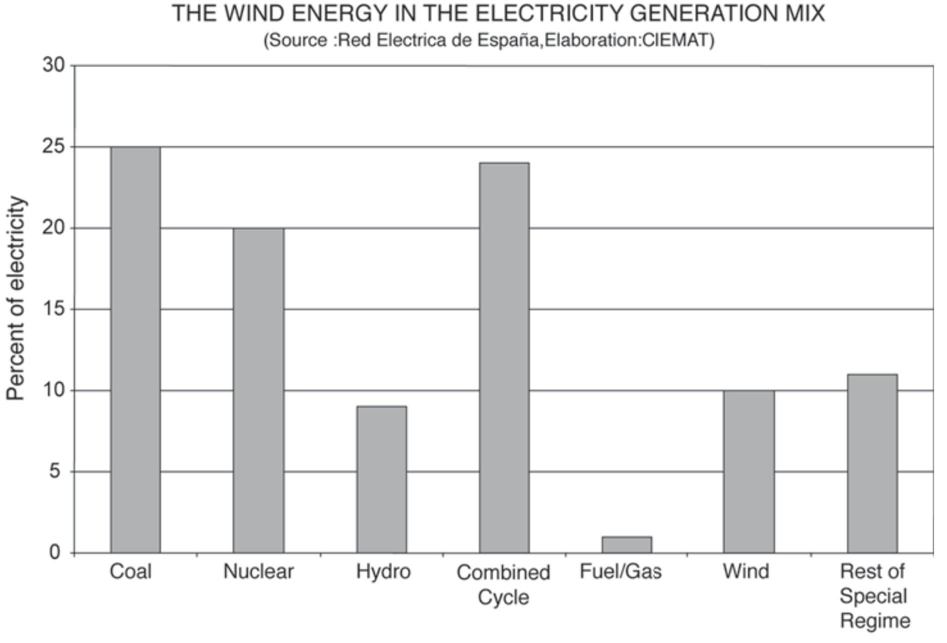

Figure 1 The electricity generation system in Spain, 2007.

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. With the new 3,522 MW installed in 2007, an important step was taken to achieve the objectives of the PER. In fact, growth of only 1,700 MW per year will meet the final objective. Developers, manufacturers, and auxiliary firms consider the 20,155 MW target well within reach. Figure 2 shows the annual cumulative wind capacity according to the PER 2005-2010.

The strength of the wind energy sector and its continuous growth has created the expectation of new targets for the next term. There is a consensus to fix a new target of 40,000 MW for 2020. The power installed in Spain during 2007 implies a growth rate of 30% as shown in Figure 3. Several factors have contributed to the accomplishments and expectations.

The majority of the Autonomous Regions (that have the responsibility for regulating wind installations) have plans which imply reaching 39,000 MW between 2010 and 2020. The main reasons considered by the local governments are related to energy pacification, local resource use, industrial development, and job creation in their zones.

The industrial sector participating in the Asociación Empresarial Eólica AEE (The Spanish Wind Energy Association) has established a new objective of 40,000 MW for 2020. 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 — 20% of the primary energy with renewables by 2020. Due to the solidity of the sector, it is likely that an important amount of the renewable objective will be covered by wind energy.

Electrical generation capacity nationwide reached over 92 GW at the end of 2007, with over 10% growth compared to 2006. Combined cycle and wind power are the technologies that contributed the most to this growth of total capacity. With the new installed wind power in 2007, there are more than 16,000 turbines operating in Spain. They are grouped in 672 wind farms. The average size of an installed wind farm in 2007 was 26.4 MW.

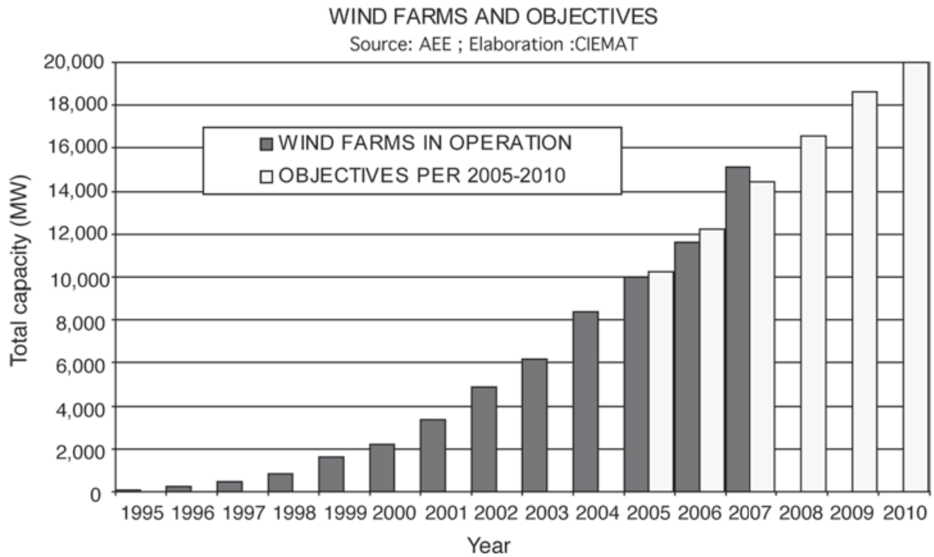

Figure 2 Wind farms in operation and objectives for 2010.

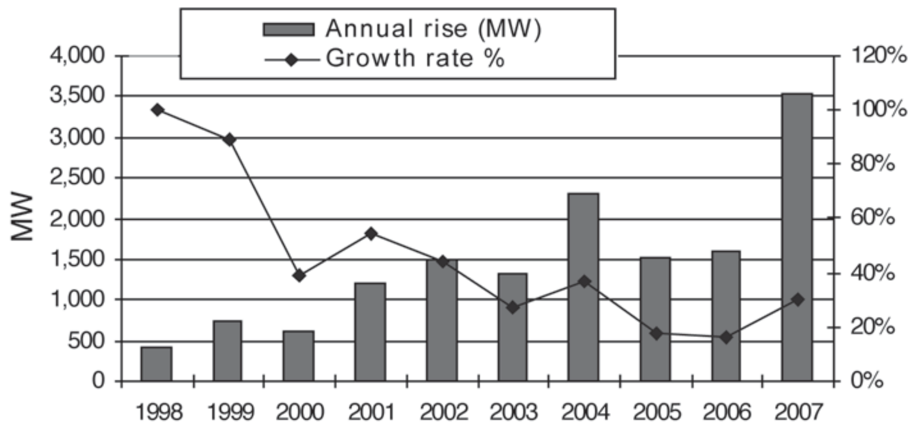

Figure 3 Annual growth of wind power.

Wind energy is present in fifteen of the seventeen Autonomous Communities, and Castilla La Mancha has the most installed power among them. Figure 4 shows traditional windmills still operating in La Mancha. Only two Autonomous Communities have not yet installed wind power, 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. Table 2 and Figure 5 show wind energy developments by regions and the annual growth.

In absolute terms, Andalucia and Castilla La Mancha are the regions where more capacity was installed in 2007, with 853 MW and 850 MW respectively. In percentages, the largest growth was in Andalucia with growth of 140% and total capacity reached 1,459 MW. Castilla La Mancha has the most capacity with 3,131 MW total and 37% growth, overcoming Galicia where more than 2,900 MW are operating and growth was 12.6%. Castilla y Leon increased to 2,818 MW and grew 32%. Aragon now has more than 1,700 MW.

Wind power has lowered CO_2 emissions by about 18 million tons just during 2007.

Figure 4 Old wind mill in La Mancha.

Furthermore, wind generation has saved up to 50 million tons of conventional fuels. It is estimated that more than 127 million tons of CO_2 emissions will be avoided over the 2005–2010 period thanks to wind energy generation in Spain. The new National Plan of Assignations 2008–2012 will mean wind generation will save more than 400 million €, assuming emission rights price of 20 € per ton.

3.0 Benefits to National Economy

3.1 Market characteristics

The number of installations during 2007 demonstrates the maturity of the wind industry, which has been able to increase despite worldwide difficulties with the supply of wind turbines and components. Installing and operating wind plants to cover 10% of the Spanish electrical demand implies a huge activity for the promoters and manufacturers.

In 2007, there was a tendency to consolidate holdings. The largest companies have accumulated the farms they put into the network and some companies are being acquired by others. Nevertheless new agents also appeared in the Spanish market as promoters and manufacturers.

Wind farm promoters are mostly utilities, civil works companies, and venture capital organizations. The large Spanish utility Iberdrola had the largest growth in capacity in 2007, increasing its wind generation by more than 670 MW and reaching a total of 4,245 MW. Acciona Wind Power (a company which began with civil works activity) is the second largest promoter with 2,678 MW in operation in Spain and a growth of 676 MW during 2007. The utility

Table 2 Wind Power Growth by Regions				
Autonomous Community	Total 01/01/2007 MW	Installed 2007 MW	Total 01/01/2008 MW	Growth 2007/2006 %
Castilla-La Mancha	2,281.46	849.90	3,131.36	37.25%
Galicia	2,619.64	332.05	2,951.69	12.68%
Castilla y León	2,122.91	695.76	2,818.67	32.77%
Aragón	1,532.44	191.10	1,723.54	12.47%
Andalucía	606.56	853.15	1,459.71	140.65%
Navarra	916.36	21.00	937.36	2.29%
Comunidad Valenciana	333.99	256.95	590.94	76.93%
La Rioja	436.62	10.00	446.62	2.29%
Cataluña	225.30	122.14	347.44	54.21%
Asturias	198.86	79.10	277.96	39.78%
País Vasco	144.27	8.50	152.77	5.89%
Murcia	67.72	84.59	152.31	124.91%
Canarias	133.24	0	133.24	0%
Cantabria	0	17.85	17.85	0%
Baleares	3.65	0	3.65	0%
TOTAL	11,623.01	3,522.09	15,145.10	30.3%
Source: AEE; Elaboration CIEMAT				

company Endesa through its subsidiary company ECYR is next with a total capacity of 1,267 MW, and 347 of them have been installed during the last twelve months. The largest percentage growth, 58%, goes to Neo Energia, a company with a strong presence of the main utility from Portugal. The company has installed 447 MW, for a grand total of 1,223 MW. Olivento (a company with participation from Australian societies) grew by 56% with a total of 150 MW in Spain. Eufer (with participation of the utility Union Fenosa) grew more than 50% by adding 198 MW to reach total capacity of 594 MW. Figure 6 shows the distribution of wind energy promoters in Spain.

Several other organizations have installed wind power capacity during 2007. For instance, Forlasa, a group of companies operating in the dairy meat and beverage sectors, now operates 3% of the wind power capacity; Medwind has 1.6% of the total; Eolia has 1.3%; and Eolica De Navarra has 1.2%.

It is worth mentioning the development work of Gamesa, which processes, builds, and hands over each year many wind farms to other companies. It does not show in statistics of owners. Gamesa delivered more than thirteen wind farms to its clients in 2007, equaling 329 MW and making the company one of the main developers of wind projects.

Spanish companies also have important activities in the international market. Iberdrola, for instance, is an important global wind promoter, with a strong presence in the markets of Ireland and the United Kingdom. Acciona also has an important international activity; it just began operating a new factory in the United States (the fourth factory in operation after two factories in Spain and one in China). The company recently commissioned the Tatanka wind farm in the United States with a total capacity of 180 MW.

3.2 Industrial development and operational experience

The important growth of wind power capacity during 2007 reveals an open market, with a larger presence of new providers, until now missing in Spain; but that has not affected the dominance of the main manufacturers. For

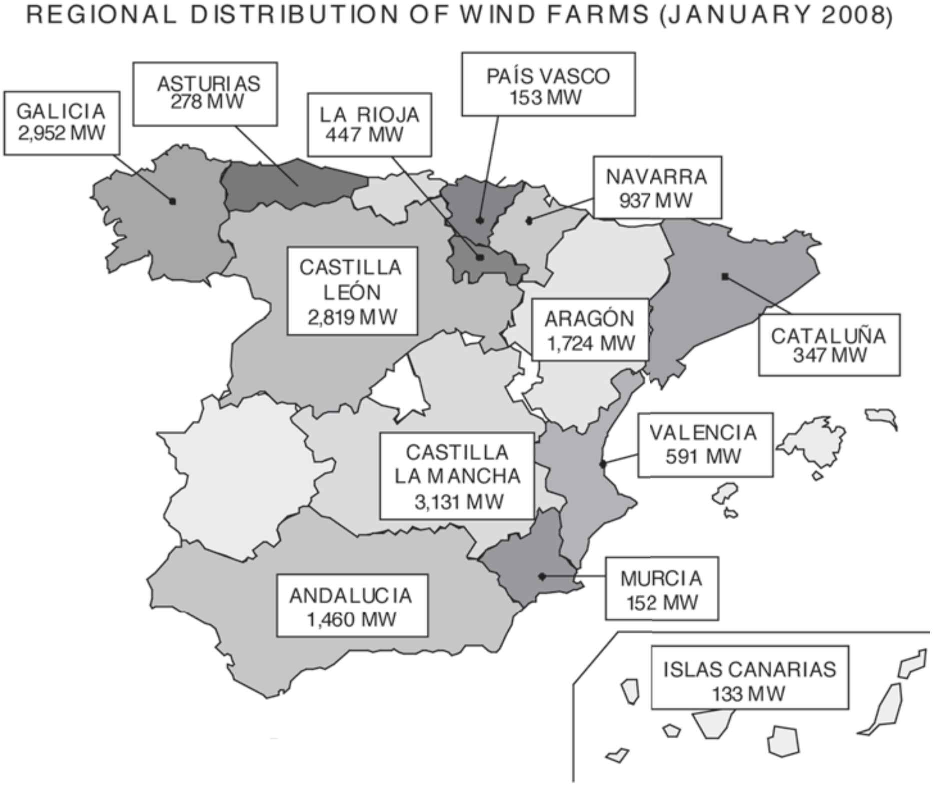

Figure 5 Regional distribution of wind farms.

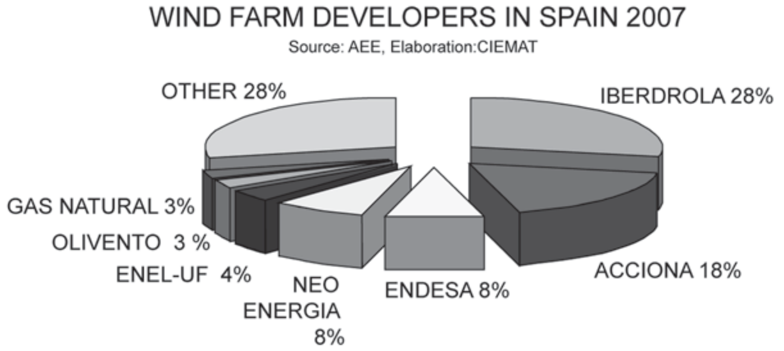

Figure 6 Installed wind capacity in 2007 by developer.

example, Gamesa installed 57% of the new capacity (including the subsidiary company MADE) in Spain, according to the Wind Power Observatory from the AEE. In 2007, Gamesa put 1,670 MW into operation compared with 700 MW in 2006, which consolidates its leadership among manufacturers. This important growth came in a year of consolidation of foreign markets that demanded a choice for export, while local production of machinery and spare parts was consolidated as well (Figure 7).

The second largest manufacturer considering installed capacity in 2007 was Vestas, with almost 700 MW. This is more than three times the capacity installed in 2006 by Vestas. This demonstrates the company's keen interest in the Mediterranean markets, and particularly in Spain. This interest is further supported by the announcement of plans to build a blade factory in central Spain with a total capacity of more than 1,000 MW per year. This will bring about 500 new direct jobs.

Acciona has also experienced important growth, with more than 670 MW put into operation last year (more than double that of 2006) for a total capacity of 1,240 MW in Spain. Acciona began with experience in the operation and maintenance of wind farms and is now one of the manufacturers with a major international image.

Ecotecnia installed around 150 MW during 2007, and it has 1,100 MW in operation in Spain. Ecotecnia is part of the French group Alstom.

Siemens through an agreement with the Spanish company Navantia put in 149 MW for a total capacity of 600 MW.

GE installed more than 100 MW for a total capacity of 890 MW, and Enercon installed 68 MW in 2007, an increase of 180%.

Figure 8 shows a modern Spanish wind farm.

The number of wind turbines in Spain increased by more than 2,200 in 2007, and the total number turbines is 16,000 units. Most of the new generation installed (42%) have a rated power of 2 MW. The rest are rated at 1.5 MW (26%) and 850 kW (16%).

The average size of a wind turbine installed in 2007 was 1.6 MW. The total electricity generated by the wind farms was over 27,000 GWh, and the equivalent hours at rated power were slightly higher than 2,000 hours for all of the wind farms. Wind turbines operating in Spain show important seasonal behavior as shown in Figure 9.

3.3. Economic details

The increasing use of large wind turbines (2 MW of nominal power), the increasing of prices of raw materials, the shortage of main components, and the excess demand for wind turbines have increased the prices for wind generators. The average cost per kilowatt installed during 2007 in Spain was around 1,250 €/kW.

4.0 National Incentive Programs

The promotion of renewable energies has been a stable national policy for several years. All political parties have kept similar policies regarding support to 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. Producers of renewable energy are entitled to receive remuneration in return.
- The Renewable Energy Plan including mid-term objectives for each technology (PER 2005-2010), and the tariff scheme are guaranteed until the fulfillment of targets.
- The Royal Decree 661/2007 regulates the price of electricity from renewable sources in Spain. The new regulation is in force since June 2007. Wind farm

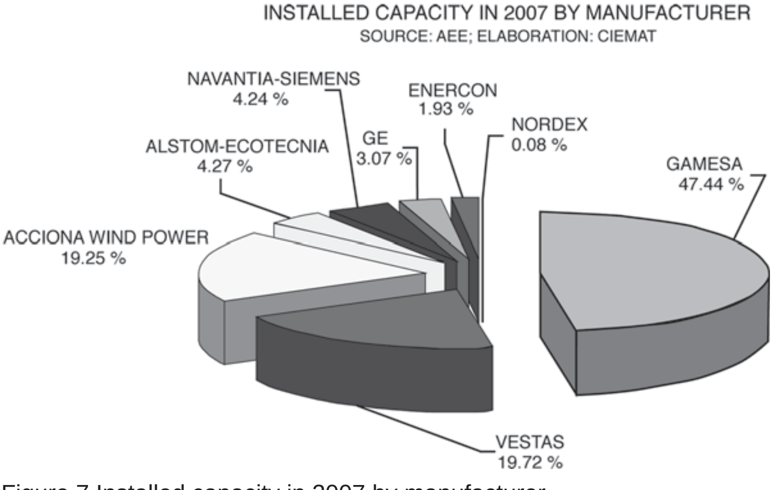

Figure 7 Installed capacity in 2007 by manufacturer.

Figure 8 Photo of a characteristic Spanish wind farm in Galicia (NW Spain).

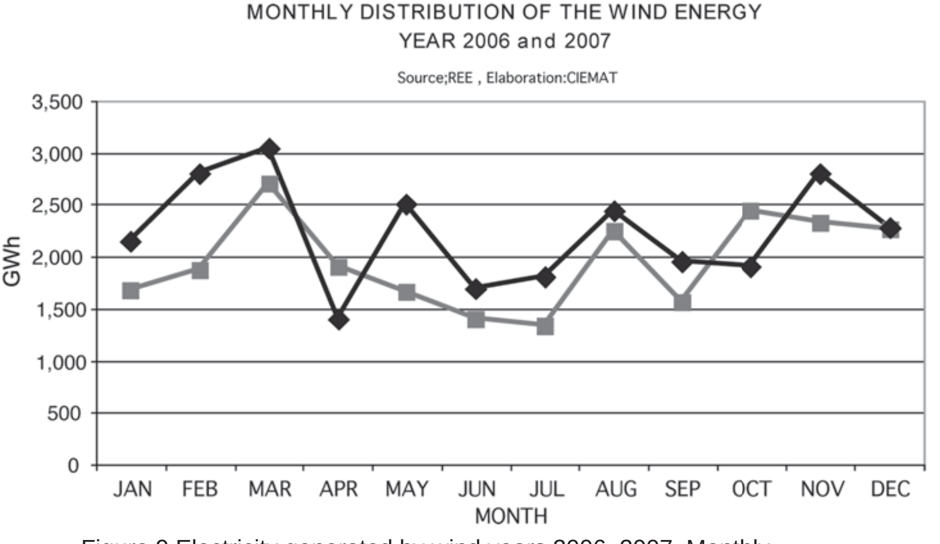

Figure 9 Electricity generated by wind years 2006–2007. Monthly distribution.

installations governed by previous regulations (RD 436/2004) have until January 2009 to decide whether they will continue to follow RD 436 or choose the new RD 661/2007.

To facilitate the integration of wind energy into the grid, supplemental incentives are based on technical considerations: reactive power and voltage dips (only for the existing wind farms, after January 2008 it is mandatory to satisfy the Grid Code PO.12.3).

The payments for electricity generated by wind farms in Spain is based on a feed-in scheme. The owners of wind farms have two options: a regulated tariff scheme or a market option. In the regulated tariff scheme, the payment for electricity generated by a wind farm is independent of the size of the installation and the year of start up. For 2008, the value is 75.68 €/MWh and the update is based on the Retail Price Index minus an adjustment factor. For the market option, the 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 in order to guarantee the economic viability of the installations and an upper limit (floor and cap). For instance, the values for 2008 are: reference premium 30.27 €/MWh, lower limit 73.66 €/MWh and upper limit 87.79 €/MWh. The price of wind electricity versus the market price is shown in Figure 10. The feed-in scheme will be valid until fulfillment of the PER objectives in 2010 (20,155 MW). An additional 2,000 MW are considered for repowering wind farms built before December 2001, and an extra bonus of 7 €/MWh is considered.

For offshore installations, only the market option is available with a maximum premium of 84.3 €/MWh over the market price and the maximum price to be paid (cap) will never exceed 164 €/MWh. No lower limit is defined. A new regulation for offshore wind energy is defined in the new RD 1028/2007 published in August 2007. It established the administrative procedure for processing requests for power generation installation authorizations in Spanish waters. Several off-shore wind farm projects are at the initial design and basic engineering stage off the South and East coasts of Spain. They add up to a total of 2,000 MW.

The market price of electricity in Spain during the years 2006 and 2007 is shown in Figure 11.

5.0 R, D&D Activities

The PER 2005–2010 makes an exhaustive analysis of the technological innovation required to achieve its objectives. In the case of wind energy, the priority for the Spanish manufacturers is to make efforts leading towards 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.

One of the instruments to increase the R&D activities is the CENIT Program carried out from the Center for Industrial Technological Development (CDTI) from the Ministry of Industry and Energy. The CENIT Program is a Spanish government project 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 there are two approved projects: Windlider 2015 and Eolia.

Windlider 2015 is an industrial research project led by Spanish turbine manufacturers Gamesa and Ecotecnia. Its objective is to keep Spain at the cutting edge of wind power technology. Specifically, the project involves the design of new high-power machinery. Windlider 2015 has received a 13-million-€ grant, almost half of the 28.5 million € estimated total investment required. The project's objectives are the following:

- Improve the design process of future turbines, reducing 'time to market' and increasing maturity of the first series, considered vital to leading the market as of 2012;
- Boost Spanish-owned enabling technologies;
- Create a holistic simulation model that reproduces as faithfully as possible the behavior of future turbines and determines the

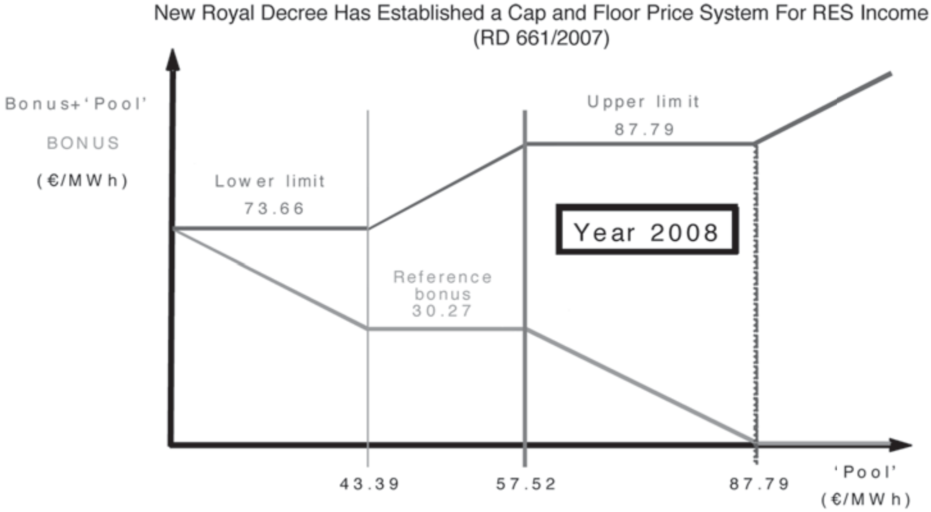

Figure 10 New regulations for the payment of electricity from wind plants.

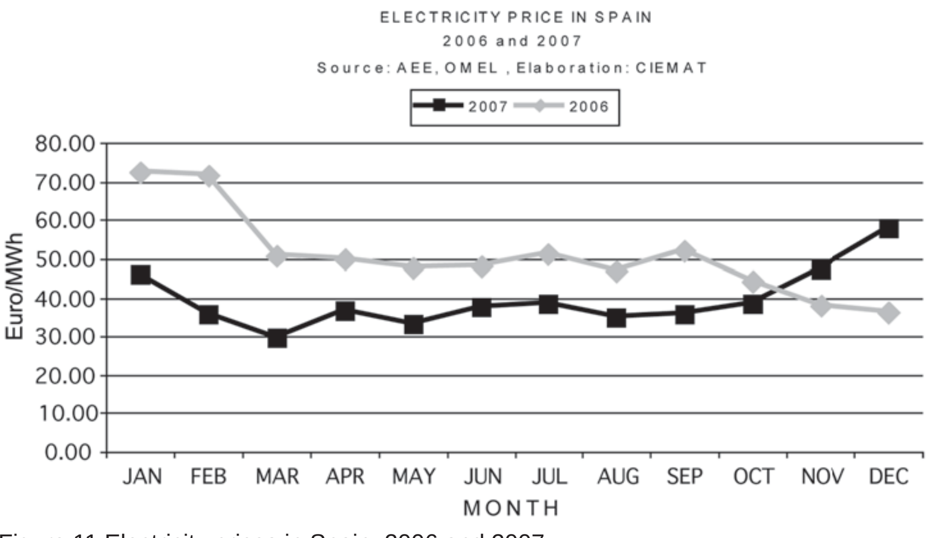

Figure 11 Electricity prices in Spain, 2006 and 2007.

effect of new configurations, new enabling technologies, and other factors on turbine performance;

• Deploy several mid-sized technological-scientific infrastructures in Spain that permit experimentation in scales up to 5 MW with complete turbine prototypes and critical components (generators, gearboxes, converter, chassis yaw, etc.).

Another R&D project is Eolia, a consortium of 16 companies led by Acciona Energia. The project has been approved by the CDTI for a 16.7 million € grant, over half the overall 33.9 million € requirement. Eolia includes 25 research centers and 7 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) aquiculture, desalination, construction, and naval technologies.

The Program for the Promotion of Technical Research (PROFIT) is an instrument through which the government makes calls for proposals for publicly-funded projects aimed at encouraging companies and other entities to adopt research and technology development activities. The program is in line with the objective established in the National Plan of Scientific Research, Development and Technological Innovation 2004–2007, in the part dedicated to promotion of technological research. The National R&D and Innovation Plan 2004–2007 set a series of objectives aimed at contributing to the general development of the science-technology-company relations. The energy objectives of PROFIT are:

- To use R&D to guarantee economically viable and environmentally friendly energy supply, based on efficiency and quality criteria, employing conventional energy sources and introducing technologies to optimize their use and
- To facilitate scientific and technologic resources contributing to the efficient and competitive deployment of renewable and emerging energy technologies, together with their improved integration within the electricity system.

During 2007 the following projects were approved.

- Hydrogen storage pilot system for regulating feed-in of wind power generation,
- Manufacturing processes optimization for laminated rims,
- Advanced control systems and automatic turbine tower cleaning systems design,
- Nanotechnology applications to improve wind plant yields,
- Lighter-weight turbine components development based on component design, improved materials, and new molding techniques,
- Floating wind-hydraulic hybrid platform for a sustainable solution to water and energy demand,
- Prefabricated concrete tower development and specific manufacturing and assembly processes for large turbines,
- Systems development for designing, manufacturing, and installing prefabricated concrete turbine towers,
- Data acquisition methods at sea for offshore wind power viability study,
- Mixed wind power system development with both grid connection and connection to an electrolyzer for producing and storing hydrogen for use in a combustion motor grid-connected generator,
- Anti-ice systems development for conventional turbine blades in existing wind plants,
- Socio-economic implications of offshore wind development along the Spanish coasts,
- Distributed micro-generation based on renewables and smart demand management,
- Off-shore wind power resources evaluation and prediction,
- Systems of reactive current injection for special electricity regime (Regimen Especial) generators.

The PSE Projects are Strategic National Consortiums for Technological Research lead by the industrial sector. In the field of wind energy, a project called Minieolica is developing to promote the Spanish small wind energy sector (new developments up to 100-kW wind turbines). The project is 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 20 kW and 100 kW;
- Technical development breaking technological barriers and advancing the technological development in key areas for small wind turbines (SWTs);
- Infrastructure development activating and supporting the SWT sector. The objective of this area is the promotion, dissemination, sensitization, and information collection for the SWT sector.

An important role in the coordination and definition of the Spanish R&D activities in wind energy it is carried out by the Wind Power Technological Platform Reoltec. Reoltec was created with the support of the Spanish Ministry of Education and Science to define priorities, as well as the procedures for optimizing the acquisition of the forecasted results.

6.0 The Next Term

The expectations for the Spanish wind energy industry for 2008 are very high. It is likely that by the end of the year, 17,000 MW of total capacity will be installed. This amount represents 85% of the objectives defined in PER 2005–2010 that established a target of 20,550 MW by the end of 2010. When the target is reached, a revision of the tariff scheme will be in order.

The electricity prices will be increasing during the next year and could exceed 70 €/MWh (especially if the decreasing contribution of hydropower to the system continues).

During 2008, increased installation costs are expected. The global wind energy market and the shortage of components and materials could influence this.

One of the main challenges for the industry during the next year is to complete the regulations for the Grid Code. Grid management has been reformed and every wind farm is assigned to a control centre, which makes the feed-in more transparent.

With joint effort between the system operators 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 in order to include the objectives of the European Union for the year 2020. A realistic estimate for wind energy in Spain would say 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.

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Chapter 27
Sweden

1.0 Introduction

For Sweden, 2007 was a record year for new wind energy installations. The new generation installed in 2007 was 217 MW. This number should be compared to previous years with annual installation rates of around 50 to 60 MW. The installation rate in 2007 was thus four times higher than in previous years. Much of the new capacity in 2007 came from the Lillgrund offshore wind farm consisting of 48 2.3-MW turbines for a total generating capacity of 110 MW. The installation rate is expected to increase further. The trade organization Swedish Wind Energy expects over 300 MW to be installed in 2008, making Sweden a member of the 1-gigawatt club.

2.0 Progress Toward National Objectives

2.1 Swedish energy and electricity mix

The Swedish energy end user consumption in 2006 (the most recent year with available data) was 405 TWh. The consumption is divided into industry use of 157 TWh; transport of 101 TWh; and residential, services, and so on of 145 TWh. The total energy supplied was 624 TWh. The difference between the consumption and production numbers represents losses and use for non-energy purposes. The largest part of the losses, 126 TWh, are from nuclear power production. The electricity production was 140.1 TWh in 2006. This is lower than normal due to a dry year with low hydropower production and several unplanned stops of nuclear reactors. This also caused high electricity prices in 2006 as noted in the *2006 IEA Wind Energy Annual Report*.

In 2007, electricity production was 144.6 TWh and electricity imported was 1.3 TWh. The distribution losses in the whole electricity system are around 11 TWh. The production mix is shown in Figure 1. About 9.6 TWh out of the "other thermal" production of 13.3 TWh was based on bio-fuels, making the renewables – bio-fuels, wind, and hydropower – 53% of electricity production.

2.2 Goals for wind power

Figure 2 shows the evolution of installed wind generation capacity in Sweden. In 2002, the parliament adopted a planning goal for wind power output of 10 TWh/yr by 2015. In principle, this means that wind energy should be considered in the spatial planning process such that it will be possible to actually build enough wind power to produce 10 TWh/yr by 2015. For production, there is no goal for wind energy on its own. The production goal in the electricity certificate system applies to new renewable energy in general as described in Section 4.0.

The EU has adopted a goal that 20% of the energy consumption should come from renewable energy by 2020. This goal will be apportioned among the member states. In Sweden, during the coming decades wind energy will likely be one of the main contributors for increasing renewable energy in the generation mix. In 2007, the Swedish Energy Agency, on commission of the government, proposed new planning goals for 2020. The planning goals were set with the overall 20% EU renewables goal in mind and the fact that a cost-effective increase of renewable energy in Sweden will require a substantial increase in wind energy production.

The Swedish Energy Agency conducted analyses which found it reasonable for Sweden to plan for the production of 30 TWh of wind power by 2020. The purpose of the planning is

Table 1 Key Statistics 2007: Sweden	
Total installed wind generation	788 MW
New wind generation installed	217 MW
Total electrical output from wind	1,429 GWh
Wind generation as % of national electric demand	1%
Planning Target	10 TWh in 2015 (Only target for planning)

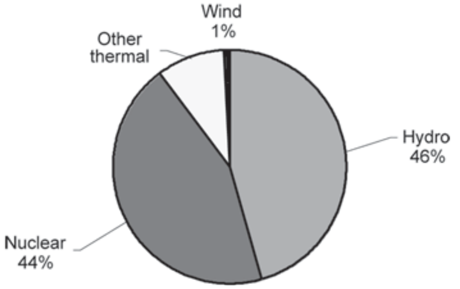

Figure 1 Electricity production mix in Sweden 2007.

to create "room" for wind in the general public planning (e.g. spatial planning and grid planning) to reach the production goal for 2020. The Swedish Energy Agency further suggested that planning should be for 20 TWh onshore and 10 TWh offshore. With the current quotas in the electricity certificate system, it is estimated that wind energy will contribute approximately 7 to 8 TWh in 2015. Without a change in quotas in the electricity certificate system, further expansion by 2020 will be marginal. However, increased quotas can work as an effective way to increase the share of renewable electricity, and wind energy will likely be a major contributor to increased renewable electricity production. The Swedish Energy Agency further noted that even though the electricity certificate system likely will work to increase wind energy on land, nothing will happen in the near future offshore unless additional support is given. The Agency will therefore look at suggestions for a dedicated support for offshore wind.

2.3. Need for changes to the legislation

A change in quotas in the electricity certificate system or other economic support systems will be needed to reach a level substantially larger than 8 TWh by 2020. In addition to such changes, the permit procedure needs to run smoother and changes in the electricity act are needed. Today several permits are required for a single application according to the Environmental code, the Planning and Building Act, the electricity act, and sometimes other regulations. This results in several different trials, even though it essentially is the same assessment that is made, with possible multiple appeals and long times from first application until permits are obtained.

The government has therefore established an inquiry to look over the legislative process and make suggestions for changes. The inquiry will put forward its suggestions at the end of 2008. Another inquiry for the net-connection for renewables recently put forward its suggestions for changes to the legislation and procedures coupled the electricity act. The inquiry found that there is a need to solve certain bottlenecks in the electricity network to make it easier to expand the network in an economically sound way. Specifically, the issue of step-costs occurring in the financing for upgrading networks needs to be addressed. The inquiry therefore proposed the creation of a grid investment fund to finance investments in the electricity grid for future renewable energy developments. It was suggested that the fund be financed via network companies and be shared according to

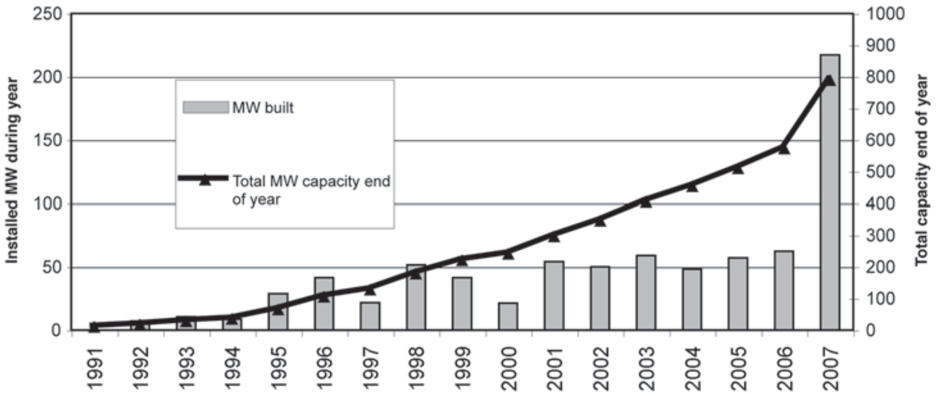

Figure 2 Installed wind power capacity since 1991.

each company's underlying electricity consumption by end customers.

3.0 Benefits to National Economy

3.1 Market characteristics

Vattenfall built the 110 MW Lillgrund wind farm in 2007, and the consortia Vindpark Vänern will complete construction of the 30 MW park in lake Vänern in 2008. A number of other offshore sites have already obtained permits or are in the permitting process. However, there is no further purchasing since onshore investments are currently more economically beneficial.

The expansion on land is driven partly by the large utilities like Vattenfall and E.ON but also by other actors. Many project developments are in forested areas with actors establishing land lease contracts with large forest owners. One such agreement has been reached between the Norwegian utility Statkraft and the paper company and large forest owner SCA. Statkraft and SCA's plans are to develop and build 2,800 GW. Another actor is Vindin which is owned by a group of large, electricity-intensive industries in Sweden (forestry, steel, chemical, and mining industries). The intention is to build projects for the production of one TWh/year, largely using land that companies in the group have in their possession. RES Skandinavien recently signed contracts with Vestas to build the 95.4-MW wind farm Havsnäs in the northern part of Sweden.

Apart from the companies mentioned above a number of companies such as utilities, developers, and real estate companies as well as private persons have smaller and larger projects in the planning phase. Of these, many of the larger onshore projects (over 25 MW each) have already obtained permits and will have a total production capacity of over 1.5 TWh.

Of the erected 217 MW in 2008, Siemens obtained a market share of around 50% with the Lillgrund park. Vestas and Enercon each had a share of around 23%, and WinWinD had a share of around 3%.

3.2 Industrial development and operational experience

Some manufacturers of small wind turbines are operating in Sweden. The large, international manufacturers Vestas, Enercon, and Nordex have sales offices in Sweden.

On the component side (supply chain) for wind energy, 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), and EWP Windtower Production. Other companies worth mentioning are Oiltech (hydraulic systems and coolers), Nexans (cables), and ESAB (welding equipment). The subcontractors are multi-national companies as well as smaller entities that find the wind power market relevant to their know-how.

One company, Dynawind (a subsidiary in the Morphic Group), has started manufacturing towers for the Finnish turbine manufacturer WinWinD and also markets the WinWinD turbines in Sweden. Morphic is also starting to market a 20-kW turbine of its own design and will be testing it with a wind-hydrogen system.

3.3 Offshore construction

Three offshore projects have been partly funded with support from the market introduction program as described in Section 4: Lillgrund, Utgrunden II project, and Kriegers Flak. The market introduction program will also support the Vindpark Vänern project to be built in the largest lake in Sweden.

The Lillgrund 110-MW offshore wind farm was put in operation in 2007. The project consists of 48 Siemens 23-MW turbines and a main transformer on a separate platform. They are erected on gravity foundations built in Poland by a Danish-German joint venture Pihl-Hochtief and transported on barges to the Lillgrund site. The turbines have a hub height of 68.5 m and a rotor diameter of 93 m. Construction of the foundations started in 2006 and was finished during spring 2007. The internal offshore cables within the wind farm and the export cable were laid during summer 2007. The first wind turbine was erected on 3 August 2007. The last turbine was erected in October. The first wind turbine was connected to the grid and started to generate electricity on 4 October 2007, and all the wind turbines were in operation on 28 November 2007.

The project has been commissioned according to its initial time schedule, though it was delayed some months due to a weather stand still and authorities' procedures in the international

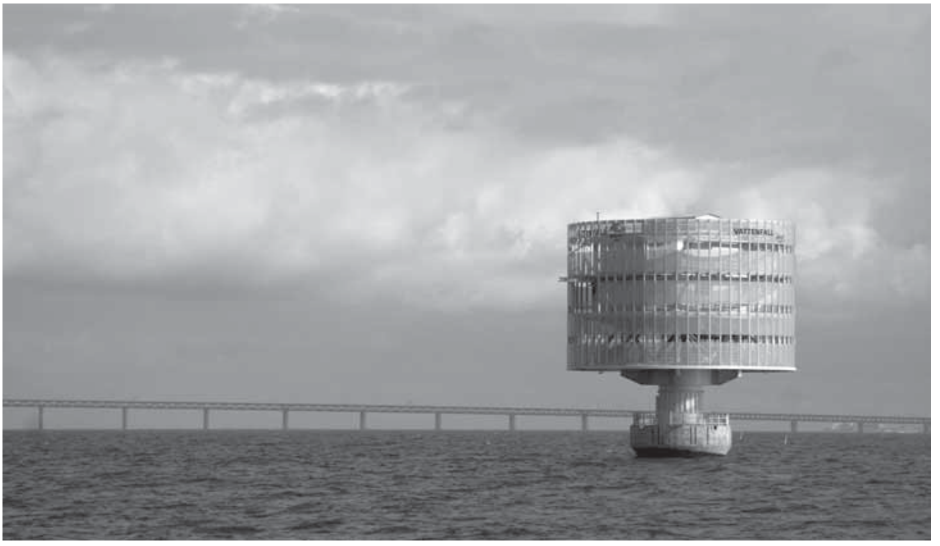

Figure 3 Lillgrund transformer station (Photo Hans Blomberg).

project during the first year of construction. The decided two-year construction schedule has shown to be successful. The Lillgrund plant started with a high-wind period and high electricity generation. At the end of January 2008 it had produced 110 GWh or 33% of a calculated normal year generation of 330 GWh.

For Utgrunden II, all the necessary permits are ready and construction was planned to start in 2007. However, in early 2007, the developer E.ON made the decision to postpone building the wind farm. Having received all tenders for the construction, the cost was considered too

Figure 4 Lillgrund from shore (Photo Hans Blomberg).

high considering their calculated revenue from the electricity and the certificates.

The Kriegers Flak project has received support for development studies. The studies are exploring different foundation principles, conducting risk assessment for ship safety, and studying how the wind farms influence marine currents. The studies will be reported in 2009.

Vindpark Vänern will be built in the lake of Vänern, the largest lake in Sweden with a total area of 5,600 km^2. The park is given financial support from the Swedish Energy Agency with 40 million SEK (3.7 million €) which is 9.5% of the total estimated investment of around 450 million SEK. The foundations were under construction in 2007. The water depth on the site is around 5-7 m. The concrete foundations are secured in the rock via 16 20-m-long pre-stressed anchors that surround each foundation. This makes it possible to have rather small foundations with minor influence on the bottom and on nature. The choice of construction method of the foundations is also affected by logistics and the fact that large construction vessels can not be shipped to the lake. Five of the ten turbines will be in operation during 2008 and the final five during 2009.

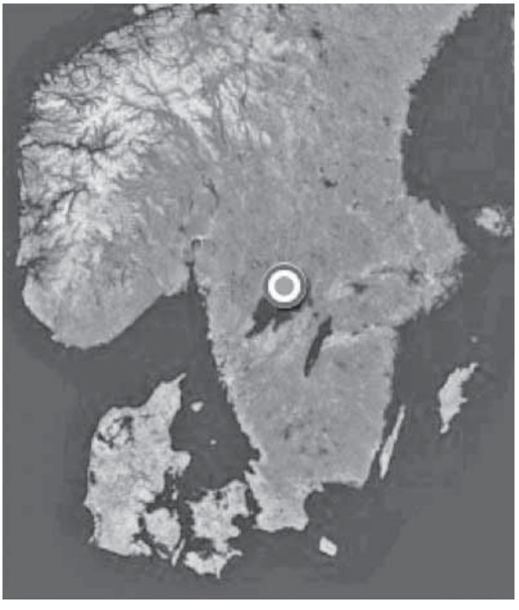

Figure 5 Lake Vänern and position of Vindpark Vänern.

3.4 Economic details

The average market electricity price on NordPool for the Swedish market area was 280 SEK/MWh (30 €/MWh). This is only 60% of the price during 2006 which was a dry year with high electricity prices. In 2007, the filling level in the hydropower reservoirs was normal to high, and the winter and fall of 2007 were warm, giving low prices in the electricity market. The average price of electricity certificates in 2007 was 195.4 SEK/MWh (21 €/MWh).

Prior to the introduction of the electricity certificate system, Sweden had a subsidy for wind power called the environmental bonus. This system is being phased out and will be removed after 2009. During 2007, the value of the environmental bonus was 40 SEK/MWh (4.3 €/MWh) onshore and 140 SEK/MWh (15 €/MWh) offshore. Figure 7 shows an average value of the total revenue for wind-generated electricity onshore in Sweden during 2007 (the price paid to a wind turbine owner can be slightly reduced to cover the balancing cost on the electricity price for the grid company). The sum is around 56 €/MWh. During 2006, the same number was 76 €/MWh.

Looking ahead, prices on the future markets for electricity and electricity certificates indicate higher prices. For 2009, the price on the forward market for electricity is around 52 €/MWh and electricity certificates are in the range of 25 to 34 €/MWh. Prices fluctuate substantially in time but it seems likely that the sum of electricity prices and the price of electricity certificates will be substantially higher in 2008 and 2009 than during 2007.

4.0 National Incentive Programs

There are three main incentive programs for the promotion of wind power: electricity certificates; production support (the so called environmental bonus); and support for technical development in coordination with market introduction for large scale plants offshore and in artic areas. The work done in assessing areas of national interest for wind power can be considered as another incentive as well.

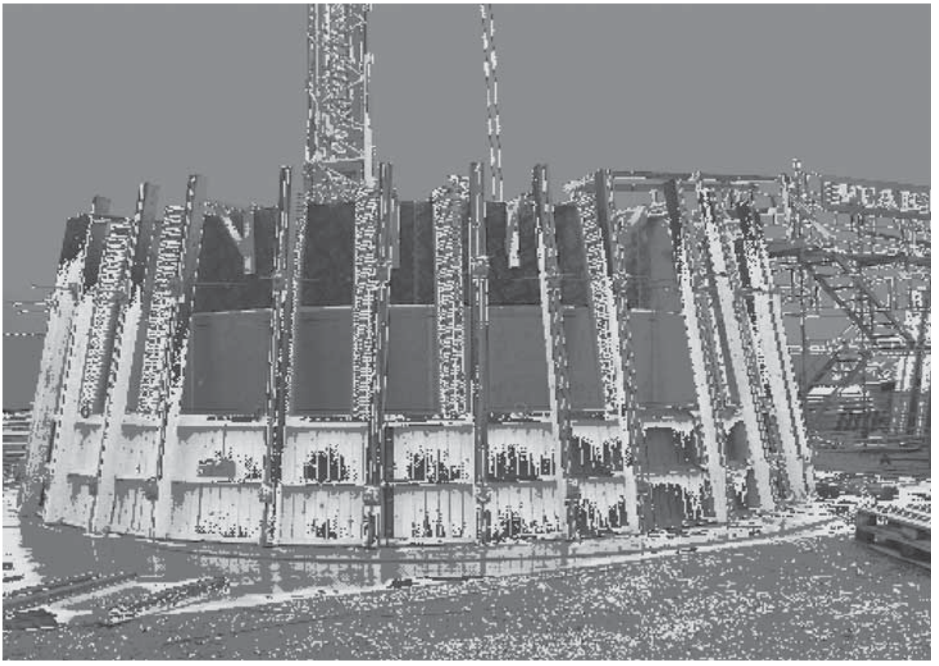

Figure 6 Foundation in preparation for casting.

4.1 Electricity Certificates

The national production target for renewable energy sources as a result of the EU directive 2001/77, implies an increase in the annual use of renewables in Sweden of 10 TWh from 2002 to 2010. The tool to meet the target is a quota-based system with electricity certificates. The system came in to force on 1 May 2003 and is intended to increase the production of renewable electricity in the most cost-efficient way. The annually increased level of the stipulated quotas (and the quota obligation fee) will drive the deployment of renewables where wind power will play a major role. The system replaces earlier public grants and subsidy systems. The principal idea 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 from the state a certificate for each MWh of renewable electricity that they produce. This certificate can be sold, to provide additional revenue above the sale of the electricity, improving the economics of electricity production from renewable energy sources and encouraging the construction of new plants for that purpose. The demand for certificates is created by a requirement under the act that all electricity suppliers and certain electricity users are required to 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. The price of certificates is determined by supply and demand, and can vary from one transaction to another. During 2007, the average price was 21 €/MWh.

The current aim of the system is to increase the level of renewable electricity by 17 TWh at 2016 relative to the 2002 level. A new production unit can receive certificates only for a period of 15 years. Old units therefore leave the system after 15 years. Around 2010 there is a "notch" in the quotas because a number of older production units are phased out of the system after 2012. Figure 8 shows the quotas and expected production.

The quota-based electricity production in 2007 was about 13.25 TWh divided into 9.6 TWh bioenergy, 2.2 TWh hydropower, and 1.4 TWh wind power. The increase in production from wind and hydropower was about equal in 2007 with wind increasing with 0.44 TWh.

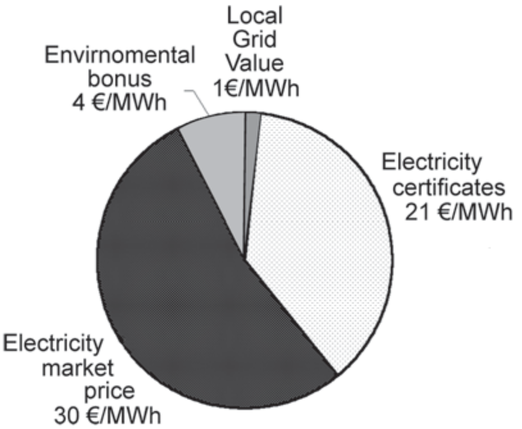

Figure 7 Breakdown of total revenue (56 € / MWh average) for a wind power plant during 2007.

4.2 Environmental bonus

The level of the environmental bonus is declining each year until 2009. It will go to zero after 2008 for onshore and after 2009 for offshore wind power. For 2007, the value was 20 SEK/MWh (2 €/MWh) onshore and 130 SEK/MWh (14 €/MWh) offshore.

4.3 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 for plants in Artic areas. The aim is to stimulate the market, achieve cost reduction, and gain knowledge about environmental effects from wind power offshore and in the arctic areas. For the years 2003 to 2007 the budget was 350 million SEK (around 38 million €). The market introduction is prolonged another five years with an additional 350 million SEK for the period 2008 to 2012. The Swedish Energy Agency will decide during 2008 on how the funding will be spent on different projects. The projects funded by the close of 2007 are shown in Table 2.

4.4 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. In the environmental code, different areas of Sweden are designated as areas of national interest for different kinds of land use. These are areas of national interest for fishery, mining, nature preservation, outdoor recreation, etc. The idea is to protect specific areas such that the specific national interest is not jeopardized. An area can be of national interest for several kinds of land use. In order to guard

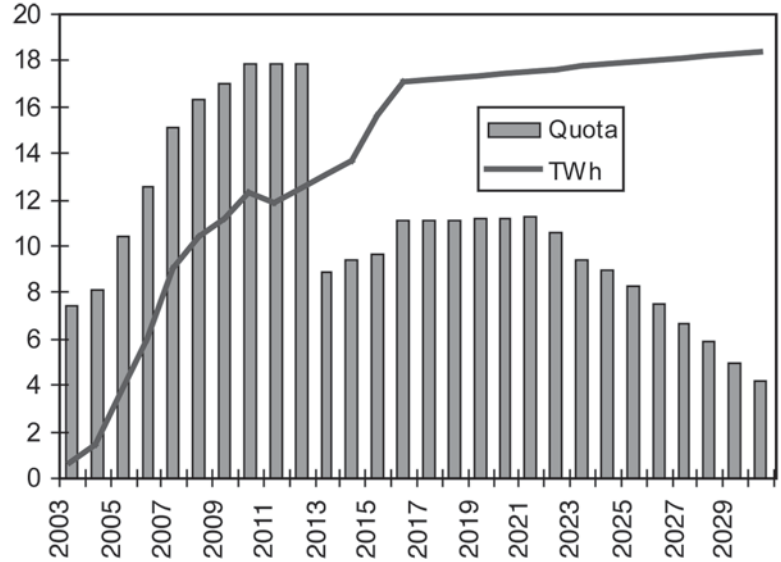

Figure 8 Quotas and production goal of the electricity certificate system.

Table 2 Projects with Support from the Market Introduction Program				
Project	Recipient company	Support	Location	Estimated production and estimated year of operation
Lillgrund	Örestads vindkraftpark AB (owned by Vattenfall)	213 MSEK (23 M€)	Offshore	330 GWh; operating since late 2007.
Utgrunden II	E.ON Vind Sverige AB	70 MSEK (7.6 M€)	Offshore	285 GWh; planned for 2008 but recently postponed.
Vindpark Vänern	Vindpark Vänern Kraft AB	40 MSEK (4.3 M€)	Largest Swedish lake	89 GWh; planned for full operation in 2009.
Uljabouoda	Skellefteå Kraft AB	35 MSEK (3.8 M€)	Onshore artic	100 GWh (2008).
Kriegers Flak	Sweden Offshore Wind AB (Vattenfall AB)	9.45 Msek (1 M€)	Offshore	No production. Only development program.
Vindval		35 MSEK (3.8 M€)		No production. Only research program.

the interest of wind energy, 49 geographical areas in 13 counties were pointed out as areas of national interest for electricity production from wind energy in 2004. New areas will be assigned during 2008.

5.0 R, D&D Activities

Publicly funded wind energy research is mainly carried out within the Vindforsk II and Vindval research programs.

The Vindforsk II program runs between 2006 and 2008 with a total budget of 45 million SEK (4.9 million €). Elforsk, the Swedish Electricity Utilities' R&D company, manages the program. Vindforsk II consists of two parts, one with basic research and one with applied research. Basic research projects are funded 100% by the Swedish Energy Agency, with a total budget of 18 million SEK (2 million €). Applied projects are funded 60% by Elforsk and 40% by the Swedish Energy Agency. The program is user-oriented and has a stronger co-operation between the utilities and the grid owners (including the Swedish TSO) than previous programs have had. Areas of research interests include grid integration, external conditions, standards, O&M, project development, and impacts on the environment and public acceptance. The two latter areas have their own research program, Vindval, where such issues are covered more thoroughly.

Six research projects on birds, fish, bats, and artificial structures were initiated during 2005 within the Vindval program. Vindval is a small part of a program called "market introduction and technology development program" which runs from 2003 to 2007. This program supports wind power deployment offshore and in the arctic areas, and is funded by the Swedish Energy Agency. The budget for Vindval is 35 million SEK (3.9 million €) for the five-year period 2003 to 2007. During the new round of the market introduction and technology development program, Vindval is likely to be prolonged during 2008 and new money assigned to the program.

Apart from projects in these programs, other R&D projects are also funded but such projects constitute only a minor part of the funding available during 2007. A group at the University of Uppsala is working on direct driven conversion systems for renewable energy. They work on implementation for wind power, wave power, and power from streaming water. For wind they are working on direct-driven vertical axis H-rotors. The generators are built with windings with high voltage cables.

5.2 Collaborative research

Research groups in Sweden participate in all of the currently operating IEA Wind research tasks. During 2007, Sweden rejoined Task 19 Wind energy in cold climates. Vattenfall AB serves as the Operating Agent for Task 11, Base technology information exchange. Participation in the IEA Wind tasks boosts work in the national programs, for example, by the invaluable sharing of expensive data from experiments and measurements.

During late 2007, Sweden also signed a Joint Declaration on Cooperation in the Field of Research on Offshore Wind Energy Deployment with Denmark and Germany. The aim is to cooperate on common research areas and share experience. No firm collaboration projects involving Sweden have started yet. The Kriegers Flak area, with projects under planning both on the Swedish and German part of the flak and under consideration on the Danish part, has been identified as a good start for collaboration.

6.0 The Next Term

New periods for continuation of the two research programs, Vindval and Vindforsk, are under planning and will start during 2008 and 2009 respectively. Much of the expected growth in wind energy deployment will be in forest areas and in the northern parts of Sweden in the "low-fjelds." The interest in those regions is caused by the rather good wind potential estimated by the Swedish wind mapping. Substantial uncertainty, however, exists in the energy capture and loads on 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.

Author: Anders Björck, Swedish Energy Agency, Sweden; input from Kenneth Averstad, Vattenfall AB, Sweden.

Chapter 28
Switzerland

1.0 Introduction

In 2006, the consumption of energy in Switzerland was equivalent to 246.8 TWh (the most recent numbers available), and consequently 0.5% lower than in the previous year due to a mild winter. In contrast, electricity consumption in Switzerland rose by 0.8% in 2006 to reach a new high of 57.8 TWh. Domestic power plants generated 62.1 TWh, or 7.3% more electricity than in 2005. Once again, Switzerland reported an electricity import surplus in 2006 of 2.7 TWh.

The latest scenarios indicate that energy consumption overall will increase, particularly in the areas of electricity, motor fuels, and industrial processes. This will mean that, in addition to the problem of satisfying increasing demand with an adequate and affordable energy supply, it will not be possible to achieve the CO_2 objectives specified in the CO_2 Act, international climate conventions, and the SwissEnergy program (1). In order to achieve these goals, efforts will need to be intensified in all areas of energy consumption.

The sharp increases in energy prices to which Switzerland has been subjected over the past few years underscore its continued heavy dependence on fossil imports. By increasing the contribution of domestic renewable energy and enhancing energy efficiency, it will be possible to reduce this dependence.

Although Switzerland has pursued a consistent energy policy since 1990 through the Energy 2000 and SwissEnergy programs, it is still a long way from achieving its goal of securing a sustainable energy supply, quoted as a "2000 Watt Society" (2). In view of the diminishing fossil fuel reserves and resulting high energy prices, 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.

For the SwissEnergy program, renewable energy is a clear priority. The term "renewable energy" refers both to conventional hydropower and to other "new" forms of renewable energy such as wind power. The proportion of the latter to Switzerland's overall energy consumption is still very modest (Figure 1); however, thanks to technological progress, increasing economic competitiveness, and the positive image of renewable energy, its growth prospects are excellent- both in the near future and over the long term. The introduction of remuneration at cost for input into the grid on 1 January 2009 will give electricity from renewable energy sources a considerable boost.

SwissEnergy will only be able to achieve its objectives relating to renewable energy by working closely with strong partners from the country's economy, who possess detailed knowledge about the general environment and the energy market. These include the Swiss Agency for Renewable Energy and Efficient Energy Use (to which various network partners as well as many trade and industry associations are affiliated, like the Swiss wind energy association "Suisse Eole"), as well as the cantons (states). SwissEnergy also promotes the transfer of new technologies from research to practical implementation (Section 4).

2.0 Progress Toward National Objectives

Since 2001, SwissEnergy has established clear goals:

• Goals for promotion of renewable energy (including small hydropower)

Table 1 Key Statistics 2007: Switzerland	
Total installed wind generation	12 MW
New wind generation installed	0 MW
Total electrical output from wind	0.016 TWh
Wind generation as % of national electric demand	0.026%
Target:	100 GWh/yr in 2010 600 GWh/yr in 2025

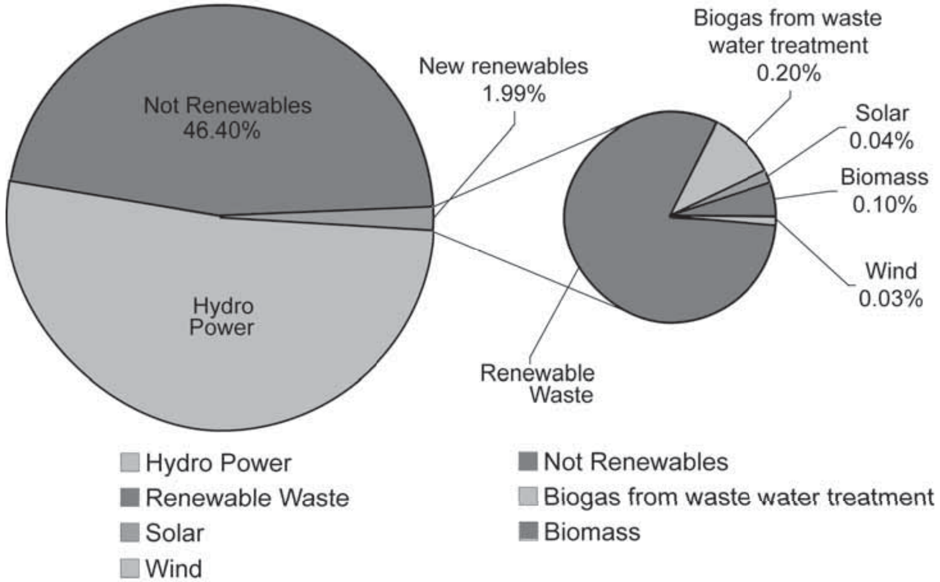

Figure 1 Distribution of Swiss electricity generation.

- Goals of the Swiss climate policy (10% fewer emissions by 2010 compared to 1990)
- Objective target of slowing down the increase of electricity consumption and promoting more efficient use (a 5% maximum increase in electricity consumption between 2000 und 2010).

With its ambitious quantitative objectives, SwissEnergy aims to actively promote the growth of renewable energy. Its targets for 2010 are as follows:

- 3%, or 3,000 GWh more heat is to be produced from renewable energy sources then the amount produced in 2000
- 1%, or 500 GWh more electricity is to be produced from renewable energy sources then the amount produced in 2000
- The production of electricity from hydropower is to be maintained at the level recorded in 2000.

The Swiss wind energy concept (3) 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 2025: 600 GWh
- Time horizon 2050: 4,000 GWh

In 2007, wind energy in Switzerland produced 15.8 GWh representing 16% of the 2010 objective. It is foreseen that by 1 January 2009 there will be a fixed feed-in tariff at production costs for renewable energy in Switzerland (Section 4). Even if the detailed figures of the corresponding ordinance are not known yet, this change of politics in promoting wind energy will lead to a boost of new projects. At the end of January 2008, the Swiss wind energy association knew of projects with a planned capacity of 177 MW – a tenfold increase of today's figures (Figure 2). In awareness of this "gold rush," various states have begun developing detailed spatial planning processes in order to prevent rank growth of critical projects and a danger of acceptance problems. The Swiss wind energy association closely follows these activities, both with finances and with its personnel.

Despite the high reputation of renewable energy in general and especially wind energy, and despite the positive decision of the federal court of Switzerland in 2006, the Swiss foundation of landscape protection still fights all projects of a significant size. In this context, the Swiss activities to start a new task, "Social Acceptance of Wind Energy Projects," are of high importance.

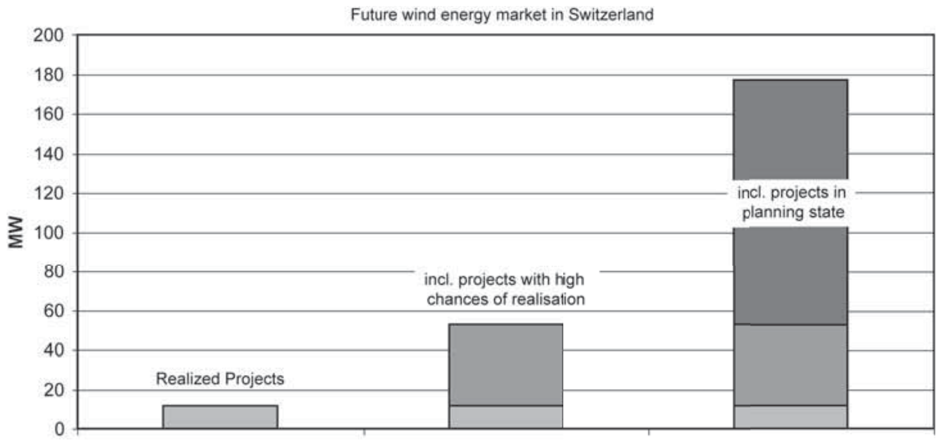

Figure 2 Future wind energy market in Switzerland.

3.0 Benefits To National Economy

3.1 Market characteristics

Because of delay in the new tariff, the installed capacity of wind energy in Switzerland did not increase during 2007. However, due to the good production of all 37 installed turbines (with a total capacity of 11.57 MW) the energy yield in 2007 increased to 15,888 MWh (Figure 3). This brings the average capacity factor up to 16%.

In 2007, 91% of the electricity from wind energy was produced by utility companies. Driven by the growing market for green electricity and the new regulation for the remuneration of green electricity, various utility companies founded new companies in 2007 for the development of renewable energy projects.

3.2 Industrial development and operational experience

Swiss industry is active in the following fields of wind energy:

- Development and production of chemical products for rotor blades, like resins, adhesives, etc. (Gurit Heberlein, Huntsman)
- Development and production of power electronics like inverters, etc. (Integral Drive Systems AG, Vivatec, VonRoll Isola)
- Services in the field of site assessments and project development (Meteotest, Interwind, NEK, Kohle/Nussbaumer)
- Niche products like ice detectors (Boschung, Markasub AG).

The total turnover in the above mentioned areas is about 100 million €/yr, which represents about 350 employees. The chemical products and power electronics industries account for 95% of this turnover and 85% is covered by the four largest companies. Some companies are mayor players in the world market despite the nearly non-existing home market.

3.3 Economic details

The specific costs of existing larger wind power plants (including installation) amounted to about 2,000 – 2,200 Swiss Francs (CHF)/kW (1,220 – 1,330 €/kW). Because of the dramatic increase of the cost of equipment, today's prices for new installation are more like 2,700 CHF/kW (1,650 €/kW). These prices will result in cost-covering tariffs in the range of 0.25 CHF/kWh (0.15 €/kWh) at windy locations.

4.0 National Incentive Programs

With the revision of the Federal Energy Act, the Federal Electricity Supply Act also contains a package of regulations governing the promotion of renewable energy and the introduction of measures to promote efficient electricity use. The most important measure concerns the remuneration of feeding-in renewable energy at cost. The idea here is for electricity produced from new power plants that use renewable energy (hydropower plants up to 10 MW) to be compensated in the form of a remuneration rate to be specified on the basis of a reference facility. An annual sum of around 320 million CHF is to

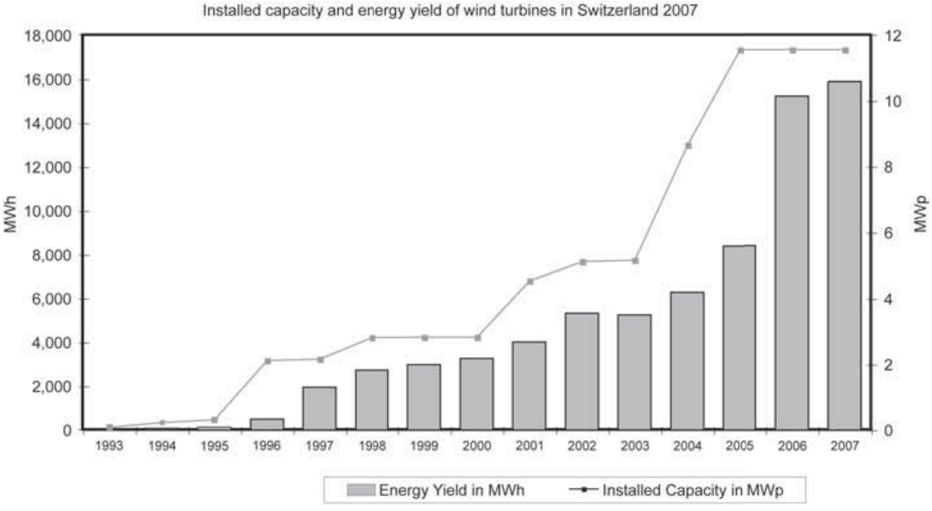

Figure 3 Installed capacity and energy yield of wind turbines in Switzerland 2007.

be earmarked for the new promotion measures called for in the Federal Energy Act. It has been decided, that a maximum share of 30% would go into wind energy. The Federal Council has scheduled the Federal Electricity Supply Act to enter into force on 1 April 2008. This means that the new provisions governing remuneration for feeding electricity into the grid will be known by then and can enter into effect at the beginning of 2009.

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 institutes of energy, energy suppliers, and energy planners. Under the title "Implementation of the concept Wind Energy Switzerland," Suisse Eole can offer certain operational and financial support for site assessments and communication measures.

Based on the important changes in the energy policy framework of Switzerland (remuneration of feeding in renewable energy at cost), we expect a dramatic rise in players on the Swiss market. To establish a high quality reference standard for future projects will be a major challenge of the Swiss Wind Energy Association.

5.0 R, D&D Activities

5.1 National R, D&D efforts

The wind energy research program 2004 – 2007 (4) focuses on:

- Increasing the acceptance of the wind power utilization
- Developing innovative components
- Developing specific concepts and components for installations in difficult areas and under rough climatic conditions.

In 2007, the budget for wind energy related R&D projects was 308,000 CHF (187,000 €). An amount of 511,000 CHF (310,000 €) is spent on promoting activities.

5.2 Collaborative research

Within this framework, the following projects were realized:

- Acceptance (Figure 4):
- "Spatial planning issues for the use of the wind energy"
- Effect of wind power installation in Switzerland
- Wind turbines in Switzerland and mortality of bats
- IEA Topical Expert Meeting "Social Acceptance."
- Development of innovative components:
- Antifreeze coatings for rotor blades of wind turbines
- Evaluation of the light wind concept AVENTA.
- Set up of a Center of competence for wind energy in alpine regions:
- Alpine Test Site Gütsch, Seminar 21. / 22 June 2007 within COST 727 (Figure 5)

• Fore- and Nowcasting of the production of wind power plants in complex terrain.

Switzerland participates in the IEA Wind Implementing Agreement Task 11 "Base Technology Information Exchange," Task 19 "Wind Energy in Cold Climates," and Annex 24 "Integration of Wind and Hydropower Systems." In May 2007 Switzerland organized an IEA Wind Topical Expert Meeting on "Social Acceptance" in Lucerne. Based on the meeting results, a proposal for a new task on "Social Acceptance of Wind Energy Projects" was presented and favorably accepted at the September 2007 meeting of the IEA Wind ExCo.

Another project, "Alpine Test Site Guetsch: Meteorological measurements and wind turbine performance analysis," expands the knowledge base on atmospheric icing- specifically in the Alps (Figure 6). It fits into an international comparison network (COST 727) and will allow for comprehensive testing and improvement of monitoring equipment.

6.0 The Next Term

Today, there are technically developed standard wind turbines on the market, with rated power from 0.5 kW to 5,000 kW. Swiss niche activities - as mentioned in the wind energy research program 2008 – 2011 (5) - should therefore concentrate on:

• Developing turbine components (sensor technology, Nano-technology) by local industry for the utilization of wind energy under specifically Swiss conditions
• Increasing the availability and the energy yield of wind turbines at extreme locations (climate, turbulences, logistics)
• Increasing the "value" of the wind energy by optimizing the integration of wind energy into the grid (Forecasting, regulating energy)
• Increasing the acceptance of wind energy through collaboration between technical and social science experts to shorten development times.

Based on operating experience and the possible optimization potential, the emphasis of the research activities should have results on the following key factors (Table 2):

• Quantifying the production losses and the downtimes due to icing; implementing 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.

Figure 4 The triangle of social acceptance shows the different areas of conflict of this topic within the ranges of politics, market, and society.

Figure 5 Site assessment of a complex wind site in the Jura mountains.

For stronger market development, the gap between research activities and concrete operating experiences should be closed with pilot and demonstration projects.

With the ongoing activities of the test station on mount Guetsch within the framework of COST Action 727, Switzerland will further its international reputation in the field of wind power utilization in cold climates. These experiences 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 is preparing a new IEA Wind Task on "Social Acceptance of Wind Energy Projects," with the following goals:

- Establish an international forum for exchange of knowledge and experiences related to social acceptance and other societal issues
- Produce a state-of-the-art report on the current knowledge and results on social acceptance of wind power

Table 2 Key Values and Indicators					Actual	Target Value
	1980	1990	2000	2004	2008	2011
1. Reduction of energy yield due to icing (%)				9	8	6
2. Downtime due to icing (hr/yr)				130	120	90
3. Average production costs (CHF/kWh)	0.5	0.35	0.28	0.23	0.26	0.24
4. Deviation of energy yield (%)				30	25	20
5. General acceptance (%)				92	89	85
6. Average time of project realization (Months)		12	36	60	30	30
7. Average availability (%)		80	90	95	98	98
8. Average full load hour (hr/yr)		900	1100	1350	1500	1700

Figure 6 Measuring tower overthrown due to heavy icing and high wind gusts at Schwyberg, 12 November 2007.

installations- including a list of studies and an online library of reports/articles
• Establish "Best Practices" and tools for policy makers and planners to; reduce project risks; Accelerate time of realization of projects; Accelerate the exploitation of the full potential of wind energy in the concerned countries.

Thanks to the new legislation for the remuneration of feeding-in renewable energy at cost, the outlook for a growing number of wind energy projects in Switzerland is rather positive.

References:

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(2) "2000 Watt Society" : http://en.wikipedia.org/wiki/2000-watt_society

(3) Konzept Windenergie Schweiz, Bundesamt für Energie, 2003;
http://www.wind-data.ch/konzept/index.php?lng=en

(4) Konzept der Energieforschung des Bundes 2004 – 2007, http://www.bfe.admin.ch/themen/00519/00521/index.html?lang=de.

(5) Energie Forschungs-Programm Windenergie für die Jahre 2008-2011

Author: Robert Horbaty, Swiss Wind Energy Program, Switzerland.

Chapter 29
United Kingdom

1.0 Introduction

The United Kingdom (UK) has one of the best wind resources in Europe and has significant potential for development of both onshore and offshore wind. The UK government has put in place a range of measures to enable the successful development of that potential resource, and it is committed to ensuring the further growth of wind generation in the UK. The proposed EU target of 15% of the UK's energy to come renewable sources, while still subject to negotiation, is likely to mean a very significant increase in the contribution from wind energy – both on and offshore – to the UK's overall energy mix.

In February 2007, the UK became the seventh country to exceed the 2 GW landmark for installed wind capacity with the commissioning of the 72-MW Braes O' Doune onshore project in Scotland. Since the first commercial turbine was installed in the UK, it took 14 years for the UK to reach the 1-GW landmark but less than two years to double that capacity to 2 GW.

In December 2007, the UK government made a major announcement concerning future phases of offshore wind leases and, in particular, a potential Round 3 offshore wind support scheme. A Strategic Environmental Assessment (SEA) of the seas surrounding the UK has begun with a view to paving the way for a possible Round 3. The government envisages a further 25 GW of offshore wind capacity in addition to the approximately 8 GW already planned (Rounds 1 and 2).

The UK's installed wind energy capacity at the end of 2007 was 2,390 MW. This includes 404 MW of offshore wind energy capacity. The UK is now second only to Denmark in the development of offshore wind. The year 2007 saw a drop in the amount of new wind energy capacity installed over both of the previous two years. In 2007, 427 MW of new capacity was added compared to 630 MW in 2006. Despite this dip in new installed capacity, the wind energy industry is still growing rapidly. Wind energy will be the single biggest contributor to the government's target of 10% of electricity from renewables by 2010. Wind is expected to deliver almost half of the 10% electricity target.

May 2007 saw the publication of the Energy White Paper. The White Paper described how the measures set out in the Energy Review

Table 1 Key Statistics 2007: United Kingdom	
Total installed wind generation*	2,390 MW (2007) 1,963 MW (2006)
New wind generation installed**	427 MW (2007) 630 MW (2006) 447 MW (2005)
Total electrical output from wind	5.381 TWh (2007)*** 4.225 TWh (2006) 2.908 TWh (2005)
Wind generation as % of national electric demand	1.32% (2007) 1.04% (2006)
Target:	10% of electricity from renewables by 2010 and proposed 15% of total energy from renewables by 2020

* Estimated from the sum of the Digest of UK Energy Statistics (DUKES) figures for 2005, which includes all known wind generation in the UK to that date and the capacity built in 2006 and 2007 as recorded by British Wind Energy Association (BWEA).
** According to BWEA.
*** Estimated assuming average capacity factor (for 2005) and new onshore capacity added uniformly across the year

of 2006 were to be implemented. The Energy Review identified three key areas that required action if the government's current and future renewable energy requirements were to be met. They were: (1) changes to the Renewables Obligation to bring forth emerging renewable technologies; (2) overhaul of the planning system to tackle problems experienced in getting planning consent; and (3) improving access to the grid for renewable energy through 2010 and beyond. Significant progress has been made in each of these three key areas.

UK renewable energy statistics can be found at the Department for Business, Enterprise and Regulatory Reform (BERR) (formerly known as the Department of Trade and Industry (DTI)) web site: www.dti.gov.uk/energy/statistics/source/renewables/page18513.html.

1.1 Overview of energy market characteristics

In the UK, primary energy supply comes from a range of sources: natural gas (37%); oil and petroleum products (36%); coal (16%); electricity (8%), and renewables and waste (2%) (1). Electricity generation stations use a mixture of energy sources: coal (41%); natural gas (30%); nuclear (20%) and renewables (4.8%). The remaining 4% comes from other fuels, oil, and electricity imports (2). Renewable energy sources accounted for 4.43 million tonnes of oil equivalent, with 3.94 million tonnes used to generate electricity and 0.49 million tonnes to generate heat (3). Use of renewable energy grew by 4.5% in 2006 (4). Total primary energy demand was 1.4% lower in 2006 than in 2005 at 244 million tonnes of oil equivalent.

UK natural gas production is declining as the UK continental shelf reserves are depleted. Production of natural gas fell by 10.9% between the third quarter of 2006 and the third quarter of 2007. UK oil production was virtually unchanged in the third quarter of 2007 when compared to the same period in 2006. Eight new oil fields started production in the nine months to September 2007. Without these new fields, production in the third quarter of 2007 would have been 18.8% lower than in 2006 (5). In 2005, (latest figures available) 3,090 million tonnes of oil and 2,007 billion cubic meters of gas were produced from the UK continental shelf reserves. Remaining reserves in present discoveries were estimated at 1,267 million tonnes and 1,006 billion cubic meters of oil and gas respectively (6).

The UK was a net importer of natural gas in the third quarter of 2007 whereas the UK was a net exporter in the same period of 2006. Imports of natural gas were 31.3% higher than in 2006 and exports were 25.0% lower. Import reliance will increase over the coming years as output from the UK declines.

The UK's energy sector has a framework that combines competition where desirable and regulation when necessary. Business and residential consumers are able to choose among competing suppliers of electricity and natural gas, and several companies operate in the electricity generation market. The electricity and gas networks are privately owned and operated but are regulated in Great Britain by the independent Office for Gas and Electricity Markets (Ofgem) and in Northern Ireland by the Office for Regulation of Electricity and Gas (Ofreg).

1.2 General summary 2007

A total of 427 MW of new wind generation capacity was commissioned in 2007, bringing the UK well over the 2-GW landmark of installed capacity. Total installed capacity now stands at 2,390 MW, an increase of close to 22% above 2006. Included in this new capacity is 72 MW from Braes O' Doune near Stirling in Scotland (Figure 1).

The overall electricity contribution from wind energy increased by approximately 27% from the 2006 figure of 4,225 GWh. Wind energy contributed 1.32% of the total electricity demand for the UK (405,764 GWh in 2006) (7). This contribution from wind is set to rise dramatically over the next few years; predictions are that wind energy could meet 5% of total demand in 2010. Projects under construction totalled 1,134 MW at the end of 2007, and a further 5,322 MW were approved but had not yet begun construction. Table 2 lists the capacity factors for wind farms in the UK in a non-attributable way—that is, it is not possible to provide actual capacity factors for all specific wind farms, and so some regions do not appear on the list.

2.0 Progress Toward National Objectives

2.1 Policy background

The UK government has four long-term goals for its energy policy:

Figure 1 Braes O' Doune Wind Farm being completed in early 2007, Dunblane, Scotland (photo courtesy of Airtricity Developments UK Ltd).

Table 2 Regional Capacity Factors for Wind Farms in the UK*

Region	1999	2000	2001	2002	2003	2004	2005	2006	Average 1998–2006
East of England	—	—	—	—	0.23	0.26	0.27	0.26	0.25
Northeast	—	—	—	0.23	0.19	0.22	0.23	0.19	0.21
Northwest	0.29	0.27	0.23	0.27	0.24	0.26	0.26	0.25	0.26
Yorkshire and the Humber	—	—	—	—	0.28	0.27	0.27	0.27	0.28
Southwest	—	—	—	—	0.24	0.24	0.24	0.24	0.25
Southeast	—	—	—	—	—	—	0.18	0.19	0.19
England	0.28	0.27	0.23	0.27	0.24	0.25	0.25	0.23	0.26
Northern Ireland	0.39	0.37	0.32	0.35	0.34	0.36	0.35	0.31	0.35
Scotland	0.29	0.29	0.27	0.29	0.28	0.34	0.30	0.26	0.30
Wales	0.29	0.26	0.23	0.26	0.25	0.26	0.25	0.27	0.26
UK average	0.31	0.29	0.26	0.28	0.26	0.29	0.28	0.27	0.28
UK aggregate load factor	0.28	0.28	0.26	0.30	0.24	0.27	0.26	0.27	0.28

* Energy Trends: March 2006, URN 06/79a, ISBN 0 85605 356 2, Special Feature – Renewables UK onshore wind capacity factors 1998–2004, www.dti.gov.uk/files/file27084.pdf, plus recent analysis.

1) To put the country on the path to reducing carbon dioxide emissions by 60% by 2050, with real progress by 2020;

2) To maintain the reliability of energy supplies;

3) To promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve our productivity; and

4) To ensure that every home is adequately and affordably heated.

The Energy Review of 2006 identified three main barriers to further the development of renewables, including onshore and offshore wind. The progress in tackling these problems is detailed below.

Renewables Obligation (RO): The RO is the main financial instrument to stimulate renewables expansion in the UK. It was designed as an incentive to encourage the most economic forms of renewable generation, and it has been less successful in bringing forward development of more emerging technologies. Proposals to 'band' are currently being introduced to define different groupings of renewable technologies. Banding means that technologies will be awarded more or less than one Renewables Obligation Certificate (ROC) for each MWh of electricity they produce depending on the stage of the technological development and associated costs (see Section 4.1).

Planning: The wind energy industry has been affected by delays in obtaining planning consent. The government has responded to this and committed itself to fundamental changes in planning systems for major energy projects (see Section 2.5).

Access to the grid: The Office of Gas and Electricity Markets (Ofgem) – the industry regulator – has worked closely with the UK's transmission and distribution licensees to develop a suite of price control proposals as investment incentives to connect renewable and distributed electricity generation and improve the environmental performance of the electricity network (see Section 2.2). However, the large volume of renewable generation projects seeking to connect to the grid in Great Britain is facing long delays, and the government considered that change to the framework was necessary to overcome this barrier.

The Energy White Paper, published on 23 May 2007 (see http://www.berr.gov.uk/files/file39387.pdf), described how the issues identified in the Energy Review of 2006 were to be addressed. It also explained how the UK government intended to deliver its four energy policy goals while addressing the long-term energy challenges the UK is facing. Those long-term energy challenges are:

- Tackling climate change by reducing carbon dioxide emissions both within the UK and abroad and
- Ensuring secure, clean, and affordable energy as the UK becomes increasingly dependent on imported fuel.

The Climate Change Bill, the first of its kind in any country, was introduced into the House of Lords (upper house of UK parliament) in November 2007. The Bill will create a new approach to managing and responding to climate change in the UK through: setting ambitious targets; taking powers to help achieve them; strengthening the institutional framework; enhancing the UK's ability to adapt to the impact of climate change; and establishing clear and regular accountability to the UK, parliament, and devolved legislatures. The aim is for the Bill to enter into force by spring or early summer 2008.

The Energy Bill, introduced in January 2008, is built on the proposals set out in the Energy White Paper. In terms of renewable energy in general and wind energy in particular, the Energy Bill will update the legislative framework by putting in place new legislation to:

- Reform the Renewables Obligation by banding it to provide different levels of support to different renewable technologies depending on the maturity of the technology involved. For example, landfill gas-to-energy projects will receive a lower level of support than onshore wind projects which in turn will receive less support than wave energy projects.
- Improve the licensing regime to ensure decommissioning of offshore energy infrastructure including offshore wind turbines and related works.
- Allow Ofgem to effectively run tenders for offshore transmission licences in order to ensure that the most economic and efficient transmission solution is encouraged to facilitate the expansion of offshore renewables.

On 23 January 2008 the European Commission put forward a "Climate action and renewable energy package." The European Union has committed to reducing its overall emissions to at least 20% below 1990 levels by 2020, and is ready to scale up this reduction to as much as 30% under a new global climate change agreement if other developed countries make comparable efforts. It has also set itself the target of increasing the share of renewables in energy use to 20% by 2020. The package also puts forward likely contributions needed from each Member State (it is expected that the figure could be in the region of 15% of energy use for the UK) to meet these targets and proposes a series of measures to help achieve them.

2.2 Access to the grid

Following the publication of the Energy White Paper in 2007, Ofgem and BERR have convened a joint review of the current framework for access to the Great Britain transmission system. The scope of the Transmission Access Review (TAR) is broad and will look at the arrangements for planning new grid infrastructure, the technical standards used to determine the need for reinforcements, the operational standards, the scope for innovation in grid operation and infrastructure, and the commercial arrangements for access to the grid and system balancing.

The review will set out proposals for changes to the framework that will better support the connection of renewable generation to the grid in the medium and long-term. The review will look ahead to 2020 and consider ways to support the delivery of the government's aspiration of 20% of electricity supplied by renewable generation. In August 2007, BERR and Ofgem published a call for evidence to be considered as part of the review. It is intended that the TAR will provide a final report in May 2008.

2.3 Offshore transmission

The development of a new offshore connection regime is necessary to meet the requirements of new offshore wind farms and the next generation of offshore renewables. An offshore electricity transmission regulatory regime needs to be implemented in order to allow renewable generation located in the sea outside the territorial waters of the UK to connect to the existing onshore network.

In March 2007, the government decided to introduce a "non-exclusive" approach to licensing transmission owner activities offshore. In practice this means that potential offshore transmission owners will compete with each other through a common tender process for the right to build, own, and maintain offshore electricity transmission connections.

In July 2007, Ofgem and BERR released for consultation a policy statement entitled "Offshore Electricity Transmission" (see http://www.berr.gov.uk/files/file40629.pdf). This consultation sought views on the initial proposals for the licensing and regulatory framework that will apply to offshore electricity transmission networks.

Having considered the responses received to the consultation document, BERR and Ofgem published the joint policy statement Regulation of Offshore Electricity Transmission, (see http://www.berr.gov.uk/files/file43555.pdf) in January 2008. This statement set out decisions in a number of key areas concerning the competitive tender process and transitional arrangements and addressed the key concerns raised in the consultation responses. In practice this means that:

- Transmitting electricity offshore at 132 kV and above will be a prohibited activity without a licence;
- The safe and secure transmission of electricity offshore will be achieved through amendments to the existing system of licences, codes, and agreements that govern onshore electricity transmission;
- The Great Britain System Operator (which will be National Grid) will be responsible for operating and coordinating both onshore and offshore grid connections;
- Offshore generation and transmission will be separate business activities; and
- The costs of building and operating the new offshore transmission assets will be recovered via National Grid's charging methodology.

Further consultations on the draft license, code, and agreement modifications are due to take place up until the publication of the final policy proposals in April 2008. Before the policy is implemented, another consultation on the full regime is planned (from June to September).

2.4 Decommissioning issues

Offshore energy installations have an important role in supplying the nation's future energy needs, meeting the UK's objectives for security of supply, and, in the case of offshore renewables, helping to reduce greenhouse gas emissions. Exploitation of the offshore energy resource also brings with it international obligations to decommission installations at the end of their life in order to ensure safety of navigation, whilst taking account of the needs of the fishing industry and protection of the marine environment. Both the oil and gas as well as the offshore renewable energy industries therefore operate under statutory decommissioning regimes: the Petroleum Act 1998 for oil and gas installations and the Energy Act 2004 for offshore wind, wave, and tidal installations.

Sections 105 to 114 of the Energy Act 2004 introduce a decommissioning scheme for offshore wind and marine energy installations. Under the terms of the act, the Secretary of State may require a person who is responsible for one of these installations to submit (and eventually carry out) a decommissioning program for the installation.

In December 2006, the government published guidance notes on the "Decommissioning of offshore renewable energy installations under the energy act 2004" (see http://www.berr.gov.uk/files/file35754.pdf). The guidance was developed to assist businesses in understanding their obligations under the scheme.

In June 2007, the DTI published a consultation document on "Decommissioning offshore renewable energy installations" (see http://www.berr.gov.uk/files/file39796.pdf). The objective of this consultation was to strengthen the government's ability to require - and operators' ability to safeguard - appropriate financial security for the costs associated with decommissioning these facilities. The aim was to minimize the risk that companies default on their obligations leaving the state to meet the costs, whilst continuing to encourage the development of the industries.

2.5 Planning issues

The UK government recognises that the wind farm industry has been significantly affected by delays in obtaining planning consent. The government is committed to resolving this by removing, as far as possible, the causes of undue delays in the planning process. To this end, the government is proposing fundamental changes in planning systems for major energy projects.

The Planning White Paper, published in May 2007, set out a wide-ranging package of reforms. The paper proposed to introduce a new system that will enable the UK to make decisions on the infrastructure that it needs to: support communities and their quality of life, achieve the goals for a secure energy supply, reduce carbon emissions, and enhance international competitiveness, all in a way that is timely, efficient, and predictable.

The Planning Bill, introduced in November 2007, built on the proposals set out in the Planning White Paper. The bill introduces a new system for nationally significant infrastructure planning alongside further reforms to the town and country planning system. The Infrastructure Planning Commission (IPC) proposed in the bill will streamline the multiple consent planning regime currently in force for large infrastructure projects including large energy projects. The IPC will be charged with making decisions on such projects in order to speed up the process. In making its decisions the IPC will be guided by National Policy Statements (NPS) to be prepared for each infrastructure area e.g. energy, water supply, etc.

The planning system in Scotland is a matter delegated to the Scottish Executive and was subject to review in 2006. All sections of the Planning etc. (Scotland) Act 2006 are now in force.

According to industry statistics, there is still over 9,000 MW of wind projects in the planning system. Even though this backlog of planning applications will take time to reduce, the proposals set out in the Planning White Paper and Planning Bill should cut the costs, risks, and uncertainty for the developers.

2.6 Defence and civil aviation interests

It is recognised that wind turbines can adversely affect the aviation domain. Therefore, developments must take place in a way that fully takes into account national air defence and air safety, with the wind energy and aviation communities understanding the needs of each other.

In the UK, BERR, which is responsible for energy policy, has set up the Wind Energy, Defence and Civil Aviation Interests Working Group to investigate the issue and improve understanding between the aviation and wind energy industries.

A program has been agreed upon to develop potential solutions to mitigate interference so that they can be safely adopted by the aviation industry. This will ensure that the aviation industry's objections do not prevent developers from constructing enough wind farms to meet the government's renewable objectives. Main activities in 2007 have included:

Planning Strategy Group: Specific issues relating to planning have moved up the agenda, particularly following recent national reviews that have recommended the streamlining of the planning process. To address these issues, a Planning Strategy Group was established. Key items being considered include database and information sharing, preparation of planning guidelines, and strategic approaches to planning.

Greater Wash area: The Collaborative Offshore Wind Research into the Environment (COWRIE) and BERR, with technical support from the Ministry of Defence (MOD), are sponsoring a study to investigate the feasibility of "in-fill" radar in the Greater Wash area. A report, published in August 2007 (see http://www.berr.gov.uk/files/file41404.pdf), confirmed that installing a new "in-fill" radar system between the two existing radars might provide an effective solution.

MOD activities: The MOD continues to be active in improving its understanding of the impact of wind turbines on its radar systems. As a result of the preliminary trials previously undertaken by the MOD, more detail is needed to understand the practicalities of implementing "in-fill" radar solutions.

Mitigating technologies: Three stealth technology projects are part of the Technology Strategy Board's Emerging Energy Technology Programme. One project was completed in December 2007 and the other two projects are still on-going. The projects investigate materials and methods that will assist in mitigating radar interference from wind turbines. The project that concluded in 2007 will issue its final report in early 2008. One of the other on-going projects is hoping to undertake trails on a full size turbine.

2.7 Progress toward national targets

Further progress has been made in 2007 toward achieving the UK's 10% from renewables generation by 2010 target. As described above, a number of important policy developments have occurred in 2007 that build on the recommendations of the Energy Review of 2006. The total generation from renewable sources eligible for the Renewables Obligation was around 3.6% of the electricity supply in 2006 (the latest year for which statistics are available), up from 1.8% in 2002. Overall demand for electricity in the UK in 2006 was 405,764 GWh, a decrease of 0.75% over 2005. The contribution from wind in 2006 was 4,225 GWh. This is an increase of 45% over the 2005 figure. Figures for 2007 will be published in mid 2008, but it is estimated that the contribution of wind energy toward total electricity demand will be approximately 5,353 GWh or 1.3%.

Regarding wind generation capacity, BWEA figures show that 2007 was a year of further growth in wind energy capacity (8). A total of 26 new projects, including two offshore projects, came on line, representing 427 MW of new capacity (Figure 2). Although more projects completed in 2007 than in 2006, when 22 were completed, the total capacity of new installations fell by 32% from 630 MW. This raised the total installed capacity to 2,390 MW, an increase of 22% over 2006 (Figure 3). Figure 4 shows the distribution of installed capacity by country within the UK. Of particular note in 2007 was the installation of Scotland's first offshore wind turbines, the 10-MW Beatrice Wind Farm in the Moray Firth. Table 3 details the projects that were commissioned in 2007. Figure 5 shows projects under construction at the end of 2007.

In 2007, 47 new projects were approved through the planning system totalling over 1,888 MW. These projects brought the total UK capacity (approved but not yet under construction) to 5,322 MW; the breakdown by country is shown in Figure 6.

All of the approved wind energy projects in the UK at the end of 2007 are shown in Figure 7. The total capacity of approved projects, including operating projects, projects being constructed, and projects that are approved but have not yet been constructed is 8,846 MW. The greatest proportion of capacity in this number is made up of English offshore projects that have been approved but have not yet been built. These make up a total of 2,848 MW. This figure includes two large offshore projects approved this year- the Greater Gabbard Wind Farm (500 MW) and the Walney Wind Farm (450 MW).

The project approval rate for new wind energy projects in 2007 was 70.1%; this rate is significantly greater than the rate of 54.7% observed in 2006 and of 59.6% in 2005. The last year that the approval rate exceeded 70% was 2003 when the rate was 75%. Despite the increased approval rate, the 1,888.28 MW of

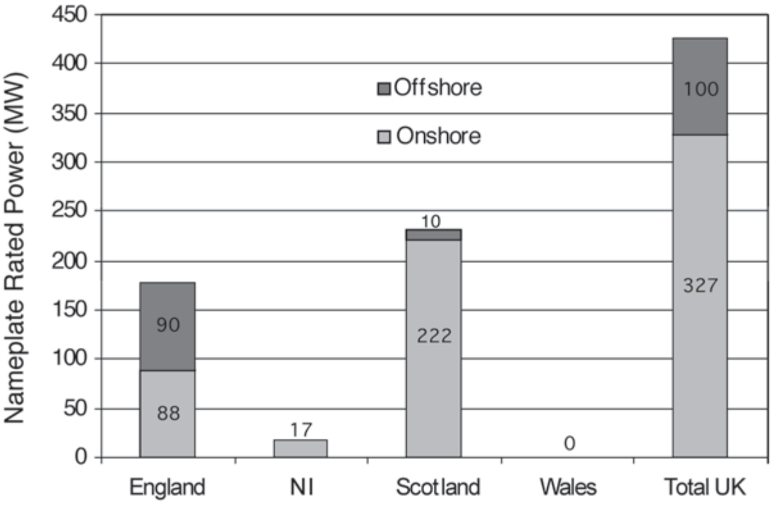

Figure 2 UK wind capacity built in 2007; total 426.95 MW.

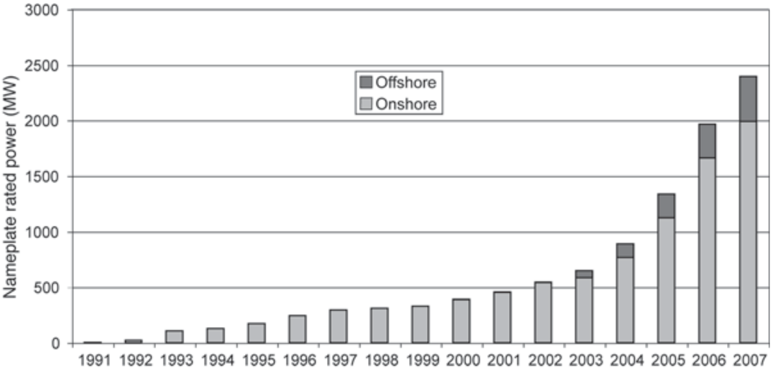

Figure 3 History of UK wind capacity growth built in the UK to the end of 2007: total 2,389.81 MW.

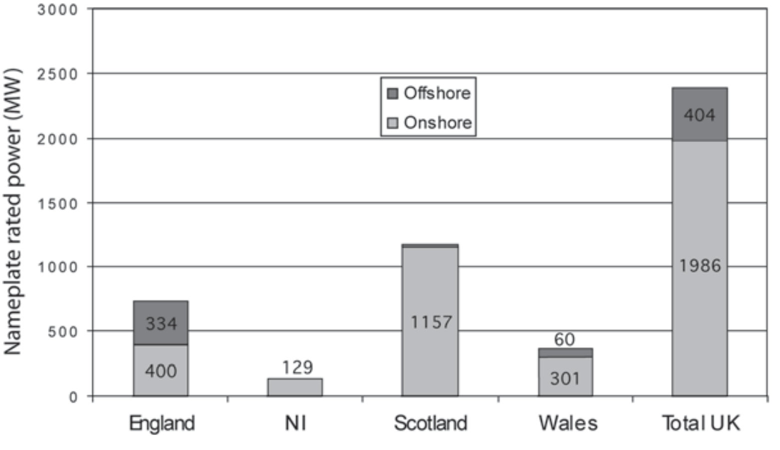

Figure 4 UK wind capacity built to the end of 2007 by country (England 733 MW, Northern Ireland [NI] 129 MW, Scotland 1167 MW, and Wales 361 MW).

Table 3 Wind Projects Commissioned in the UK in 2007					
Name of wind farm	Region	No. of turbines	Power of turbine (MW)*	Capacity (MW)	Date online
Beatrice (offshore)	Scotland	2	5.0	10.0	July 2007
Ben Aketil	Scotland	10	2.3	23.0	Dec. 2007
Bin Mountain	Northern Ireland	6	1.5	9.0	Aug. 2007
Black Hill	Scotland	22	1.3	28.6	Feb. 2007
Braes O' Doune	Scotland	36	2.0	72.0	Feb. 2007
Bristol Port Wind Park	England	3	2.0	6.0	Aug. 2007
Burbo Bank (offshore)	England	25	3.6	90.0	Oct. 2007
Craig Wind Farm	Scotland	4	2.0	8.0	Sept. 2007
Crystal Rig 1a	England	5	2.5	12.5	May 2007
Dummuie	Scotland	7	1.75	10.4	April 2007
Earlsburn	Scotland	14	2.5	35.0	Aug. 2007
Fintry (The FREE Turbine)	Scotland	1	2.5	2.5	Aug. 2007
Greendykeside Wind Farm	Scotland	2	2.0	4.0	Dec. 2007
Hill of Balquhindachy	Scotland	1	0.85	0.85	July 2007
Hill of Eastertown	Scotland	2	0.85	1.7	July 2007
Lough Hill Resubmission	Northern Ireland	6	1.3	7.8	July 2007
McCains Foods	England	3	3.0	9.0	Dec. 2007
Ransonmoor Farm	England	5	2.0	10.0	May 2007
Red Tile	England	12	2.0	24.0	Mar. 2007
Stags Holt	England	9	2.0	18.0	Oct. 2007
Wether Hill	Scotland	14	1.3	18.2	May 2007
Wharels Hill	England	8	1.3	10.4	Aug. 2007
WWA High Sharpley	England	2	1.3	2.6	Mar. 2007
WWB Burgar Hill	Scotland	2	2.5	5.0	Feb. 2007
WWP Hameldon Hill	England	3	1.5	4.5	Feb. 2007
WWU High Pow	England	3	1.3	3.9	Mar. 2007
		207		426.95	
*Average turbine size: 2.06 MW					

new capacity approvals in 2007 is only 98.7 MW greater than the capacity approved in 2006. This represents a 5.5% increase in new capacity approvals for the year compared with a corresponding increase in 2006 of 133% over the 2005 figures. Of particular note is the approval of the Walney Offshore Wind Farm, a 450 MW project located 14 km west of Walney Island in the East Irish Sea. Wind farm planning application success and failure rates from 1999 to 2007 are shown in Figures 8 and 9.

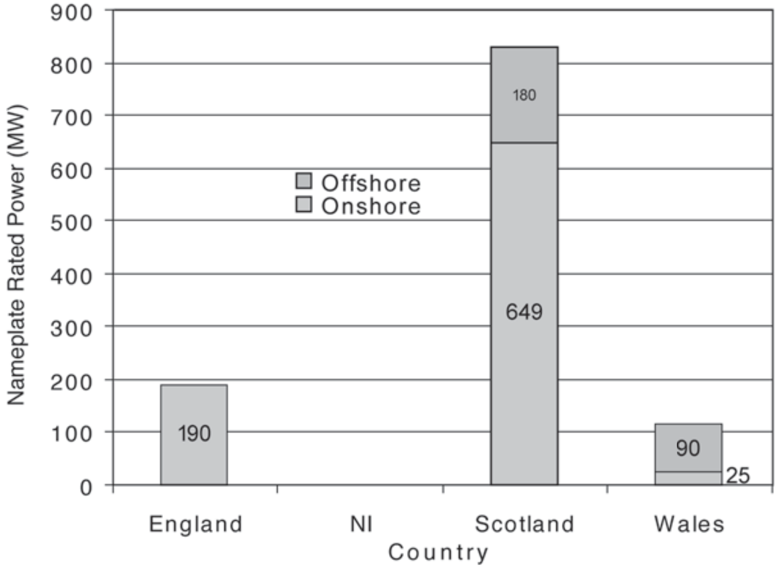

Figure 5 UK wind capacity under construction at the end of 2007; total 1,134 MW.

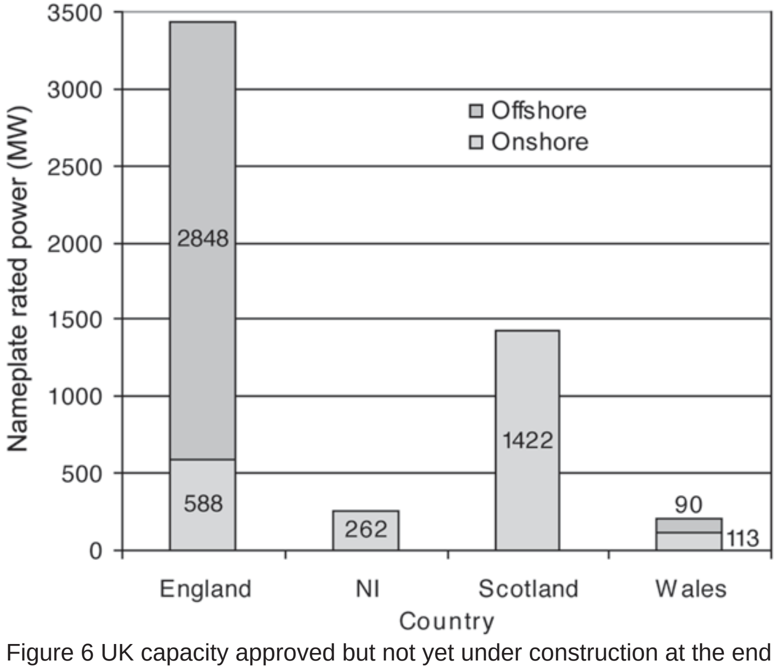

Figure 6 UK capacity approved but not yet under construction at the end of 2007; total 5,322 MW.

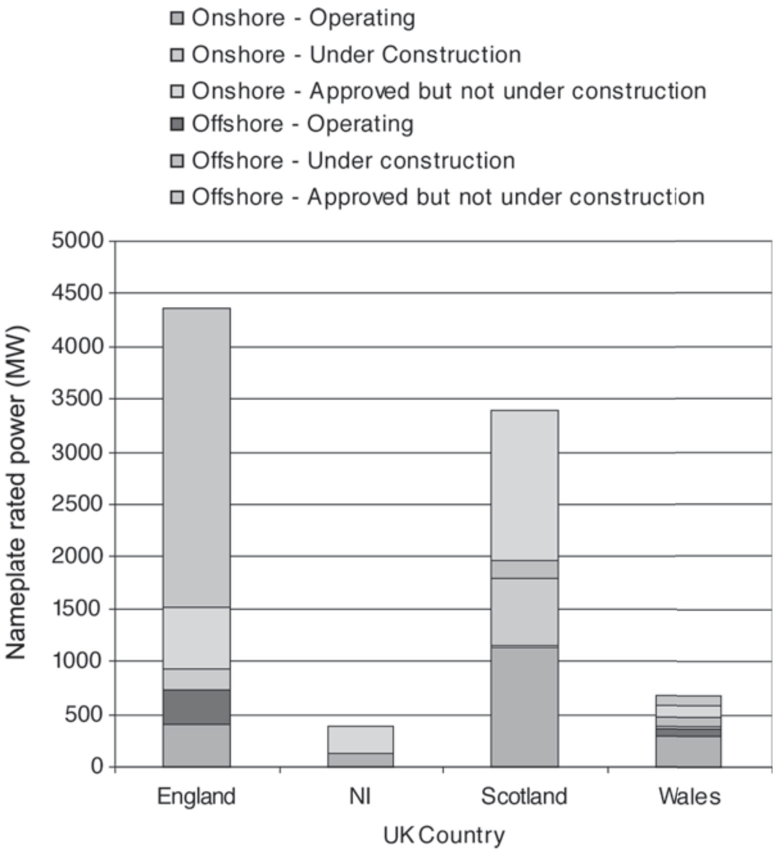

Figure 7 All UK-approved projects at the end of 2007; total 8,825 MW.

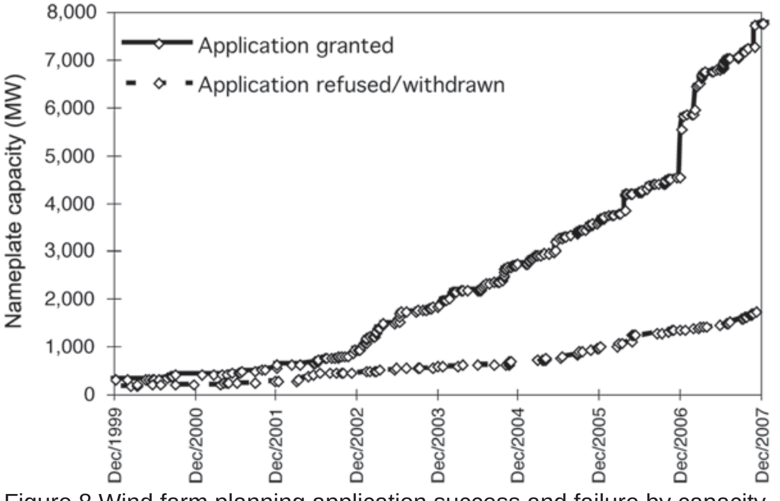

Figure 8 Wind farm planning application success and failure by capacity, UK.

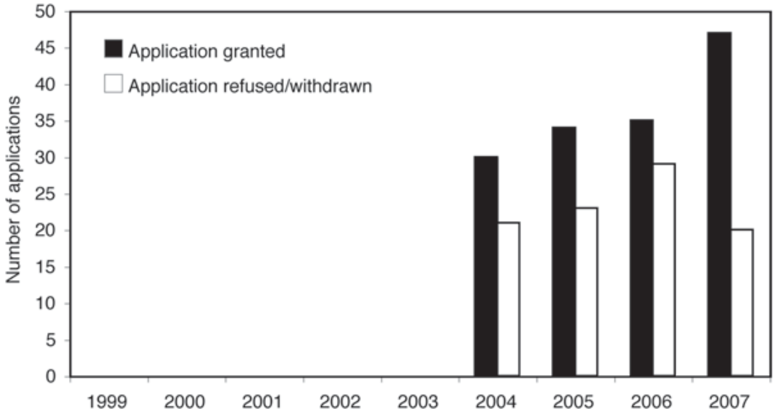

Figure 9 Wind farm planning application successes and failures, UK.

2.8 Offshore wind

Significant development of offshore wind in the UK began in April 2001 when 18 companies were awarded agreements for leases by the Crown Estate (CE) in the first round (Round 1) of offshore wind farm sites on the UK seabed. Round 1 consists of 18 sites, limited to 30 turbines per site, grouped at 13 locations around the UK (Table 6).

Progress with Round 1 has been slower than anticipated. Despite delays, five of these Round 1 projects are now generating electricity totalling 390 MW. A further two offshore projects, outside of the Round 1 developments, have also been completed: the 10-MW Beatrice Project (completed in 2007) (Figure 10) and the 4-MW Blyth Offshore Wind Farm. Table 4 shows the details of the seven operating offshore wind farms in the UK. These developments mean that the UK is second only to Denmark in the development of offshore wind. Installed offshore projects include the 90-MW Burbo Bank Offshore Wind Farm, which was commissioned in October 2007. Burbo Bank is located in the East Irish Sea, 10 km off the northwest coast of England (Figure 11).

The second phase of offshore wind farm development in the UK, Round 2, allows for much more ambitious project arrangements. Options for site lease agreements totalling close to 7,200 MW were offered to 15 sites. These are to be developed in three strategic areas in waters around the UK coastline: the Thames Estuary; the Greater Wash area off England's east coast; and in the northwest, including the Liverpool Bay area and the Renewable Energy Zones outside the territorial sea. Five applications have now been granted consent and are progressing toward construction, and four are currently in the planning process awaiting decisions. Table 5 lists these Round 2 sites and their current status.

Table 4 Completed Offshore Wind Projects in the UK

Project name	Turbine brand	No. of turbines	Total capacity	Year online
Burbo Bank	3.6-MW Siemens	25	90	2007
Beatrice	5-MW RE Power	2	10	2007
Barrow	3-MW Vestas	30	90	2006
Kentish Flats	3-MW Vestas	30	90	2005
Scroby Sands	2-MW Vestas	30	60	2004
North Hoyle	2-MW Vestas	30	60	2003
Blyth	2-MW Vestas	2	4	2000

Figure 10 Beatrice Offshore Wind Farm in the Moray Firth, Scotland (photo courtesy of Talisman Energy Inc. © 2008).

A government announcement concerning future phases of offshore wind leases and, in particular, a potential Round 3 was made in December 2007. A Strategic Environmental Assessment (SEA) of the seas surrounding the UK has been initiated with a view to paving the way for a possible Round 3. The government envisages a further 25 GW of offshore wind capacity in addition to the approximately 8 GW already planned under Rounds 1 and 2.

3.0 Benefits to National Economy

3.1 Market characteristics

The consistently high level of project development undertaken over the last three years together with the large number of projects that have gained planning consent and are on the drawing board underlines the fact that wind energy remains one of the fastest-growing energy sectors in the UK. It is estimated that companies working in the renewables sector currently sustain about 8,000 jobs in the UK, and this number is projected to increase as the wind industry grows. About 1,500 of these jobs are in Scotland, and the rest are located elsewhere in the UK. BERR has estimated that Round 2 of offshore wind development alone could bring a further 20,000 jobs for Britain.

The supply chain that supports the UK wind energy industry includes developers; professional services providers such as accountants, solicitors, and insurers; and technical consultants in the areas of wind resource assessment, planning, civil engineering, environmental impact assessment, and electrical engineering. Also included are supply chain manufacturers covering all major elements of a wind turbine, including blade manufacture, foundations, seabed survey, logistics and port storage, installation, cable laying, connections, standards/certification, and O&M services. Significant entry to the turbine supply chain market is currently limited for UK suppliers, and turbine suppliers obtain the bulk of their components outside the UK.

Currently, details concerning 478 companies and the services that they offer for wind energy are listed in an open marketing database available from the WindSupply Web site, www.windsupply.co.uk. WindSupply was established in 2006 with support from BERR, several UK regional development agencies, and the European Regional Development Fund to:

Figure 11 Burbo Bank Offshore Wind Farm, Liverpool Bay, England (photo courtesy of Dong Energy. © 2008).

Table 5 Round 2 Offshore Wind Projects		
Name of Round 2 Offshore Wind Farm	Capacity (MW)	Status
London Array Offshore Wind Farm	1,000	Consented
Thanet Offshore Wind Farm	300	Consented
Greater Gabbard Offshore Wind Farm	500	Consented
Walney Offshore Wind Farm	450	Consented
Gunfleet Sands II Offshore Wind Farm	64	Consented
Gwynt y Mor Offshore Wind Farm	750	Under Consideration
West of Duddon Sands Offshore Wind Farm	500	Under Consideration
Sheringham Shoal Offshore Wind Farm	315	Under Consideration
Lincs Offshore Wind Farm	250	Under Consideration
Humber Gateway Offshore Wind Farm	300	Awaited
Docking Shoal Offshore Wind Farm	500	Awaited
Race Bank Offshore Wind Farm	500	Awaited
Triton Knoll Offshore Wind Farm	1,200	Awaited
Dudgeon East Offshore Wind Farm	300	Awaited
Westermost Rough Offshore Wind Farm	240	Awaited
Total	7,169	

- Identify, contact, evaluate, encourage, support, and promote UK companies to enable them to enter the wind energy component supply chain and
- Identify opportunities for product development and innovation and encourage supplier groupings to bring these to market.

3.2 Economic details

Financing for wind farms is obtained largely from the balance sheet of corporate investors and banks, although there is a small amount of private investment. The Renewables Obligation has greatly increased the development of wind projects, with utilities, conventional power generators, and new developers active in the market. Because of the high value the RO places on renewables, corporate investment will yield good returns through an expansion of the core business while reducing exposure to penalty payments. Onshore wind energy has found particular favor because of its economics, maturity, and ability to deliver relatively quickly.

The present-day costs of installing wind energy in the UK are between 585 £/kW and 800 £/kW onshore, rising to 1,200 £/kW to 1,600 £/kW offshore. The higher capital expenditure costs of offshore development are due to the increased size of structures and the logistics of installing the turbines at sea. The costs of offshore foundations, construction, installations, and grid connection are significantly higher than onshore. For example, typical offshore turbines are 20% more expensive, and towers and foundations cost more than 2.5 times the price for a project of similar size onshore.

Indications of power purchase prices come from published auction prices and trading prices from renewable energy certificates. Currently, the Non-Fossil Fuel Purchasing Agency Ltd. (NFPA) conducts biannual green power auctions. These auctions are for electrical output that will be produced by NFFO (Non-Fossil Fuel Obligation) generators during a six-month period (starting 1 April or 1 October) following the end of the auction. These auction prices are for electrical output, together with (depending on the generation technology) Climate Change Levy Exemption Certificates (LECs) and Renewables Obligations Certificates (ROCs), which are explained further in Section 4.

In the NFFO power auction completed on 23 August 2008, the price for wind was the highest to date at 106 £/MWh. This compares with the February 2007 price of 102.3 £/kWh, the February 2006 price of 84.8 £/MWh and the prices in 2005 of 67.5 £/MWh and 90.5 £/MWh for February and August, respectively.

The prices of ROCs traded quarterly in 2007 have continued to increase from 46.17 £/MWh in January to 49.26 £/MWh in October. The first auction of 2008 was held in January 2008 where ROC values hit a 3.5 year high of 49.92 £/MWh.

4.0 National Incentive Programs

4.1 Renewables Obligation (RO)

The RO remains the UK's main financial instrument to stimulate expansion of electricity from renewable sources to achieve the UK's 10% target by 2010 and the government's aspiration to double this to 20% by 2020. The RO is also expected to play a key role in achieving the EU 2020 target for the UK of 15% of total energy demand announced in January 2008. The RO places an obligation on licensed electricity suppliers to source an increasing percentage of electricity from renewable sources. Since its introduction in 2002, the UK's renewable electricity generation has more than doubled.

For 2007–2008, the RO percentage target was 7.9%, which will increase each year to reach 15.4% by 2015/16. In the 2007 Energy White Paper - Meeting the Energy Challenge, the government renewed its commitment to these existing targets as a minimum, and introduced the possibility of increasing the level of the RO up to a maximum of 20% in case the level of renewable electricity generation were to outstrip the RO.

The RO was originally designed as an incentive to encourage the most economic forms of renewable generation. Since its introduction, it has been effective in achieving this—stimulating significant development of onshore wind, co-firing, and landfill gas. However, there are constraints on the availability and deployment of the cheaper forms of renewables. This means that to move beyond 10% of electricity generated from renewable sources, other technologies such as offshore wind, wave, and biomass will have to come forward.

The 2007 Energy White Paper set out the government's intention to introduce "banding" to the RO to bring on additional deployable technologies by providing differentiated levels of support to different renewable technologies. Banding the RO is predicted to increase the deployment of renewables by 40% from 2009-2015 compared with the existing RO.

Under the banded RO, onshore wind would fall into the 'reference' band, receiving 1 RO Certificate (ROC)/MWh. Offshore wind would fall into the 'post demonstration' band and receive 1.5 ROCs/MWh. A further change to the RO set out in the 2007 Energy White Paper was to remove the current caps on co-firing biomass alongside fossil fuels.

A consultation, Reforming the Renewables Obligation, which sought views on the detailed implementation of the changes was published alongside the 2007 Energy White Paper. The consultation closed in September 2007. The Energy Bill 2007–08 will implement the legislative changes set out in the 2007 Energy White Paper and the reforms to the RO will come into effect in April 2009.

4.2 Climate Change Levy

The government introduced the Climate Change Levy (CCL) on 1 April 2001 to encourage businesses to reduce energy use and thus carbon emissions. The CCL is a tax on the use of energy in industry, commerce, and the public sector. The levy is to encourage non-domestic electricity users to become more energy efficient as well as to favour renewable energy supplies (which are levy-exempt) and so reduce carbon emissions. From April 2007 the CCL rates are being increased on a yearly basis in line with inflation.

4.3 Capital Grant Programme

The Offshore Wind Capital Grant Programme was launched by the DTI and Big Lottery Fund in early 2002 to stimulate the early development of offshore wind schemes. The scheme awarded grants of 97 million £ to 11 projects. The grants provided the additional financial support required to get early projects started and aim to allow developers to gain experience and confidence to help reduce costs for subsequent projects. Five projects with a combined capacity of 390 MW are now complete and operating. Construction is underway at a further five projects, and the construction of an additional project will start in 2008. The scheme is now closed. Progress of projects up to 2007 is shown in Table 6.

5.0 R, D&D Activities

5.1 National R, D&D program

The Technology Strategy Board (TSB), sponsored by the Department for Innovation, Universities and Skills, was established as an executive body at arm's length from the government in July 2007. After the organization has identified which technology areas to develop, it provides support to businesses in the form of grants to support research and development.

The TSB's vision is for the UK to be seen as a global leader in innovation and a magnet for technology-intensive companies, where new technology is applied rapidly and effectively to create wealth. For the period 2005–2008, at least 20 million £/yr of Technology Programme funding is expected to support research and development in renewable energy and low-carbon technologies. In 2007, approximately 3.5 million £ was spent on the wind program to support cost-shared R, D&D with industry.

To complement this, some of the world's biggest energy companies have agreed to work in partnership to create a new energy and environmental research institute. This will enable the UK to be at the cutting edge of science

Table 6 Round 1 Offshore Wind Farms and Capital Grant Programme

Name of Round 1 Offshore Wind Farm	Capacity (MW)	Status	Date online	Grant value (£M)
Barrow Offshore Wind Farm	90	Commissioned	July 2006	10
Kentish Flats Offshore Wind Farm	90	Commissioned	Nov. 2005	10
North Hoyle Offshore Wind Farm	60	Commissioned	July 2004	10
Scroby Sands Offshore Wind Farm	60	Commissioned	Dec. 2004	10
Burbo Offshore Wind Farm*	90	Commissioned	Oct. 2007	10
Inner Dowsing Offshore Wind Farm	97.2	Constructing	Dec. 2008	10
Lynn Offshore Wind Farm	97.2	Constructing	Dec. 2008	10
Rhyl Flats Offshore Wind Farm	90	Constructing	Aug. 2008	10
Robin Rigg Offshore Wind Farm (OERL)	108	Constructing	April 2009	9
Robin Rigg Offshore Wind Farm (Solway)	108	Constructing	April 2009	9
Scarweather Sands	108	Approved	On Hold	0
Shell Flats (three projects combined)	270	Submitted (S36**)	Dec. 2013	0
Teeside/Redcar	90	Approved	April 2011	0
Gunfleet Sands (1) Offshore Wind Farm	108	Approved	Sept. 2010	9
Norfolk Offshore Wind Farm (Cromer)	100	Withdrawn	Withdrawn	Withdrawn
Ormonde	108	Approved	Dec. 2010	0
Total	1,674.4			107

* Funded by the Big Lottery

** Appeal under Section 36 of the Town and Country Planning Act and engineering. In December 2007, the new Energy Technologies Institute (ETI) formally commenced operations with its first Invitation for Expressions of Interest to participate in programs to develop new technologies for offshore wind and for marine, tidal, and wave energy.

The ETI is a significant milestone in the UK's wide-ranging program to combat climate change. The institute will spearhead the collaborative development of new commercially viable, sustainable, low-carbon energy technologies to provide a secure, sustainable, and affordable energy supply for this and future generations. BERR announced that it was prepared to provide matched funding of up to 500 million £, creating the potential for a 1 billion £ institute over 10 years.

5.2 R&D priorities

5.2.1 Technology Programme

In 2007, the Technology Programme ran two new competitions for funding in spring and autumn, inviting proposals on offshore wind technology. Specifically, the autumn call focused on the continued need to develop materials for aggressive environments as one of the key factors in improving the economics of this technology. Innovative collaborative R&D proposals were aimed at, but not restricted to, the development of materials for:

- Efficient, low-emission energy generation;
- Cost-effective materials and coatings with improved intrinsic and through-life properties;
- Improved understanding of fundamental materials degradation mechanisms.

Projects range from small, highly-focused basic research aimed at establishing technical feasibility to applied research and experimental development projects configured to produce technology demonstrations. Projects ideally include at least one partner with defined end-user needs. Typically, a project lasts two to three years and requires TSB support in the range of 1 to 2 million £. Projects generally aim to implement significant business change in five to seven years. Further details about the Technology Programme can be found at http://www.berr.gov.uk/dius/innovation/technologystrategyboard/index.html.

5.2.2 Energy Technologies Institute

The ETI and the Carbon Trust have joined forces to announce plans for a 40 million £ initiative aimed at cutting the costs of offshore wind power and accelerating its deployment around the UK. The Offshore Wind program will maximise the innovation potential of all organizations that express interest in participating in this program. The Carbon Trust and ETI both see offshore wind as a strategic priority and the combined expertise and resources of these two organizations is expected to have a significant impact in accelerating progress in the sector. To support increasing levels of deployment in line with the government's ambition, the initiative has the following goals for 2020:

- Reduced costs: cost of energy to be reduced to the prevailing least-cost wholesale price of electricity, or lower;
- Increased yields: annual farm availability to be increased to 97%-98% or better, equivalent to onshore wind today;
- Reduced risks: reduction in technical uncertainties to allow farms to be financed in a manner and at costs equivalent to onshore wind today.

The initiative will include a range of projects involving research, development, and demonstration activities, generally funded at a level between 1 and 20 million £ each, and overall, the initiative will comprise a small number of major activities. The exact technical scope of each project will be worked up later in a portfolio development process; however, the Offshore Wind program is interested in the following areas of work:

- Design and demonstration of novel offshore systems;
- Improvements to existing technologies; and
- Supporting studies on other issues critical to deployment.

5.3 R, D&D projects

R, D&D projects supported by the Technology Programme during this reporting period include:

- Finite-Element Modelling of Offshore Wind Turbine Support Structures
- Stealth Technology for Wind Turbines

- Stealthy Wind Turbines – Addressing the Radar Issue
- A Low Cost, Safety Critical Radar Absorbing Material for Wind Turbine Nacelles and Towers
- Affordable Innovative Rapid Production of Offshore Wind Energy Rotor-Blades
- Innovative High-Power Direct-Drive Superconducting Generator for Offshore Wind
- Competitive Concrete Towers and Foundations for Future Offshore Wind Farms
- Offshore wind field sensor using Lidar Anemometer
- Cost Reduction and Life Extension of Offshore Wind Farms
- Deepwater Offshore Windfarm Demonstrator Project

These projects are at various stages of the project cycle from inception to completion. More details about three of the projects that have either started or were proposed in 2007 are given in the following sections.

5.3.1 Radar absorbing composite for blades

The project aims to develop radar absorbing composite structures for wind turbine blades that will achieve Civil Aviation Authority (CAA) approval by reducing the radar effect by 20 dB within the S-band and 20 dB within the X-band. The composite will consist of fibers with tailored electrical conductivity, woven into a pyramid structure with continuously graded impedance that will be integrated into the blade structure during manufacture.

5.3.2 Rotor blades for offshore

This project Affordable Innovative Rapid Production of Offshore Wind Energy Rotor-Blades aims to develop cost effective, rapid manufacturing of large-scale wind turbine rotor blades using innovative materials such as high stiffness fibers and automated, high-deposition fiber placement technology.

5.3.3 Offshore foundations

This project aims to enable fast, efficient, and cheaper production of offshore marine foundations. The proposed work is targeted at making a step change in production capability using a new fabrication process called Reduced Pressure Electron Beam Welding, and it will take advantage of novel steel formulations that are just becoming available.

6.0 The Next Term

The government will be undertaking a Strategic Environmental Assessment (SEA) of the seas surrounding the UK. This SEA will inform the government's decision on the development of any future Round 3 of offshore wind farm development licensing. Building on the extensive consultation and consideration given to the area during 2007, the government intends to publish, in April 2008, its final policy proposals for an offshore transmission regime. Before the policy is implemented there will be further consultation in 2008. The Climate Change Bill is expected to enter into force during the summer of 2008.

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Authors: Kieran Lettice, Tom Willcock, and Ben Poole, AEA Energy & Environment; John Overton, Department of Business, Enterprise and Regulatory Reform, United Kingdom.

Chapter 30
United States

1.0 Introduction

Total national wind generation capacity for the United States increased to 16,904 MW in 2007 from 11,575 MW in 2006 (Figure 1), an increase of 5,329 MW or 46%. This is more than twice the new capacity added in 2006 (2,454 MW), which was also a record year. The industry reports about 1,500 MW of projects under construction at the close of 2007, and 2008 is expected to be another banner year for wind energy with total capacity growth in excess of 5,000 MW.

The U.S. capacity added in 2007 represented more than 27% of worldwide additions to wind capacity in that year. The United States was second in total generating capacity behind Germany and first place in the world for growth in capacity, followed by China and Spain.

Approximately 45 new projects (excluding projects less than 2 MW) were installed in 18 states that commissioned more than 3,200 turbines in 2007. The average size of the turbines installed in 2007 was 1.65 MW, a slight increase from 1.6 MW in 2006. However the average size of turbines in projects under construction was about 1.7 MW. The largest wind plant operating is the 735-MW Horse Hollow wind plant in Texas.

Wind energy projects accounted for about 35% of the new generation capacity installed in 2007. The current wind capacity will generate approximately 48 million MWh per year—enough to provide power for 4.3 million U.S. homes—and displace approximately 30 million metric tons of carbon dioxide that would have been emitted by traditional resources (based on average U.S. electricity sector CO_2 emissions in 2006 as reported by the Energy Information Administration).

Wind energy is the fastest-growing energy technology and has increased its contribution to just over 1% of total U.S. generation. However, in Minnesota and Iowa nearly 7.5% of the electricity consumed is generated by wind power.

The small wind turbine industry also experienced significant growth in 2007. According to the American Wind Energy Association (AWEA), the small wind turbine (defined as wind turbines with a capacity rating of 100 kW or less) industry grew by almost 20% in 2007. The industry added 9.7 MW of new capacity, bringing the total small wind capacity to more than 55 MW. More than 9,000 units were sold for 42 million USD, and 98% of the units were sold by U.S. manufacturers (1).

2.0 Progress Toward National Objectives

In 2006, the President announced an Advanced Energy Initiative that calls for the accelerated development and use of clean energy technologies, including wind. According to the initiative, areas with good wind resources have the potential to supply up to 20% of the total U.S. electricity demand. This prompted a collaborative effort in 2007 by industry and government to explore what it would take to provide 20% of U.S. electricity from wind energy by 2030 (2). The resulting report concluded that producing 20% of the nation's electricity from wind technology is technically feasible and would require an increase in wind generating capacity from the current 16.9 GW to more than 300 GW. To achieve this increase by 2030, annual increases in wind capacity will need to exceed 16 GW after an initial 10-year ramp up period.

Table 1 Key Statistics 2007: United States	
Total installed wind generation	16,904 MW
New wind generation installed	5,329 MW
Total electrical output from wind	48 TWh
Wind generation as % of national electric demand	1%
Target:	NA

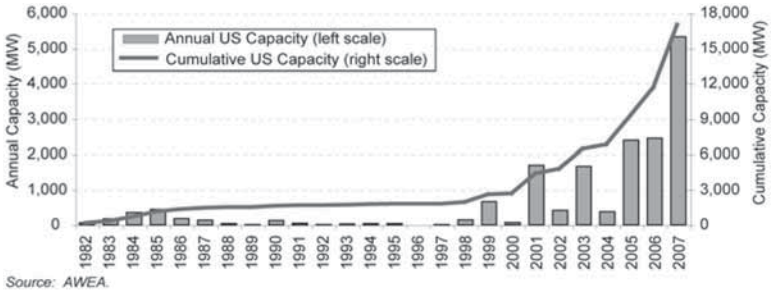

Figure 1 Annual and cumulative U.S. wind energy capacity 1982–2007.

In the nearer term, a goal of the U.S. Department of Energy (DOE) Wind Energy Program's Wind Powering America (WPA) project has been for 30 of the 50 states to each have more than 100 MW of generating capacity by 2010. By the close of 2007, 16 states had reached the 100-MW level, the same number as in 2006. However, within these states generation grew significantly. Six states now have more than 1,000 MW of generating capacity:

- Texas: 4,446 MW
- California: 2,439 MW
- Minnesota: 1,298 MW
- Washington: 1,163 MW
- Iowa: 1,271 MW
- Colorado: 1,067 MW

In addition, 22 states now have 50 MW or more of generation to build upon in the coming years. In all, 34 states had wind plants by the close of 2007.

3.0 Benefits to the National Economy

The new generating capacity installed in 2007 represents an investment of nearly 9 billion USD that provided 17,000 to 19,000 new job-years nationwide (17,000 one-year jobs or 1,700 long-term 10-year jobs). Wind developments paid 10 to 16 million USD or more in annual payments to landowners.

Even states that do not have a significant wind resource have benefited from the increased investment in manufacturing facilities and services as a result of wind power development. For example, more than 775 new jobs were created in 2007 with the opening of six manufacturing plants for wind turbine components in Illinois, Iowa, South Dakota, Texas, and Wisconsin. Also in 2007, planned manufacturing plants announced will create more than 5,000 new jobs in Arkansas, Colorado, Iowa, New York, Oklahoma, North Carolina, and South Dakota.

According to AWEA (1), the small wind industry brought 42 million USD in sales to the U.S. economy and generated 300 full-time and 95 part-time manufacturing jobs. These jobs do not include the hundreds of dealers, installers, component vendors, and industry support businesses located throughout the U.S.

3.1 Market characteristics

Ownership patterns for operating wind plants are changing as dominant developers are buying projects developed by others and bringing them under central operation, maintenance, and marketing structures. For example, Babcock & Brown acquired seven wind projects totaling more than 750 MW from Gamesa Energy USA, LLC. With this acquisition, Babcock and Brown operated 20 U.S. wind plants in nine states with more than 1,500 MW of installed capacity.

According to a report published by DOE (3), private independent power producers (IPPs) continued to dominate the wind industry in 2007, owning 83% of all new capacity. Sixteen percent of the new additions are owned by local electric utilities and 1% by community wind power projects. Community wind power projects are defined as projects using turbines over 50 kilowatts (kW) in size. These projects are completely or partly owned by towns, schools, commercial customers, or farmers.

Wind projects are now rivaling the size of nuclear or coal-generation projects. The largest wind project proposed so far was announced in 2007 by T. Boone Pickens, a Texas oil developer. The Mesa Power LP project is planned for up to 4,000 MW in West Texas. Another large project was announced in July 2007 by Shell WindEnergy Inc. and Luminant. A subsidiary of TX Corp., Luminant has more than 18,000 MW of generation in Texas, including 2,300 MW of nuclear and 5,800 of coal-fired generation capacity. Luminant and Shell WindEnergy plan to add a 3,000-MW wind power plant in the Texas panhandle to the TX Corp. portfolio. This location will take advantage of excellent wind resources and relatively low-cost transmission to wholesale markets. This project will also explore compressed air storage, using excess electricity to pump air underground for later use in generating electricity.

Another market approach is to install wind turbines in areas once used for heavy industrial production. These brownfield sites, located near load centers, can be adapted for clean energy production. Because nearby communities are accustomed to industrial development, the permitting process rarely includes objections from the citizenry. In fact, wind development is seen as an improvement to the area. For example, in 2007, eight 2.5-MW turbines manufactured by Clipper Windpower were installed on 30 acres of a former steel production site in Lackawanna, New York, on Lake Erie (Figure 2). The project used the old steel mill's roads and off-site transmission lines and so required little new infrastructure. It is expected to produce 20 MW of electricity for sale to retail customers. The project won the 2007 Best Renewables Project of the Year Award from *Power Engineering Magazine* in part because the project demonstrated wind power's potential to revitalize industrial as well as rural communities.

3.2 Industrial development

The majority of the U.S. wind turbine manufacturing market in 2007 was claimed by General Electric Energy (GE), Vestas, and Siemens. GE remained the dominant manufacturer, claiming 44% of the market; Vestas 18%, Siemens 16%, Gamesa 11%, Mitsubishi 7%, Suzlon 4%, Clipper Windpower 1%, and Nordex 0.05% (Figure 3).

During 2007, GE supplied nearly half of the new wind capacity in the United States and its wind business revenues exceeded 4 billion USD for the year. AWEA, a wind energy trade group, estimated that GE installed more than 1,560 of its 1.5-MW wind turbines in the United States during the year. In 2007, GE began commercial production of its new 2.5xl wind turbine (Figure 4) with a 100-m rotor for land-based applications. According to the company, the 2.5xl can operate at sites with average wind speeds of up to 8.5 mps, resulting in a 12% increase in annual energy yield over turbines that shut down at such high wind speeds. GE also announced a

Figure 2 The Steel Winds (Niagara) development in Lackawanna, New York, will generate enough electricity to power approximately 5,000 homes.

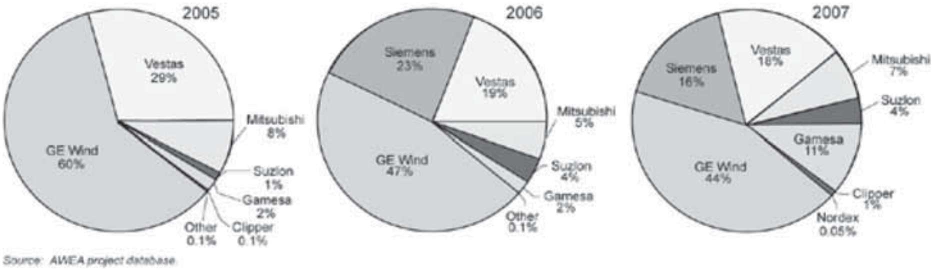

Figure 3 Top manufacturers contributing to the U.S. market for large-scale wind turbines.

deal with wind developer Invenergy to supply more than 1 billion USD of turbines for 2009. The deal includes 1.5-MW turbines for the U.S. market and 2.5-MW turbines for the European market.

In September 2007, Clipper Windpower of Carpinteria, California, and the National Renewable Energy Laboratory (NREL) received an Outstanding Research and Development Partnership Award from the U.S. Department of Energy for the design and development of its 2.5-MW Liberty wind turbine, the largest wind turbine manufactured in the United States. The variable-speed turbine incorporates a multiple-drive-path gearbox feeding four permanent-magnet generators. Clipper Windpower installed 170 MW of its 2.5-MW Liberty wind turbine in 2007.

Figure 4 GE Energy's 2.5xl wind turbine has a 100-meter rotor and operates at sites with average wind speeds of up to 8.5 mps.

A consolidation between Clipper Windpower and Hemeretik, a construction and real estate business based in Spain, will form a global renewable energy development business called CAPGEN. According to Clipper, CAPGEN will have 10,500 MW in wind development assets, and the majority of its portfolio will be located in the United States. In October, Clipper also announced development of a Centre of Excellence for Offshore Wind in Blyth, United Kingdom, to develop the world's largest offshore wind turbine at 7.5 MW. The Britannia Project attracted support from the UK's One NorthEast Regional Development Agency.

The manufacture of wind turbines in the United States is increasing with the establishment of factories by major international suppliers. For example, Acciona, based in Madrid, completed a wind turbine manufacturing facility in West Branch, Iowa, that will employ more than 100 people. The facility will produce 200 of its AWP 1.5-77 model in 2008 for Acciona Energy wind plants in North America. When the plant reaches full capacity, it will supply approximately 2,610 MW of capacity per year worldwide.

U.S. production capacity for wind turbine blades also increased dramatically in 2007, promising to help reduce manufacturing and transportation costs associated with this major wind turbine component. The wind blade division of Knight & Carver opened a 2,415-m^2 blade manufacturing and repair facility in Howard, South Dakota. LM Glasfiber, headquartered in Denmark, will open its third North American production facility in Little Rock, Arkansas, employing more than 1,000 people in 2008. Vestas Blades of Denmark broke ground on its first North American manufacturing facility in

Windsor, Colorado. The 18,581-m², 62-million-USD facility will produce about 1,200 blades per year and provide about 450 manufacturing jobs beginning in 2008.

Production of small wind turbines in the United States is also a significant economic activity. According to AWEA's 2008 Small Wind Turbine Global Market Report (1), U.S. manufacturers maintained their global sales lead in small wind turbines during 2007. Approximately 49 U.S. companies manufacture or plan to manufacture small wind turbines. U.S. manufacturers export to more than 120 countries and exports account for approximately 40% of U.S. manufacturers' sales. Domestic demand for small wind systems increased for homes, farms, or small businesses.

With increasing sales of small turbines has come an issue of product quality. Small wind turbine consumers have no third-party information to compare turbines and estimate performance. To address this issue, the Small Wind Certification Council (SWCC) was incorporated as an independent certification body for North America. The SWCC will certify small wind turbines that meet or exceed performance, durability, and safety requirements.

The Board of the SWCC was elected in early 2008 and will commence certifying turbines beginning in 2009. Some turbines submitted by manufacturers for certification will be tested in the United States at NREL's National Wind Technology Center (NWTC) in Boulder, Colorado; others may be tested in Canada at the Wind Energy Institute of Canada's North Cape facility. The SWCC is currently developing protocols for certifying small wind turbine systems, including those not tested at accredited facilities. Certified turbines will be labeled for rated power, rated annual energy production, and rated sound level.

3.3 Economic details

Although project costs are influenced by many factors, turbine costs are the largest contributor. According to DOE's Annual Report (3), between 2006 and 2007, capacity-weighted-average turbine prices increased by roughly 115 USD/kW–from 1,125 USD/kW to 1,240 USD/kW–and project costs have increased on average by roughly 370 USD/kW during the last several years (Figure 5). This increase in costs is driven by increasing commodities prices, unfavorable exchange rates, and fully committed production capacities (3).

Despite rising turbine costs, the cost of electricity from wind energy is still competitive with that generated by conventional sources in many areas. A database of wind power sales prices maintained by DOE contains price data for 128 wind projects installed between 1998, and the end of 2007. At the end of 2007, the capacity-weighted average (projects are weighted by nameplate capacity to represent actual market prices) 2007 sales price for projects built in 2007 was roughly 45 USD/MWh. Although this price is slightly less than the 2006 price of 48 USD/MWh, it is higher than the average price in 2004–2005 of 37 USD/MWh. This price is what the utility pays to the wind plant operator and includes the benefit of the federal production tax credit and state incentives.

The booming wind energy business has not gone unnoticed on Wall Street. The New York Mercantile Exchange Inc. (NYMEX)—the largest physical commodity futures exchange in the world—has launched an "alternative energy" equity index futures contract on its Globex

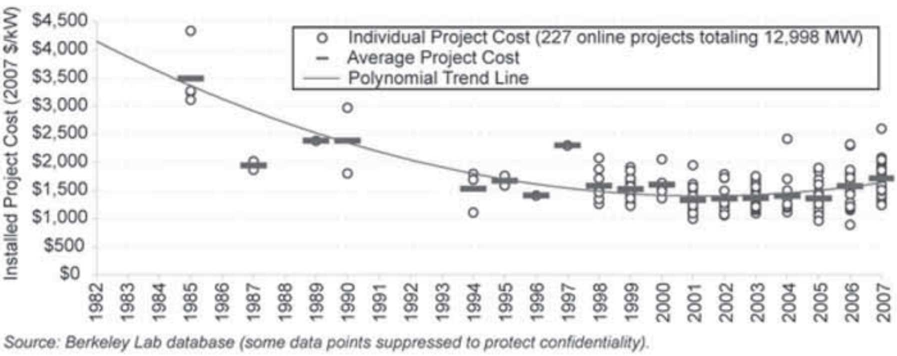

Figure 5 Wind project capital costs, 1982–2007.

electronic trading platform to help investors gain exposure to the growing sector. The new contract is based on the Ardour Global XL Index, which is comprised of 30 publicly traded companies. Wind turbine manufacturers such as Vestas, Gamesa, and Nordex are included in the Index.

4.0 National Incentive Programs

Federal tax incentives along with state Renewable Portfolio Standards (RPS) and incentives played important roles in the record growth of 2007. The federal tax credits approved for 2005–2008 have given companies time to expand production. In addition, the mandatory state RPS policies established through the end of 2007 will cover 46% of the nationwide retail electricity, according to a report published by DOE (3). The report states that more than 50% of the non-hydro renewable capacity additions in the United States from 1998 through 2007 occurred in states with mandatory RPS programs; 93% of these additions came from wind power, 4% from biomass, 2% from solar, and 1% from geothermal.

Approaches to reduce carbon emissions may also impact wind energy development. Six states have entered into a cap-and-trade agreement, and a carbon tax has been mentioned, but federal legislation on either approach is uncertain.

4.1 Federal incentive programs

The U.S. government provides R&D funding and tax incentives for energy sector development because of its importance to society. In 2007, a key vehicle to promote renewable energy development was the federal Energy Policy Act (EPAct) of 2005 (4). The EPAct contains several provisions that benefit the wind energy industry, including the extension of the federal production tax credit (PTC). In addition to the PTC, the EPAct requires development of utility system reliability rules that are ‘nondiscriminatory’ and provides incentives to encourage construction of new and upgraded transmission lines.

In 2007, the inflation-adjusted value of the PTC was 0.02 USD/kWh for wind energy. To be eligible, projects must be in service by the close of 2008. The PTC goes to the owner(s) of the eligible renewable generating project, and the PTC is reduced if projects also receive certain types of government grants, tax-exempt bonds, subsidized energy financing, or other federal tax credits. Only projects located in the United States that sell their output to an ‘unrelated person’ may qualify for the PTC.

The record-breaking increases in capacity in 2006 and 2007 are evidence of the effectiveness of the PTC. An analysis of the effect of the PTC on the wind energy market (5) shows that extension for a longer term could reduce the cost of wind energy developments. The analysts projected that longer terms would result in 5%–15% lower costs for wind projects relative to the historical cycle of one- or two-year extension of the PTC. Savings would result from increased local manufacturing and elimination of a capital cost premium, estimated at 12%, that results from the ‘boom and bust’ cycle of expiring incentives.

Other federal incentives currently offered include: Modified Accelerated Cost-Recovery Systems, Renewable Energy and Energy Efficiency Improvements Program, and the Energy Efficiency and Renewable Energy’s Tribal Energy Program.

4.2 State incentive programs

The voluntary purchase of wind-generated electricity through green power or green pricing programs has had a significant effect on wind industry growth in the United States. According to a report published by NREL in December 2007 (6), about 25% of the nation’s utilities (more than 750) offer green power programs to customers. Green power is available to most electricity customers living in 46 out of the 50 U.S. states. In addition, any consumer can purchase green power through renewable energy certificates (RECs). In 2006 (the latest year with numbers available), an estimated 700,000 electricity customers purchased green power products through regulated utility companies, from green power marketers in a competitive market setting, or in the form of RECs. Wind energy provided 7.4 billion kWh of green power purchases in 2006. The estimated market value of this electricity was between 40 million and 53 million USD.

Green power purchases are growing among corporations. In 2007, the Environmental Protection Agency (EPA) reported 53 Fortune 500 companies participating in the Green Power Partners program that tracks purchases of RECs.

REC purchase agreements in 2007 totaled more than 13 billion kWh per year.

Initially, green power was almost always purchased at a higher price than that provided by conventional power sources. However, in Wisconsin the combination of green energy capacity provided at stable long-term contract prices and higher costs for fossil fuel has closed the price gap between the two in 2007. To pass this savings on to customers, Wisconsin Public Power, Inc. filed a plan with its regulatory commission to supply twice the green electricity for each block of green power purchased, essentially cutting the premium in half. The company foresees continuing price reductions as it adds new wind facilities in Iowa and Wisconsin to its generation mix.

State mandated RPS have also had a significant effect on the wind industry. An RPS requires utilities to purchase a percentage of their overall generating capacity from renewable resources. By the end of 2007, 25 states and the District of Columbia had adopted RPS, according to a DOE study (7) . In 2007, four states established new RPS policies, 11 states significantly revised pre-existing RPS programs, and three states created non-binding renewable goals. The goals for renewable contributions adopted by these states range from 4% by 2009 (Massachusetts) to 40% by 2009 (Maine). Assuming that full compliance is achieved, current mandatory state RPS policies will require the addition of roughly 61 GW of new renewable capacity by 2025, equivalent to 4.7% of projected 2025 electricity generation in the United States.

Other state programs that provide stimulus for market growth include: grant programs, loan programs, production incentives, and utility resource planning.

4.3 Transmission policies

The Federal Energy Regulatory Commission (FERC) adopted a new regulation in 2007 that allows greater access to transmission lines for power generators of all types, including wind energy projects. The new rule exempts intermittent power generators, such as wind power plants, from excessive 'imbalance' charges when the amount of energy they deliver is different than the amount of energy they are scheduled to deliver. The new rule requires public utilities to work with the North American Electric Reliability Corporation to develop consistent methods of calculating the available capacity and to publish those calculations to increase transparency. It also calls for open, coordinated, and transparent planning on both local and regional levels. The new final rule applies to all public utility transmission providers, including regional transmission organizations and independent system operators (8).

By the close of 2007, California, Colorado, Minnesota, New Mexico, and Texas had passed legislation to facilitate construction of necessary transmission lines from windy areas to load centers. These states are demonstrating the effectiveness of renewables-oriented transmission legislation to solve the two-fold problem facing wind development in the United States. Utilities will not construct transmission lines to windy areas unless they have generation facilities, and developers will not build generation in windy areas unless there are transmission lines. The solution has been to pass legislation calling for utilities to identify transmission-constrained 'energy resource zones' or 'competitive renewable energy zones.' Then utilities must report to the regulatory public utilities commission how they intend to address the constraints. Once plans to build lines are approved by the regulators, the utilities can recover the costs from customers when construction begins.

The Texas Public Utility Commission designated eight competitive renewable energy zones. This means that the Electric Reliability Council of Texas must plan transmission lines to good resource areas to handle wind (or other renewables) capacity of between 10,000 MW and 25,000 MW. These lines will be paid for by all consumers in Texas. A utility in the windy Texas panhandle, Sharyland Utilities, L.P., has proposed an 800-mile transmission loop to access up to 4,200 MW of wind power resources (9).

In southern California, the 1.8-billion-USD Tehachapi Transmission project approved in 2007 will increase grid access for large amounts of planned geothermal, solar, and wind generation. An innovative financing vehicle for new transmission lines has been proposed that would allow utilities to invest in a transmission line and then charge renewable generators for the line as they use it.

4.4 Small wind

Many states also have policies and incentives for small wind electric systems. These incentives include rebates and buy-downs, production incentives, tax incentives, and net metering. Several states have adopted buy-down programs that levy a small charge on every kilowatt-hour of electricity sold. The money raised is then used to buy down or subsidize the purchase of small renewable energy systems. The subsidy or rebate may be as much as 50% of the cost of a small wind turbine. The rebates become even more effective when combined with low-interest loans and net metering programs.

Under net metering policies, electric customers who install their own grid-connected wind turbines are allowed to interconnect their turbines on a reverse-the-meter basis with a periodic load offset. The customer is billed only for the net electricity consumed over the entire billing period. In most states with net metering, excess generation beyond what the customer uses to offset consumption during the billing period is sold to the utility at avoided cost or granted back to the utility without payment to the customer. In 2007, 40 states and the District of Columbia offered some form of net metering policy.

For more information on state and federal incentive programs, visit the Database for State Incentives for Renewables & Efficiency at http://www.dsireusa.org/.

5.0 R, D&D Activities

The U.S. national R, D&D program supports research to improve cost, performance, and reliability of large-scale land-based technology; improve the performance and reliability of distributed generation technologies using smaller turbines; anticipate and address issues with integration of wind into the electric transmission system; work to increase acceptance of the technology; and promote collaborative research to benefit from worldwide wind energy research.

The total budget for the DOE Wind Energy Program was 49.3 million USD in 2007. For the 2008 fiscal year, the budget was 49.5 million USD.

5.1 Large wind turbines

Reducing the cost of electricity from large wind systems on land is the goal of the DOE large wind turbine (LWT) research program (11). As a result of LWT research, utility-scale land-based wind turbines should produce electricity (not including subsidies and credits) for 0.036 USD/kWh by 2012 in 5.8 m/s wind regimes at a height of 10 m (Class 4 winds). In 2007, wind-generated electricity cost between 0.04 USD/kWh and 0.09 USD/kWh in Class 4 wind regimes, which are found across the United States; however, costs depend on many factors, including project financial structure.

The strategy of the LWT research is to improve the reliability and operability, increase capacity factors, and improve manufacturability of existing technology while developing tools for designing and testing new approaches. Using better design methods and new materials will allow turbine generation capacity to increase faster than the weight of components. Reducing the weight/kilowatt of generation capacity should reduce the cost of energy generated (10). Each major component is being investigated including gearboxes, blades, and control systems, as well as complete wind turbine systems.

5.1.1 Gearboxes

Reducing drive train weight and cost while improving reliability have been the goals of the WindPACT drive train project (11). Simple gearbox designs and moderate-sized generators show potential for reducing tower-head weight and drivetrain costs. One approach has resulted in a prototype 1.5-MW direct-drive generator using rare earth permanent magnets that was built and tested at the NWTC in 2007. It uses 56 poles and is 4 m in diameter compared to 10 m for a typical wound rotor of the same capacity.

Another approach to reducing size and weight is a single-stage drive that uses a medium-speed generator. The medium-speed generator is smaller than a comparable direct-drive design. The WindPACT prototype design uses a single-stage planetary drive operating at a gearbox ratio of 9.16:1. The gearbox drives a 190-RPM, 72-pole, permanent-magnet generator. This approach reduces the diameter of a 1.5-MW generator to 2 m. The prototype was tested in 2007 on the NREL dynamometer. The generator is currently being upgraded, and a second phase of testing is planned for 2008.

Improving gearbox reliability will reduce operation and repair costs in the wind industry. In response to industry requests for leadership in this area, NREL initiated a long-term Gearbox Reliability Collaborative to improve the performance and durability of gearboxes.

The collaborative will validate the typical design process, beginning with calculating system loads and moving all the way to the rating of bearings. Extensively instrumented gearboxes will undergo comprehensive dynamometer tests as well as full-scale field tests. These tests will identify weaknesses in current design approaches and point out ways to improve initial designs and retrofit packages. With support from facilities and expertise at NREL and Sandia National Laboratories, this activity is designed to sustain the rapid growth in the wind industry by achieving gearboxes that live up to their design lives.

In 2007, the Gearbox Reliability Collaborative sponsored a workshop on wind turbine bearing technology at the NWTC taught by an expert on bearings. Attendees included representatives of owners, operators, and designers of wind turbines from the United States and Europe as well as NREL staff and consultants. Improving bearing reliability is a primary focus of the Collaborative. Presenting information and engaging wind industry members with the Gearbox Reliability Collaborative is designed to identify the most likely causes of bearing failure.

5.1.2 Blades

In response to the increased industrial activity across North America and the larger blades being deployed on wind turbines, NREL is sponsoring development of two new blade test facilities in Massachusetts and Texas. Consortiums will design, build, and operate the new facilities to test the next generation of wind turbine blades up to 330 ft (100 m) in length. Testing ensures that blades meet design standards, and it reduces the financial and technical risk of deploying mass-produced wind turbine blades.

In 2007, the NWTC operated the only independent test center for full-scale testing of megawatt-size wind turbine blades. During that time, blade handling at the NWTC was improved with the addition of a 75-ton industrial mobile hoist. The hoist was used to move the Clipper Windpower 47-m blade into place for tests. The hoist will also be used to transport and position towers, drivetrains, and other heavy equipment at the test site.

Sections of multi-megawatt blades were instrumented and tested in 2007 to validate wind tunnel models and designs. The work was conducted in collaboration with Clipper Windpower, GE Energy, and Risoe National Laboratory. Before beginning systematic production testing in the Virginia Polytechnic Institute and State University Stability Wind Tunnel, validation of the facility, airfoil models, and four different sets of instrumentation were completed. Validation will ensure that these models and instrumentation sets will be able to characterize airfoil surface pressure distribution, boundary layer profile, wake momentum profile, and aeroacoustic signature.

Research on blade design came to fruition when Knight & Carver of Howard, South Dakota produced the first in a series of wind turbine blades under a Cooperative Research and Development Contract (CRADA) with Sandia National Laboratories. Referred to as the STAR blade (sweep-twist adaptive rotor), the 27.5-m blade is curved to relieve pressure on both the turbine and the blade (Figure 6). Reducing pressure and therefore loads allows a larger, more productive rotor. This concept also shows potential for significant cost and manufacturing

Figure 6 Knight and Carver's STAR blade installed on a Zond Z-48 wind turbine in Tehachapi, California for testing in 2008.

advantages. CRADAs are cost-shared development contracts. They are used to design, fabricate, and test wind turbine components that are expected to have a definitive effect on the overall cost of wind generated electricity.

5.1.3 Control systems

In 2007, the NWTC upgraded two test beds, known as the Controls Advanced Research Turbines (CARTs). One was converted from a 2-bladed rotor to a 3-bladed, 40-m rotor adapted from GE. Now called CART3, this test bed for turbine generators, power electronics, and controls strategy will be used to validate approaches for the popular 3-bladed configurations used in most wind plants. The 2-bladed, dynamically soft test bed, CART2, was modified to test new control algorithms designed to alleviate loads and to enhance energy capture.

5.1.4 Turbine testing

The NWTC's quality assurance program is accredited by the American Association for Laboratory Accreditation for power performance, loads, power quality, acoustic noise, and blade testing. In 2007, the NWTC conducted loads, power quality, and acoustic emissions tests on full-scale prototypes of two large wind turbines: the Clipper Windpower 2.5-MW Liberty turbine and the John Deere (Suzlon) 2.2-MW turbine.

To solve key questions in utility-scale wind technologies, the Wind Energy Program requested proposals in 2007 to erect commercial turbines (500 kW or larger) at the NWTC for full-scale testing over the next 1 to 3 years. The objectives of this testing are to provide manufacturers with information to optimize turbine structures, mitigate loads, increase power production, test safety systems, develop and validate controls, and improve system and component reliability. If other tests or objectives are needed, they may also be included. The NWTC is an extreme-event test site, where turbines would be exposed to a wide spectrum of diverse and extreme conditions within a single wind season.

5.2 Distributed wind technology

In 2007, the DOE Wind Program expanded its definition of distributed applications to include wind turbines of any size that are installed off the grid or are connected to the grid at a distribution level voltage.

Based on initial findings from the Market Assessment report [1] for small wind turbines, market opportunities exist in distributed applications for three categories of machines: 100-kW or smaller machines for homeowners; 100-kW to 500-kW machines for commercial and farm applications; and 500-kW to 1-MW machines for small communities.

To supply the commercial and farm market, Northern Power Systems reconfigured its 100-kW cold weather turbine for applications in temperate climates. The company began building its machine in 2007 and says that the new machine costs less to produce than the model designed for cold climates. In 2007, the prototype 100-kW turbine was undergoing loads, power quality, and acoustic emissions tests at the NWTC (Figure 7).

In 2007, NREL solicited participation by manufacturers in a test program of commercially available small wind turbines and issued a subcontract to the first of four companies to install and operate their machine at the NWTC. The goal is to provide high-quality, detailed and independent results on safety, function, power performance, acoustic emissions, power quality, and duration testing. Tests will be conducted to International Electrotechnical Commission (IEC) standards, to standards under development by AWEA, and in compliance with the NWTC's accreditation by the American Association of Laboratory Accreditation. In 2007, the NWTC test site was prepared with data acquisition systems and grid-connections for the test turbines and for the turbines from an additional three manufacturers expected in 2008.

To develop an economical and reliable small wind turbine, DOE, NREL, and Southwest Windpower have worked on the Skystream 1.8-kW turbine that has integrated inverter and controls and uses low-noise, swept fiberglass blades. The Skystream won the Best of What's New Award from *Popular Science* magazine and was listed as a best invention for 2006 by *Time* magazine. In 2007, the company began commercial production and applied for certification from Germanischer Lloyd WindEnergie GmbH (GL). Working with Southwest Windpower, researchers at NREL's NWTC conducted performance optimization and blade-fatigue tests on the company's wind generator. Southwest Windpower's first Skystream model was tested at the USDA-

Figure 7 Northern Power Systems' new 100-kW machine will undergo loads, power quality, and acoustic emissions tests at the NWTC in 2008.

Bushland Texas test facility where it underwent IEC duration and power performance tests.

As part of its small wind research, the Wind Energy Program worked with Windward Engineering to conduct tests on its 5-kW Endurance wind turbine. The turbine is sized to offset the energy consumption of an average U.S. home (~11,000 kWh/yr) when installed in a Class 3 wind regime (5 m/s at a height of 10m). Windward used off-the-shelf components from other industries to reduce system cost. It employs an induction generator to simplify grid compatibility and a brake that is capable of stopping the rotor on command in any wind condition—a unique feature for a small wind system. IEC duration testing of the Endurance turbine began in 2007 and will continue through 2008 at the NWTC. To complete the test, the turbine must operate for 2,500 hours of power production. All of the required high wind hours, > 15 m/s, were fulfilled in 2007. This prototype turbine has been spun out of Windward Engineering and into a new company called Endurance Wind Power.

5.3 Systems integration and transmission

Systems integration research supplies important data and analysis tools for those developing rules to ensure reliable grid operations for utilities and transmission operators. In 2007, the Wind Energy Program participated in several studies of the operational impact of high contributions of wind energy in specific utilities. The studies looked at energy penetrations of wind up to 25% in Minnesota and up to 33% (wind and other renewables) in California. At these levels, ancillary costs were below 0.005 USD/kWh, indicating that significant wind energy generation can be integrated into the electricity grid with minimal costs in large transmission systems.

In another effort, researchers are conducting studies that examine the operating impacts of wind variability and uncertainty and mitigation options for grid operators. These regional studies look at five states addressing issues such as: cost of operational impacts, benefits of geographic diversity, benefits of balancing area operations to manage variability, the value of forecasting, contributions of wind energy to reliability and capacity value, and issues of wind integrated with hydropower. Data collection was underway in 2007. In 2008, a detailed wind speed and power database will be developed under contract to NREL. These data will be used by consultants to model the power system in the 5-state region to determine the impact of large wind penetration on power system operations, economics, and reliability.

The reliability coordinator for the Western Interconnection is the Western Electricity Coordinating Council (WECC). It covers large geographic areas with relatively low population densities some of which are experiencing significant wind energy development. To evaluate system-specific requirements for interconnection of wind generation, a generator modeling group of WECC began working on planning models in 2005. As part of this effort, NREL began a project working with manufacturers, power plant operators, and others to validate the standard models being used by WECC. The project uses field measurements of staged tests and naturally occurring disturbances to identify areas in the models that need improvement.

Many believe that some impacts on distribution systems could be mitigated by storing electricity from wind plants. To investigate the potential for this technology, DOE and Sandia National Laboratories provided $2.9 million in funding and technical support for the Iowa Stored Energy Plant Agency. The Agency will build a 200-MW compressed air energy storage power plant and 75-MW wind plant in Iowa. The project will compress and store air in an underground aquifer, using inexpensive off-peak electricity from the grid and from wind turbines. When electricity is needed, the compressed air would be released from storage to drive natural-gas-fired combustion turbines. A reservoir in central Iowa, about 30 miles from Des Moines, has been chosen to act as the project's aquifer. Commercial operation is planned to begin in July 2011.

Another potential storage option involves using the electricity from wind generation to make hydrogen. NREL, in partnership with Xcel Energy, launched a wind-to-hydrogen demonstration project at the NWTC. The project uses two wind turbines (a 10-kW and a 100-kW), two proton exchange membrane electrolyzers, and one alkaline electrolyzer to produce hydrogen from water. The hydrogen is compressed and stored for later use in a hydrogen internal combustion engine where it is converted into electricity and fed into the utility grid during peak demand hours (13).

5.4 Technology acceptance

In response to the President's Advanced Energy Initiative (See Section 2), a collaborative conducted a thorough analysis of the costs and benefits of various scenarios to provide 20% of the nation's electricity demand with wind energy by 2030 (2). The analysis concluded that the 20% wind energy scenario is technically feasible and will require concerted efforts by industry, governments, and research laboratories. Identifying barriers and developing strategies to overcome them is one way the DOE Wind Energy Program aims to increase acceptance of wind energy technology in the country.

An important factor in technology acceptance is the confidence consumers have in products that have been certified by accredited laboratories. The Wind Energy Program has been working to help organizations become certifying bodies for wind energy systems. In 2007, the first accreditation for power performance testing by a private company in the United States was awarded to Global Energy Concepts (GEC) by the American Association for Laboratory Accreditation. GEC is accredited for power performance tests in accordance with IEC 614-12-1:1995, IEC 61400-12:1998 and MEASNET Power Performance Measurements (Version 3, November 2000).

The Wind Energy Program also works to resolve environmental issues affecting the deployment of wind energy technologies. To this end, the NWTC and the National Wind Coordinating Collaborative (NWCC) hosted the seventh Wildlife Research Meeting that brings participants up to date on research being conducted to understand the interaction of birds, bats, and other wildlife with wind energy development. The participants from universities, utilities, the industry, environmental groups, and government organizations examined what has been learned about ways to minimize or mitigate wind energy's impacts on wildlife. They also worked to identify gaps in knowledge and set research priorities. In 2007, several publications were added to the information available about methodologies and environmental impacts of wind energy projects (13).

Information is one of the keys to technology acceptance. The Wind Program's WPA project provides information about the technology and the benefits of wind energy (11) with regional organizations, federal agencies, state and local energy offices, Native American agencies, rural agencies, electrical cooperatives, and utilities. The goal of WPA is for 30 states to have 100 MW of wind installed by 2010.

In 2007, WPA was working with 28 state working groups to increase understanding of the issues surrounding wind energy development. The program's annual State Summit attracted 160 participants from 39 states, so working groups in new states are expected in 2008. This year, WPA added Regional Wind Energy Institutes in the Southwest, Great Lakes, and the Mid-Atlantic areas to help wind advocates move policies forward that support wind development. In 2007, WPA also began a series of workshops on Wind for Schools to engage universities and rural schools in wind energy education. At five universities, WPA launched wind application centers. These centers will host workshops for K-12 schools.

Local and regional wind resource information is very important for planning wind development. To improve the quality of resource information available at the state level, WPA worked to develop and distribute maps of the wind energy resource. In 2007, the Northern New England map was completed which shows significant offshore resource areas. Maps are under development for the Great Lakes areas that will provide accurate estimates of the winds for offshore development, for example near the Cleveland area.

5.5 Collaborative research

In addition to working with industry partners, universities, and special-interest groups in the United States, in 2007, the Wind Energy Program signed collaborative agreements with Denmark's Risø National Laboratory, Technical University of Denmark (DTU), and Spain's Centro Nacional de Energias Renovables (CENER). The program is collaborating with Risø on research in areas such as meteorology, aerodynamics, wind turbine structures and materials, control systems, and electrical grid integration. NREL signed a $6 million cooperative research and development agreement (CRADA) with Spain's Centro Nacional de Energias Renovables (CENER) in July that will enable the two organizations to collaborate on the development of a new wind turbine component test facility in Pamplona Spain. The CRADA will allow the two organizations to exchange test facility and equipment design information that will enable each to develop advanced technology to serve their respective regional interests.

The Wind Energy Program also benefits from participation in the IEA Wind international agreement. Program representatives gain information by attending executive committee meetings. In addition, U.S. researchers serve as operating agents for three IEA Wind tasks and integrate that cooperative research into ongoing U.S. activities. The U.S. research community also benefits from DOE's participation in other IEA Wind research tasks. Participation makes it possible for U.S. researchers to contribute to and benefit from cutting-edge analyses of the most pressing issues facing wind energy development worldwide. The following IEA Wind tasks are managed by researchers from the United States.

Task 20 HAWT Aerodynamics and Models from Wind Tunnel Measurements. As the operating agent for this task, the U.S. shared data from a full-scale wind tunnel experiment in 2000 at the NASA wind tunnel in Ames, Iowa. Participants used the data to test and refine their aerodynamics models. A final report will be issued in 2008.

Task 23 Offshore Wind Energy Technology and Deployment. The United States supports this task in joint leadership with Denmark and participates in offshore technology R&D by sharing much of its offshore modeling work.

Task 24 Integration of Wind and Hydropower Systems. In addition to being the operating agent for this task, and gaining results from the six participating countries, the United States is sharing three wind and hydropower case studies: Missouri River Wind Integration Study, Mid-Columbia River Study: Grant County Public Utility District, Lower Colorado River: Arizona Power Authority (APA). This task will complete its work in 2008 with the publication of a final report.

In addition to managing three tasks, the United States participates in the following IEA Wind research Tasks.

Task 11 Base Technology Information Exchange. This ongoing task promotes wind turbine technology through information exchange between experts on R&D topics of common interest. U.S. representatives attend Task 11 meetings on a regular basis to share information and benefit from the input of experts from around the world.

Task 19 Wind Energy in Cold Climates. This task develops guidelines for applying wind energy in cold climates by gathering and sharing information on operational experience and modeling. Participants established a preliminary site classification formula for wind turbine designers, manufacturers, project developers, and wind energy producers.

Task 21 Dynamic Models of Wind Farms for Power Systems Studies. The United States validated a model for a small wind plant (four 180-kW wind turbines) in Alsvik, Sweden, using data provided by task participants. Results of the validation were published in the Task 21 final report in 2007.

Task 25 Power System Operation with Large Amounts of Wind Power. This task provides information to facilitate the highest economically feasible wind energy penetration within electricity power systems worldwide. As its contribution to this effort, the United States is reviewing the methodologies and studies in progress and recently completed in the United States.

Task 26 Cost of Wind Energy. This task began in 2007 to develop a common, transparent methodology for estimating the cost of wind energy and to identify the primary differences among countries. The work of this task should help efforts in the United States to compare cost of energy for various technologies.

In addition to the Wind Energy Program's efforts, DOE's Office of Electricity Delivery and Energy Reliability is working with the IEA Implementing Agreement on Distributed Generation on integration of demand-side management, distributed generation, and renewable energy sources and energy storage.

6.0 The Next Term

All sources expect 2008 to be another record year for wind energy installations in the United States. Development after that will be somewhat dependent on extension of the federal production tax credit, which was uncertain at the close of 2007.

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(8) For more information see Open Access Transmission Tariff Reform at http://www.ferc.gov/

(9) For more information visit http://www.su-power.com/panhandle_loop.asp.

(10) Goals using cost of energy are tracked to a fixed technology baseline that reflects a set of standard financial and technology assumptions for each technology (land-based, offshore, and distributed wind technologies). Cost-of-energy targets differ from actual market conditions, as baseline technology assumptions do not include such factors as the on-and-off nature of the production tax credit that leads to turbine demand spikes, changing financial variables, fluctuating commodity prices and currency exchange rates, and changes in expected equipment life.

(11) NREL's WindPACT and large wind turbine studies can be downloaded from www.nrel.gov/wind/advanced_technology.html and www.nrel.gov/wind/publications.html.

(12) For more information visit http://www.nrel.gov/hydrogen/proj_wind_hydrogen.html

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"Assessing Impacts of Wind-Energy Developments on Nocturnally Active Birds & Bats: A Guidance Document," (October 2007), *Journal of Wildlife Management*.

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Author: NREL, United States.

Appendix A

Attendees of the 59th Executive Committee Meeting on Jeju Island, Republic of Korea.

IEA WIND
EXECUTIVE COMMITTEE 2007

[for current contact information, visit www.ieawind.org Contact List]

CHAIR (2006-2008)
Ana ESTANQUEIRO
INETI – Departamento de Energias Renováveis

SECRETARY
Patricia WEIS-TAYLOR
PWT Communications
5191 Ellsworth Place
BOULDER, CO 80303
UNITED STATES
Tel/fax: +1 303 545 2068
Email:
PWT_Communications@comcast.net

VICE CHAIRS
Morel OPRISAN
Natural Resources Canada
CANADA

Brian SMITH
National Renewable Energy Laboratory
UNITED STATES

MEMBERS and ALTERNATE MEMBERS

AUSTRALIA
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Australian Wind Energy Association

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Hans-Günther SCHWARZ
BMVIT – III/13 (Energie-und Umwelttechnologien)

CANADA
Member:
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Natural Resources Canada

Alternate Member
Antoine LACROIX
Natural Resources Canada

Simone LALANDE
Natural Resources Canada

DENMARK
Member:
Lene NIELSEN
Ministry of Transport and Energy
Danish Energy Authority

Alternate Member:
Jørgen K. LEMMING
Wind Energy Department
Risoe National Laboratory

EUROPEAN COMMISSION
Member:
Thierry LANGLOIS d'ESTAINTOT
European Commission
DG Research

EUROPEAN WIND ENERGY ASSOCIATION
Member:
Christian KJAER
European Wind Energy Association

Alternate Members:
Bruce DOUGLAS
European Wind Energy Association

Frans VANHULLE
European Wind Energy Association

FINLAND
Member:
Mauri M. MARJANIEMI
Cygnaeuksenkatu 1

Alternate Members:
Esa PELTOLA
Technical Research Center of Finland
VTT

Hannele HOLTTINEN
Technical Research Center of Finland
VTT

GERMANY
Member:
Ralf CHRISTMANN
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Division KI III 5, Research and Development in the Field of Renewable Energies

Alternate Member:
Joachim KUTSCHER
Forschungszentrum Jülich GmbH

GREECE
Member:
Pantelis VIONIS
C.R.E.S.

IRELAND
Member:
John MCCANN
Sustainable Energy Ireland

Alternate Member:
Morgan BAZILIAN
Sustainable Energy Ireland

ITALY
Member:
Claudio CASALE
CESI RICERCA S.p.A.

Member:
Luciano PIRAZZI
ENEA Casaccia

Alternate Member:
Alberto ARENA
ENEA Casaccia

JAPAN
Member:
Yoshiro OWADANO
Energy Technology Research Institute
National Institute of Advanced Industrial Science and Technology (AIST)

Alternate Members:
Hikaru MATSUMIYA
AIST

Tetsuya KOGAKI
AIST

REPUBLIC of KOREA
Member:
Kijune KIM
New and Renewable Energy Team
Ministry of Commerce, Industry, and Energy (MOCIE)

Alternate Member:
ChinWha CHUNG
Pohang Wind Energy Research Center

MEXICO
Member:
Marco A. BORJA
Instituto de Investigaciones Electricas

NETHERLANDS
Member:
Imar O. Doornbos
Ministerie van Economische Zaken

Alternate Member:
Jaap 't HOOFT
SENTER/NOVEM

NORWAY
Member:
Knut HOFSTAD
Norwegian Water Resources and Energy Directorate (NVE)

Member:
Viggo IVERSEN
Enova SF

PORTUGAL
Member:
Aan ESTANQUEIRO
INETI – Departamento de Energias Renováveis

Alternate Member:
Alvaro RODRIGUES
FEUP – Faculdade de Engenharia da

SPAIN
Member:
Enrique SORIA
CIEMAT
Departamento de Energias Renovables

Alternate Member:
Ignacio CRUZ
CIEMAT
Departamento de Energias Renovables

SWEDEN
Member:
Anders BJÖRCK
Swedish National Energy Agency

Alternate Member:
Kenneth AVERSTAD
Vattenfall AB

SWITZERLAND
Member:
Markus GEISSMANN
Swiss federal office of energy

Alternate Members:
Robert HORBATY
Enco AG

Reto RIGASSI
Eicher + Pauli AG

UNITED KINGDOM
Member:
John OVERTON
Department of Trade & Industry

UNITED STATES
Member:
Stan CALVERT
Wind and Hydro Power Technologies
United States Department of Energy

Alternate Members:
Robert W. THRESHER
National Renewable Energy Laboratory

Brian SMITH
National Renewable Energy Laboratory

OPERATING AGENT REPRESENTATIVES

Task 11 Base Technology Information Exchange
Sven-Erik THOR
Vattenfall, Sweden

Task 19 Wind Energy in Cold Climates
Esa PELTOLA
VTT Processes, Finland

Task 20 HAWT Aerodynamics and Models from Wind Tunnel Measurements
Scott SCHRECK
National Renewable Energy Laboratory, USA

Task 21 Dynamic Models of Wind Farms for Power System Studies
John Olav TANDE
Sintef Energy Research, Norway

Task 23 Offshore Wind Energy Technology Development
Jørgen LEMMING
Wind Energy Dept.
Riso National Laboratory, Denmark

Walt MUSIAL
National Wind Technology Center
National Renewable Energy Laboratory, USA

Sandy BUTTERFIELD
National Renewable Energy Laboratory, USA

Task 24 Integration of Wind and Hydropower Systems
Thomas L. ACKER
Northern Arizona University and NREL, USA

Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power
Hannele HOLTTINEN
Technical Research Center of Finland
VTT

INTERNATIONAL ENERGY AGENCY
Nobuyuki HARA
International Energy Agency
Renewable Energy Unit, Paris, France

Appendix C

Currency conversion rates IEA wind annual report 2007			
Country	Currency	1 €	1 USD
Australia	AUD	0.601	0.878
Austria	Euro	1.000	1.460
Canada	CAD	0.693	1.012
Denmark	DKK	0.134	0.196
Finland	Euro	1.000	1.460
Germany	Euro	1.000	1.460
Greece	Euro	1.000	1.460
Ireland	Euro	1.000	1.460
Italy	Euro	1.000	1.460
Japan	JPY	0.006	0.009
Republic of Korea	KRW	0.00073	0.00106
Mexico	MXP	0.063	0.092
Netherlands	Euro	1.000	1.460
Norway	NOK	0.126	0.184
Portugal	Euro	1.000	1.460
Spain	Euro	1.000	1.460
Sweden	SEK	0.106	0.155
Switzerland	CHF	0.604	0.883
United Kingdom	GBP	1.359	1.984
United States	USD	0.685	1.000
"Source: Federal Reserve Bank of New York (www.x-rates.com) 31 December 2007"			

Appendix D

Glossary of terms and abbreviations.

CCGT	Combined cycle gas turbine
CEN/ CENELEC	European Committee for Standardization/European Committee for Electrotechnical Standardization (the original language is French); similar to ISO/IEC
CHP	combined heating and power or cogeneration of heat and power
CIGRE	International Council on Large Electric Systems
COD	Concerted action on Offshore Deployment, an EU project with participating countries Netherlands, United Kingdom, Germany, Denmark, Sweden, Ireland, Belgium, and Poland that compares and shares information on nontechnical aspects of offshore wind farms
COE	cost of energy
DFIG	doubly fed induction generator
DG	distributed generation
DNV	certifying organization (Danish)
DSM	Demand-side management
EC	European Commission
EEZ	Exclusive Economic Zone
EIA	Environmental impact assessment
ENARD	Electricity Networks Analysis Research and Development
EU	European Union
ExCo	Executive Committee of IEA Wind
FY	fiscal year
GB	giga bytes
GEF	Global Environment Facility
GHG	greenhouse gas
GW	gigawatts
GWh	gigawatt hour
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; Italy
kW	kilowatt
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
MWh	megawatt hour
m/s	meters per second
NA	not applicable
NDA	no data available
NEDO	New Energy and Industrial Technology Development Organization
NGO	non-governmental organizations
O&M	operations and maintenance
pdf	portable document format
PJ	peta joule
PSO	Public Service Obligation
PV	photovoltaics or solar cells
R&D	research and development
R, D&D	research, development, and deployment
RE	renewable energy
RES	renewable energy systems
repowering	taking down old turbines at a site and installing newer ones with more generating capacity
RETD	Renewable Energy Technology Deployment
RPS	renewables portfolio standard
S.A.	Sociedad Anonyma
tCO_2-e per capita	tonnes of carbon dioxide emissions per person
TNO	transmission network operator
TSO	transmission system operators
TW	terawatt
TWh	terawatt hour
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
U.S.	United States
VAWT	vertical axis wind turbine
wind index	describes the energy in the wind for the year, compared with a normal year
WT	wind turbine
yr	year

PRODUCTION CREDITS

Technical Editors
Patricia Weis-Taylor
Linda Bevard
Alex Taylor

Cover Design, Document Layout, and Computer Graphics
Rick Hinrichs

Produced for IEA Wind by

PWT Communications
5191 Ellsworth Place
Boulder, Colorado 80303
USA
http://www.pwtcommunications.com

Printed by
Johnson Publishing Company
Greg Walz
gwalz@jpcolorado.com

July 2008

ISBN 0-9786383-2-8