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Executive Committee for the

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of Wind Energy Systems of the

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iea wind

Front cover: Starfish Hill 34.5 megawatt (MW) wind farm near Cape Jervis on the Fleurieu Peninsula is South Australia's first wind farm. Starfish Hill Wind Farm provides enough energy to meet the needs of about 18,000 households, representing 2% of South Australia's residential customers. Photo Courtesy: Roaring 40s.

Back cover: Multi-megawatt wind turbine gearboxes (ranging in size from 1.5 MW to 3 MW) undergo run-in and qualification tests at this test station at the Hansen Transmissions Lommel factory. The IEA Wind Executive Committee members posed during a technical tour. Photo credit: Rick Hinrichs.

Foreword

The twenty-ninth IEA Wind Energy Annual Report reviews the progress during 2006 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 2006, 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 2006 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
2006-2007

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.

Web site for additional information on IEA Wind
www.ieawind.org

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Message From the Chair

I am very pleased to report that during 2006 installed wind power capacity again grew at a fast pace—26% worldwide and 20% in the member countries of the IEA Wind Implementing Agreement. The IEA Wind member countries represent 83% of worldwide wind capacity. They operate close to 62,000 MW of wind power that contributes about 118 TWh or 1.42% of the total electrical demand of their nations. In 2007, I hope to extend the IEA Wind cooperation to additional countries so we may share experience and research results for the benefit of the planet.

In 2006, our members continued to address challenges to the increased exploitation of clean, renewable wind generation through our cooperative research tasks. Responding to the need to clearly report and track the cost and value of electricity from wind energy systems, the member countries approved a new task to survey the state of the art and develop new methodologies to estimate cost of wind energy. To share experience on operation and maintenance of wind power systems, Task 11 convened a workshop of experts, and continuing communication is expected relevant to today's power plants. For expanding wind energy into colder climate areas, Task 19 is documenting research and operational experience on icing and working on recommendations for standards.

Supporting the push to install more wind turbines offshore, Task 23 addresses issues related to offshore deployment. Supporting the development of highly innovative technology, the group is exploring deep water applications, adopted a baseline turbine model, and developed a procedure and database for code comparison and benchmarking. This research is supporting the overall Task 23 work and contributing to the integrated project UPWIND supported by the EU DG Research. The special issues of integrating offshore wind farms to onshore grids were also addressed in Task 23 work that shares information from the national research programs of the participating countries.

Regarding the impacts of large amounts of wind power on electrical systems, key players are working together under several research tasks. Task 25 will produce guidelines and analytic case studies and has participants from countries that have or foresee high wind penetration. Contributors also include the most active European transmission system operators and the Utility Wind Integration Group from the United States. Task 24 is documenting issues around the correlation between wind and hydropower systems to address the need for storage and regulation of time variable production. Under Task 21, research in dynamic models of wind farms for power system studies has addressed some of the challenges of electrical system operation. Participants have developed models that provide solutions to those challenges and will issue a final report in 2007.

Ana Estanqueiro, Chair of the Executive Committee, 2006 to 2007.

For continuing improvement of the technology, Task 11 held a workshop on the application of smart structures for large wind turbine rotor blades and Task 20 continued work on aerodynamics. Renewed interest in improving the technology and consumer information about small wind turbines led to a Task 11 workshop on this issue.

Continuing our efforts in 2007, we will address issues raised by our member countries and coordinate our research tasks with activities sponsored by the EU and organizations in other areas of the world. We will continue to seek out and welcome observers to IEA Wind from countries that have a demonstrated commitment to develop wind energy. I strongly believe that the synergies created by many countries working together in IEA Wind contribute to a more sustainable development of our world.

Executive Summary

1.0 Introduction

In 2006, cumulative installed wind power capacity increased 26% worldwide and 20% in the member countries of the IEA Wind Implementing Agreement. In the IEA Wind member countries, nearly 10,500 MW was added in 2006 for a total of close to 62 GW of generating capacity. Even more encouraging, electrical production from wind also increased 20% in IEA Wind countries to about 118 TWh (Table 1). This electrical production from wind met 1.42% of the total electrical demand in the reporting IEA Wind member countries–up from 1.2% in 2005. The percentage contribution from wind grew slowly because electrical demand is also steadily growing in many of the countries. Even so, the electrical output from wind in the IEA Wind member countries was sufficient to cover the total electricity consumption of the Netherlands.

At the close of 2006, 83% of the more than 74 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 in this co-operation.

This Executive Summary of the 2006 IEA Wind Annual Report synthesizes the information presented for 2006 by the IEA Wind member countries, the European Commission, and the European Wind Energy Association (Chapters 10 through 29) and in the reports of the Research Tasks (Chapters 2 through 8). As background for 2006, data from the past 11 years as reported in documents of IEA Wind (3, 4, and 7) are also included. In this 2006 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 its 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 62 GW in 2006. In 2006, the member countries added more than 10 GW of new wind generating capacity (Table 3), and much more is being planned for 2007 and beyond (Table 4 and Table 5). Thirteen member countries added more than 100 MW of new capacity, and three countries again added more than a gigawatt each of new capacity: the United States (2,454), Germany (2,207), and Spain (1,587).

Canada, Portugal, the United Kingdom, and Japan added 490 MW or more. Total generating capacities of each country varied greatly, from Germany with 20,622 MW to Switzerland with about 12 MW. The United States wind energy capacity grew 27% in 2006 and was the second largest source of new power capacity in the country behind natural gas plants, contributing 19% of the total new capacity built. The United Kingdom had its most productive year, adding more than 630 MW and generating nearly 4.6 TWh of electricity. Mexico experienced

Table 1 Key statistics of IEA Wind Member Countries 2006*

	2005	2006
Total installed capacity	51,364 MW	61,855 MW
Total offshore wind generation	686 MW	927 MW
Total new wind generation installed	8,927 MW	10,461 MW
Total annual output from wind	99 TWh	118 TWh
Wind generation as % of national electric demand	1.2%	1.42%

* includes estimates ; see Table 3 for country specifics.

Table 2 Worldwide installed wind capacity at the close of 2006	
IEA Wind Members*	
Country	MW
Germany	20,622
Spain	11,615
United States	11,575
Denmark	3,137
Italy	2,123
United Kingdom	1,963
Portugal	1,698
Japan	1,574
Netherlands	1,559
Canada	1,460
Austria	965
Australia	817
Greece	749
Ireland	744
Sweden	571
Norway	325
Korea	175
Finland	86
Mexico	86
Switzerland	12
Total IEA Wind	61,855

Table 2 Continued Rest of World**	
Country	MW
India	6,270
China	2,594
France	1,469
Brazil	256
Egypt	230
Poland	204
Belgium	188
Taiwan	188
New Zealand	171
Morocco	124
Ukraine	86
Turkey	84
Costa Rica	74
Caribbean	57
Czech Republic	56
Lithuania	56
Iran	48
Hungary	37
Estonia	35
Luxembourg	35
Bulgaria	30
Argentina	27
Latvia	27
Philippines	25
Pacific Islands	24
Tunisia	20
Colombia	20
Croatia	17
Reunion (France)	10
Others (<10 MW)	43
Total rest of world	12,505
World Total	**74,360**

* Data provided by IEA Wind member countries.

** Data from Windpower Monthly, April 2007 (2).

astounding growth in capacity with its new wind farm La Venta II that added 83 MW to the existing 3 MW of generation.

Growth in some other countries was also well above the 20% average for the IEA Wind group: Canada 114%, Republic of Korea 79%, Portugal 60%, Ireland 50%, Japan 46%, and the United Kingdom 47%. Greece, Italy, the Netherlands, Norway, and the United States also exceeded 20% growth (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 for final connection to the grid (Table 5).

Offshore generating capacity increased 30% in the seven countries reporting such installations. And much more offshore capacity is in the planning stages. In the United Kingdom, for example, London Array Limited received consent in December

Table 3 National statistics of the IEA Wind member countries for 2006

Country	Total installed wind capacity	Offshore installed wind capacity	Annual net increase in capacity	Total Number of Turbines	Average new turbine capacity	Wind-generated electricity	National electricity demand	% of national electricity demand from wind*
	(MW)	(MW)	(MW)		(kW)	(GWh/yr)	(TWh/yr)	
Australia	817	0	109	544	1,750	2,504	208.0	1.20%
Austria**	965		146					
Canada	1,460	0	776	1,186	1,230	3,800	***550.0***	0.69%
Denmark	3,137	423	8	5,274	1,287	6,108	36.4	16.78%
Finland	86	0	4	96	2,000	154	90.0	0.17%
Germany	20,622	7	2,207	18,685	1,848	30,500	540.0	5.65%
Greece	749	0	142	1,051	1,146	***1,580***	***51.0***	3.10%
Ireland	744	**<u>25</u>**	251			1,617	28.9	5.59%
Italy	2,123	0	405	2,575	1,148	3,215	338.0	0.95%
Japan	1,574	1	494	1,358	1,159	1,910	882.6	0.22%
Korea	175	0	77	118		247	381.2	0.06%
Mexico	86	0	83	105				
Netherlands	1,559	108	335	1,792	2,248	2,747	116.0	2.37%
Norway	325	0	57	163	2,280	671	122.0	0.55%
Portugal	1,698	0	634	964	2,400	2,926	***49.0***	5.97%
Spain	11,615	0	1,587	13,842	1,375	23,372	268.0	8.72%
Sweden	571	23	62	812	1,879	986	150.0	0.66%
Switzerland	12	0	0	34	0	15	58.0	0.03%
United Kingdom	1,963	340	631		2,103	4,591	**<u>408.8</u>**	1.12%
United States	11,575	0	2,454		1,600	31,000	4,027.0	0.77%
Totals	61,855	927	10,461	48,599	1,697	117,886	8,280.2	1.42%

*% of national electricity demand from wind= (wind-generated electricity/national electricity demand)*100 ** Numbers from Wind Power Monthly

Bold italic= estimated value **<u>Bold underlined</u>** = value from 2005/2004

Table 4 Increase in wind energy capacity from end of 2005 to end of 2006		
Country	Capacity added in 2006	% Wind capacity increase
United States	2,454	27%
Germany	2,207	12%
Spain	1,587	16%
Canada	776	114%
Portugal	634	60%
United Kingdom	631	47%
Japan	494	46%
Italy	405	24%
Netherlands	335	27%
Ireland	251	50%
Austria	146	18%
Greece	142	24%
Australia	109	15%
Mexico*	83	*
Republic of Korea	77	79%
Sweden	62	12%
Norway	57	21%
Denmark	8	<1%
Finland	4	5%
Switzerland	0	0%

* Mexico added 83 MW in 2006 to its existing 3 MW for a greater than 1,000 percentage increase.

2006 for the world's largest offshore wind farm to be built in the London Estuary. At 1,000 MW of capacity, it will be capable of powering one-quarter of the homes in London.

Another trend that affects 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 2006, Denmark reduced the total number of turbines, but capacity was increased by 8 MW. Germany removed 79 turbines and added 135 MW of new machines in these areas. In Italy, 46 turbines ranging from 200 kW to 450 kW were replaced by 15 larger machines in the range of 800 kW to 1,500 kW. This increased total in-field capacity by 4 MW but had a larger benefit reported in terms of energy production. The Netherlands decommissioned 40 turbines in 2006. Twenty-one of these with total capacity of 4.3 MW were replaced with 13 turbines with a capacity of 26.5 MW, for a net "repowering effect" of 22 MW.

2.2 Contribution to Electrical Demand

Total electrical generation from wind in the IEA Wind member countries has increased from less than 10 TWh in 1995 to nearly 118 TWh in 2006 (Figure 1). The contribution from wind energy to the combined electricity demand of the member countries has increased from under 0.2% overall in 1995 to 1.42% in 2006. Within the member countries, contribution to national electrical demand varied from under 1% to 16.8% in Denmark. In five countries wind energy exceeded 5% contribution to national electrical demand, and ten countries exceeded the 1% mark (Table 3).

Wind energy can be a significant source of electrical generation. For example, Spain supplies a full 9% of its electricity demand with wind, which is the fifth largest generation technology after coal, nuclear energy, natural gas, and hydropower. In Spain, the maximum hourly production by wind energy of 8,140 MW took place on 8 December 2006, and 31% of total electricity production at that moment was supplied by wind energy. The maximum peak demand during the year in Spain took place on 30 January 2006, when the total power produced was 42,100 MW. At this time, wind energy supplied about 8% of the total. In Denmark, the highest average coverage of wind power yearly was nearly 17%; between 27% and 29% of the total electricity consumption was covered by wind power in November and December alone.

Some countries are tracking production in relation to the wind index, a local indicator of the energy in the wind for a year compared to the average year. Several countries linked lower than expected wind energy production to a poor wind season in 2006 (Finland, Denmark, Germany, Italy, and Spain).

2.3 National Targets

All countries recognize the need to reduce carbon emissions. They maintain that renewable energy in general and wind and solar energy in particular offer great potential to reduce overall carbon emission of the power industry. In addition, reducing the cost of electricity and the reliance on imported fuels is an element of several national targets. Establishing various types of national objectives or targets is used to define goals, develop policies, measure progress, and revise policies and goals as needed along the way.

An important contributor to the growth of 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 sources provide 21% of EU electricity consumption by 2010. This target was established by the Renew-

Table 5 Estimates of potential increases to wind energy capacity in 2007 and beyond*

Country	Planning application	Planning approval	Under construction	Estimated total planned and/or under construction
	(MW)	(MW)	(MW)	(MW)
Australia				1,500
Canada	2,533	1,888	854	5,275
Denmark	Offshore 200 Repowering 350	Offshore 200		750
Finland		100	35	135
Ireland	3,314	449		3,763
Italy	Offshore 300 Onshore 1,000		700	2,000
Republic of Korea	Offshore demonstration 4			4
Mexico		300		300
Norway	4,400	1,200	120	5,720
Switzerland	70	6		76
United Kingdom	1,265	Offshore 1,300	Offshore 180	2,745

* Includes onshore, repowering, and offshore

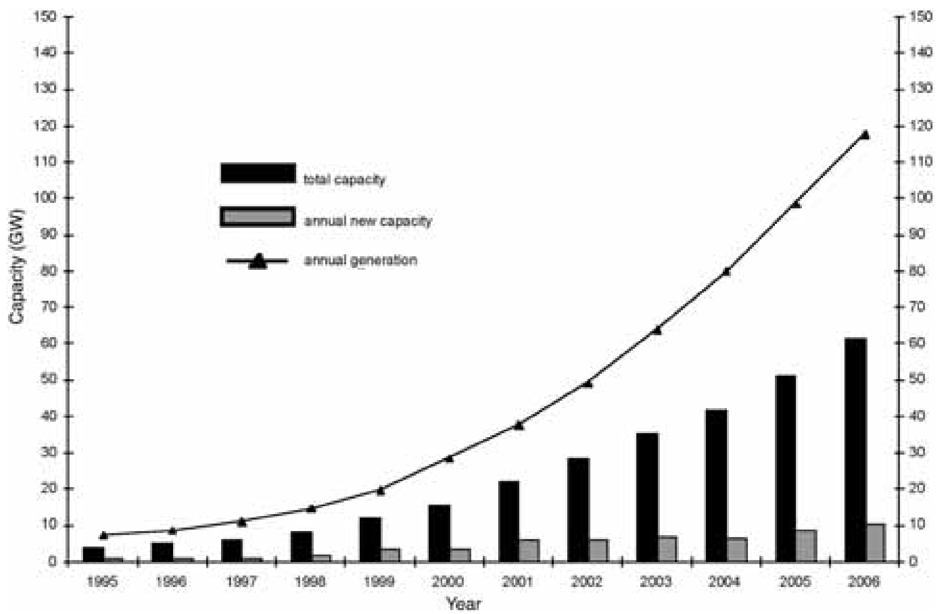

Figure 1 Annual installed capacity, cumulative installed capacity, and annual generation as reported by the IEA Wind member countries, 1995–2006.

able Electricity Directive (77/2001/EC), which sets out differentiated national indicative targets for each member state. The Renewable Electricity Directive constitutes the main driving force behind new policies being implemented.

Whether a country is seeking to reduce emissions by displacing demand or by meeting rising demand, wind energy was figured into national planning. For example, Mexico expects electrical demand to grow at 5.2% per year through 2014. Its targets are designed to meet a significant amount of that growth with wind energy. On the other hand, the Kyoto Protocol seeks to roll back CO_2 emissions by combinations of reducing demand and displacing conventional generation with renewables. Many IEA Wind member countries have targets for carbon emissions that serve as the motivation for policy initiatives regarding wind energy.

Wind energy is making a significant contribution to reaching national goals. In Australia, progress is measured toward the Kyoto target of 108% of 1990 emissions over the period 2008–2012. Figures in January 2007 show that the Australian wind energy industry offset 3.26 million tonnes of CO_2 per year, the equivalent of taking 752,000 cars off the road or planting 4.86 million trees.

In Finland, a project titled Demand for Finnish Energy Technology and Business Opportunities in Global Markets used the GlobalTimes model to analyze cost-optimal scenarios for future energy systems that are trying to achieve the CO_2 reductions needed to limit global temperature increase to 2°C. In these scenarios, the role of wind power in electricity generation grows rapidly, and production could reach an annual rate of 3,000 TWh/yr by 2030.

In Spain, wind power helped decrease fossil fuel imports, achieving a reported savings of more than 730 million € in 2006, mainly due to the reduction in purchases of natural gas and coal. In addition, the Spanish economy saved around 18 million tonnes of CO_2 and did not have to purchase emission permits that would otherwise have been required in 2006. This represents nearly 360 million € of savings, assuming a price of 20 €/tonne of CO_2 emissions.

In the United States, the current wind capacity will generate 31 TWh/yr—enough to provide power for 2.9 million U.S. homes and displace approximately 23 million tons of CO_2 that would have been emitted by traditional resources.

Several types of targets are set in the IEA Wind member countries. Renewable energy targets have been set by Australia, Finland, Germany, Ireland, Italy, the Netherlands, and the United Kingdom. Wind generating capacity (MW) or production (MWh) targets for a certain year have been established by Greece, Japan, Republic of Korea, Norway, Portugal, Spain, Sweden, and Switzerland. Although targets are popular, Canada, Denmark, and the United States have rapidly growing wind capacity without the benefit of official targets. (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 cooperative 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.)

2.4.1 Grid capacity, integration, and transmission

Access to the grid is essential for wind farm development, the main vehicle for increasing wind energy capacity. The grids that we have today are the result of previous planning, adapted to the needs of an electricity system made up of centralized, large-scale power plants. The move toward smaller and more decentralized generation units thus requires the adaptation of the grid; high growth rates of electricity demand in several IEA Wind member countries are challenging grid capacity.

Several countries mentioned grid capacity as a limiting factor being addressed in 2006. In Mexico, an agreement was reached between the Federal Electricity Commission and several private wind project developers for construction of a transmission line to several wind power plants planned for the Isthmus of Tehuantepec. These will remove the main technical barrier for the expected installation of around 2,000 MW of wind power in that region.

The rate of wind energy installation reportedly will be limited in Ireland by the rate at which offers for grid connection are issued and the lead times for the associated grid infrastructure. A slightly slower than predicted growth in capacity in Spain was attributed to problems with the connection of wind farms to the electrical grid due to delays in the construction of electrical infrastructures such as transport lines and high-voltage substations. Finland mentioned distribution network charges as an obstacle to development, and Canada cited a surplus of generation capacity in many areas as a slowing influence.

Uncertainty about the impact of wind energy on the power system is being addressed by work to raise the level of wind farm modeling under way in the IEA Wind Task 21—Dynamic Models of Wind Farms for Power Systems Studies. Denmark, Finland, Ireland, Netherlands, Norway (operating agent), Portugal, Sweden, the United Kingdom, and the United States have worked to develop and validate wind farm models that are suitable for evaluating power system dynamics and transient stability. The final report, to be released in 2007, will provide an overview of the available wind farm models and present a systematic approach for model benchmark testing.

Integrating wind energy into weak grids is a concern for transmission system operators (TSOs) in many countries. For example, compared with EU countries, Japan's electric system is isolated and the influence of wind generation on grid stability is considered very large, regardless of how small the penetration level. Therefore, some electric power companies limit new wind farm projects and choose them by drawing lots.

System operation impacts from wind power are a concern of TSOs. 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 with Finland (operating agent), Denmark, Germany, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States participating. In 2006, Task 25 established an international forum to exchange knowledge and experiences on integration issues and produced a draft report on the state of the art of wind integration issues. Three Task 25 meetings included system operators from Denmark, Germany, Ireland, and Portugal, and TSO organisations CIGRE and ETSO received information about the work of the task. Trans-national grid issues to be addressed in order to efficiently integrate wind energy in Europe (for example the need for improved interconnection) are addressed in two European studies also included in the reporting of Task 25 (EWIS, TradeWind). Presentations of Task 25 work and case studies from Denmark, Finland, Norway, Portugal, Sweden, and the United States were presented in special sessions of international conferences in North America, Europe, and Australia.

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 conditions are being addressed (as well as other issues with offshore deployment of wind turbines). Denmark (operating agent), Germany, Korea, the

Netherlands, Norway, Sweden, the United Kingdom, and the United States (operating agent) participate in this task.

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 are being explored in the IEA Wind Task 24—Integration of Wind and Hydropower Systems. Australia, Canada, Finland, Norway, Sweden, Switzerland, and the United States (operating agent) participate in this task. Expected outcomes of this work 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.

2.4.2 Limited available land and public resistance

Several surveys have shown that wind power is extremely popular across Europe and beyond, typically hitting positive scores of 60–80% (5). In addition, those polls have shown that the strongest support for wind energy technology comes from people living near a wind park.

In terms of land availability, excellent sites remain unexploited in many IEA Wind member countries, although the situation is changing due to rapid installation rates as explained in Section 1. Yet, countries where wind energy has already been actively exploited and with ambitious wind development plans report finding two situations: 1) good sites are already taken by older, smaller turbines and/or 2) the public is becoming resistant to the addition of more turbines to the landscape.

One approach to these situations is repowering–removing smaller turbines and replacing them with fewer larger machines on taller towers. This has the effect of increasing production on land without developing new projects. Denmark, Germany, Italy, the Netherlands, and the United States have formal or informal activities or incentives that result in repowering. The decommissioned machines are providing a market in used machines in other countries for smaller projects. For example, Finland reports that used turbines from the first demonstration projects in Finland and from the Netherlands have encouraged some farmers to acquire a second-hand turbine.

A second response to limited land availability and public opposition for countries with a shoreline is to move to offshore. For example, Korea faces public resistance and mountainous terrain and so is supporting R&D into offshore installations. (See Section 3.2.3.)

Yet another response to public resistance is to expand engagement of all interested stakeholders in the planning and approval process so as to influence public opinion. Public information efforts and legislation to streamline the planning and approval process have been reported in several countries. For example, opinion polling carried out in October 2006 on behalf of AusWind by A. C. Nielsen showed overwhelming acceptance of wind energy by the broader Australian community. The three-stage Wind Farms and Landscape Values project addressed the complexities associated with wind farm siting issues by giving all stakeholders the opportunity to assist in formulating an agreed-upon set of national landscape issues for the Australian wind energy industry. More than fifty organizations and many more individuals were consulted in the first stage of the project. In Switzerland, where public acceptance is an issue, researchers will host an IEA Wind Task 11 experts meeting on the topic in 2007.

The planning and approval process is lengthy in most countries and is one barrier to the full exploitation of wind power. In the UK, a recent research study commissioned by the British Wind Energy Association (6) reports that the length of time taken through planning for onshore wind farm applications is three times greater than the recommended time for all developments, with decisions taking nearly one year and longer from submission. The study states that the provision of robust and objective planning policies in local development documents should ensure that there is an effective framework in place, from which well-informed and consistent decisions can be made. Efforts in several countries are reported to ease this burden on developers.

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

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 6). 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,

Table 6 Capacity in relation to estimated jobs and economic impact in 2006

Country	Capacity (MW)	Estimated number of jobs	Economic impact (Million EURO)	
Germany	20,622	70,000	turnover	5,650
Spain	11,615	35,000	nda	
United States	11,575	10,000+	new capacity investment	3,030
Denmark	3,137	26,000*	turnover**	5,100
Italy	2,123	4,500	turnover	500
United Kingdom	1,963	4,000+	turnover	965
Portugal	1,698	nda	nda	
Japan	1,574	nda	nda	
Netherlands	1,559	nda	investment	480
Canada	1,460	1,200	turnover	479
Austria	965	nda	nda	
Australia	817	794	nda	
Greece	749	nda	nda	
Ireland	746	nda	construction	374
Sweden	571	nda	nda	
Norway	325	200+	turnover	50+
Korea	175	nda	nda	
Finland	86	3,000***	turnover***	320
Mexico	86	nda	turnover	1
Switzerland	12	350	turnover	100

*Wind turbine manufacturing industry, electricity production industries, institutes, and consultants.

**Turnover in the wind turbine manufacturing industry including exports (4,402 million €) and turnover in the rest of the wind turbine sector.

*** Jobs and turnover in the supply chain.

construction, and value of exports. More countries than ever are estimating the number of jobs created by wind energy manufacturing, development, and operation.

3.2 Industrial Development and Operational Experience

3.2.1 Turbines

The average rated capacity of new turbines installed in 2006 continued the trend toward larger machines. The average rating in 2006 rose to nearly 1.7 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, the Netherlands, Norway, 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, Portugal, Switzerland, and the United Kingdom). These include blades, control systems, power inverters, generators, nacelle assembly, or towers.

In addition to MW-scale wind turbines, intermediate-sized turbines, 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).

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). Italy established net metering and reduced the minimum amount of energy required for green certificates. In Japan, Zephyr Corporation has developed the Z-1000 Airdolphin, a small 1-kW wind turbine. The prototype machine is being demonstrated at many sites around the world. In the UK and in Portugal a micro-generation strategy is being implemented.

Trade associations and organizations promoting wind energy are having important effects on development of wind energy. For example, the Mexican Association of Wind Power (Amdee), founded in 2005, became an important stakeholder in the negotiation and lobbying of legislative and regulatory bodies. 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 in Mexico. At the international level, the Global Wind Energy Council (GWEC), established in 2005, is providing a platform for promoting the interests of the wind sector in the international policy arena and intergovernmental forums. In the EU, the European Wind Energy Association (EWEA) played a key role in the debate that took place in Europe regarding its future energy mix in the medium to long term with an agreed binding target of 20% by 2020 of renewable energy sources.

3.2.2 Ownership patterns

Wind farms are usually owned by private corporations, independent power producers (IPPs), utilities, or income funds. In 2006, the consolidation and acquisition of large development companies and wind farm operators was reported (Canada, Finland, Italy, Netherlands, Spain, and the United States). In the United States, although private IPPs continued to dominate the industry, electrical utilities expressed a greater interest in wind asset ownership. Of the total 2006 wind additions, approximately 25% (615 MW) was owned by local electrical utilities, the vast majority of which are investor-owned utilities.

A different pattern of deployment is reported in some countries. In Finland, some farmers have acquired smaller second-hand turbines. In the UK and the United States, patterns are changing to include community ownership. Another trend observed in the U.S. market in 2006 is the acquisition of American wind assets by European-based companies.

3.2.3 Offshore installations

By the close of 2006, more than 925 MW of capacity was located offshore in seven IEA Wind member countries (up from five countries in 2005): Denmark, Germany, Ireland, Japan, Netherlands, Sweden, and the United Kingdom.

Countries that report either planning their first offshore installations or having them under construction include Finland, Korea, Spain, and the United States. 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 Spain, new draft incentive rules in 2006 mentioned offshore wind farms for the first time. They defined a bonus of 84.7 €/MWh over the market price for electricity and specified a maximum price of 164 €/MWh. No minimum level was defined. Although the wind energy sector had a positive reaction to this regulation, it said that the payments are not enough to start the offshore market in Spain.

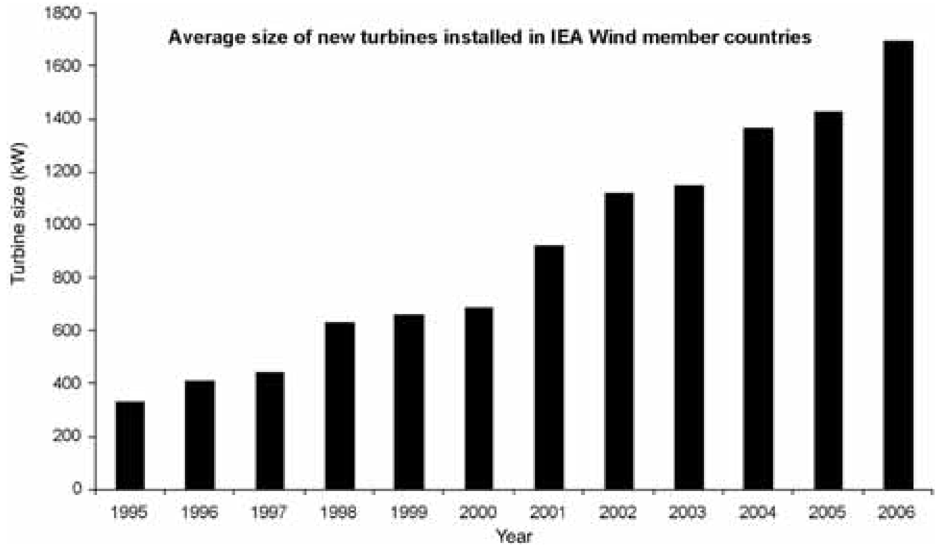

Figure 2 Average size of new turbines installed in the IEA Wind member countries for 1995–2006

3.2.4 Operational experience

Wind farm operation is well established in many of the IEA Wind member countries, drawing on decades of experience in turbine manufacture, project development, and generation operations. Turbine availability is high in all countries, ranging between 95 and 99% with most reporting 98% or higher. Productivity is also relatively high—the result of good siting of farms based on national wind resource assessment or atlas data. Large onshore farms have higher availability than offshore farms. For example, the UK reports offshore availability between 81 and 91.2%. Capacity factor estimates were reported by the following countries: Australia 35–50%; Mexico 30–40%; Switzerland 15–25%; and UK onshore: average 26.6%, offshore 24–36%.

The causes of nearly 350 turbine failures from 2004 to 2006 have been analyzed by Japan and are being used as input to design efforts for a new J-class turbine. Lightning strikes were the biggest known cause of wind turbine failure in Japan.

3.3 Economic Details

3.3.1 Turbine and total installed project costs

Turbine costs reported by the IEA Wind member countries averaged from a low of 637 €/kW (Japan) to a high of 982 €/kW (Germany) for 2006 (Figure 3 and Table 7). Higher turbine costs over 2005 are reported by several countries in 2006. The higher costs were attributed to shortage of materials, insufficient production of turbines, rising cost of raw materials, costly technology innovations such as LVRTF (low-voltage ride-through fault) technology, and use of larger (more expensive) blades at less windy sites. Spain reports increased turbine size and cost. However, it reports that it has not experienced the lack of major components (gearboxes, electric generators, blades, and so on) that other countries experience because many companies in Spain are both wind turbine manufacturers and wind farm developers.

Total installed costs for 2006 in the reporting countries ranged from a low of 980 €/kW (Denmark) to a high of 1,366 €/kW onshore (Canada) or 2,375 €/kW offshore (UK). Most countries report the installed cost of wind projects rising in 2006 (Figure 3 and Table 7). In 2005, the range was 970 €/kW onshore to 2,075 €/kW offshore. Some member countries have reported how costs of wind projects are distributed. For example, Canada estimates breakdown of costs for a typical 30-MW onshore wind farm to be 68% wind turbine, 11% foundation and civil works, 8% electrical connection, and less than 5% for each of transportation, legal, installation, project preparation, and contingency.

Italy estimates that project costs have increased 20–30% in 2006 over 2004 and 2005. The cost increase is attributed to insufficient wind turbine production. In addition to turbine cost, the cost of electrical and civil works is estimated to be around

30% of total investment cost for plants with smaller turbines (capacity <1 MW) and 20% of total investment cost for plants with larger turbines (capacity >1 MW). The United States reports project costs have risen to about 1,480 USD/kW (1,121 €), up from 1,260 USD/kW (954 €) in 2005. Although project costs are influenced by numerous factors, increasing turbine costs are the largest contributor to the cost of onshore projects. Turbine prices have increased, on average, by over 400 USD/kW (303 €) since 2001.

The Netherlands, where 108 MW of offshore wind was installed in 2006, reports an international spread for offshore project costs of 1,650–2,250 €/kW. Offshore costs are largely dependent on weather and wave conditions, water depth, and distance to the coast.

The most detailed cost information on recent offshore installations comes from the UK, where 90 MW were added in 2006. The present-day costs of installing wind energy in the UK are between 585 and 800 £/kW (868 and 1,187 €/kW) onshore, rising to 1,200 to 1,600 £/kW (1,781 to 2,375 €/kW) offshore. The higher capital costs of offshore projects are due to the larger structures and complex logistics of installing the towers. The costs of offshore foundations, construction, installations, and grid connection are significantly higher than for onshore. For example, typically, 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.

A study in the UK by ODE Ltd commissioned by DTI estimated the future costs of offshore wind generation and the potential for cost reductions. It identified raw materials—especially steel, which accounts for about 90% of the turbine—as a primary cost driver. The report emphasized that major savings can be realized if turbines are made of lighter, more reliable materials and if major components are developed to be more fatigue resistant. A cost model based on 2006 costs predicted that costs will rise from approximately 1.6 million £/MW to approximately 1.75 million £/MW (2.37 to 2.6 million €/MW) in 2011 before falling by around 20% of the cost by 2020.

3.3.3 Operations & Maintenance Costs

Costs for service, consumables, repair, insurance, administration, lease of site, etc. for new large turbines ranged from 2–3.5% 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.

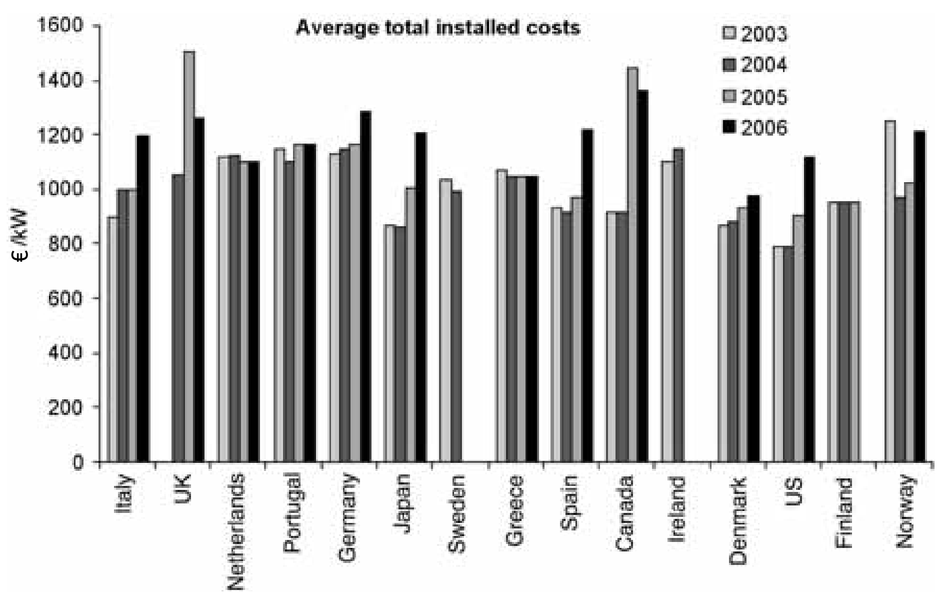

Figure 3 Average total installed costs of wind turbine projects 2003–2006 as reported by IEA Wind member countries. These include costs for turbine, roads, electrical, installation, development, and grid connection.

Table 7 Estimated average turbine cost and total project cost 2006 where data is available		
Country	Turbine cost	Total installed cost
	(€/kW)	
Canada		1,366
Denmark	845	980
Germany	982	1,289
Greece		1,050
Italy	950	1,200
Japan	637	1,210
Mexico		1,088
Netherlands		1,100
Norway	912	1,217
Portugal	800	1,170
Spain		1,220
Switzerland		1,243
United Kingdom		1,262
United States	871	1,121

3.3.4 Cost of energy

Using various analysis methods, several IEA Wind members report the cost of energy from wind in their countries. Canada: 75–120 CAD/MWh (49–78 €/MWh); Finland: 45–65 €/MWh without investment subsidy; Greece: 26–47 €/MWh; Japan: 9.00–11.00 JPY/kWh (57–70 €/MWh) for 500-kw to 1,000-kW machines) and 7.00–9.00 JPY/kWh (40–57 €/MWh) for 1,000-kW and larger machines; Norway: 46 €/MWh; Switzerland: 135 €/MWh.

3.3.5 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 buy-back 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 are estimated averages or ranges. For the reporting countries, the price paid to wind project operators in 2006 ranged from 49–183 €/MWh (Figure 4).

4.0 National Incentive Programs

As can be seen in Table 8, the four most often used incentives are: offering 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. For example, in Australia, the major incentive scheme was the federal government's MRET scheme, which required large energy users and energy wholesalers to purchase 2% of their energy from renewable sources by 2010. MRET reached its effective conclusion in 2006 when the target of 9,500 GWh of new renewable generation (much of it from wind energy) was achieved four years ahead of schedule. This left developers with no active incentive scheme until six states came to the rescue in the second half of 2006 with various incentive programs.

4.1 Capital Investment

Incentive programs that help offset the capital cost of wind farm development to varying degrees

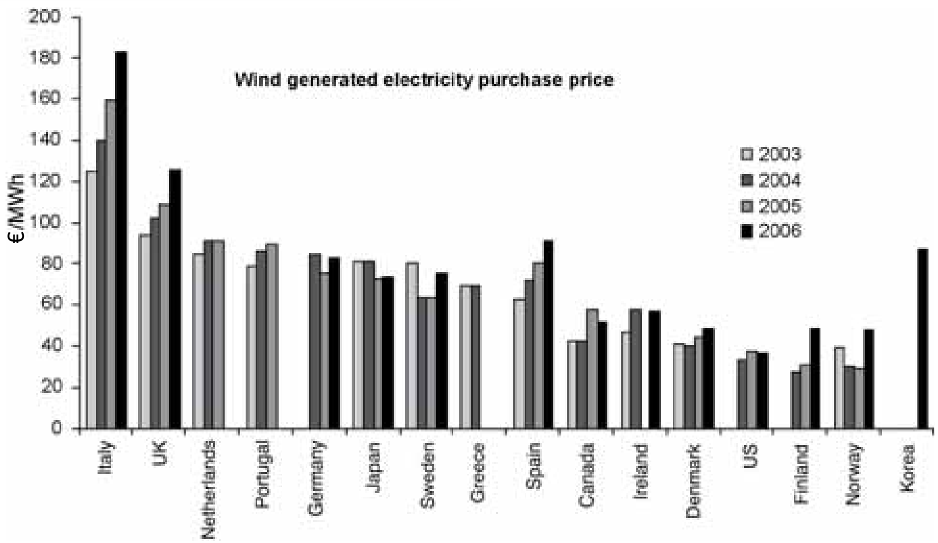

Figure 4 Price paid to wind farm project owner for reporting countries in 2003–2006. Some of these prices include incentives such as green certificates.

have been successful in several countries. In Finland, projects that applied for a subsidy between 2001 and 2006 received an investment subsidy of 35% on average. In Greece, public aid accounts for 30% of the eligible cost of the projects; it goes up to 50% in the case of transmission lines that will be constructed to connect renewable energy plants to the grids. During 2006, 38 projects were approved, of these, 36 were financed with 50% and 2 were financed with 45% due to their location. In Japan, initial cost for business development of generation plant and local new energy development plant can be subsidized by government programs up to 30%. Non-profit organizations can receive subsidies up to 50%. In the Republic of Korea, government subsidies to developers covered up to 70% of installation costs for demonstration projects between 2000 and 2005. However, beginning in 2006, these subsidies were only available to small wind projects (<10 kW). The Korean government also compensates commercial banks for the difference between commercial rates and lower-than-commercial rates up to a certain portion as long-term project financing to renewable energy construction projects.

In Mexico, the federal income tax law allows accelerated depreciation of investments in renewable technologies (wind energy is specifically included). Investors may deduct 100% of the investment in a year (one year of depreciation). The equipment must operate for at least five years following the tax deduction declaration.

In the UK, the Offshore Wind Capital Grant Programme launched by DTI and the Big Lottery Fund in early 2002 has stimulated the early development of offshore wind projects. The result has been more than 1,666 MW of offshore development completed or under way.

4.2 Price Incentives

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.

In Canada, the most influential market stimulation instrument so far has been the federal government's Wind Power Production Incentive (WPPI) program, which provides qualifying facilities an incentive payment of 10 CAD/MWh (6.5 €/MWh) of production for the first ten years of operation. This has helped provide a stable, long-term revenue source. The program had funded a total of 924 MW by the end of 2006. The recently announced ecoENERGY for Renewable Power program will provide the same incentive under similar terms and conditions for an additional 3,000 MW to be built by 2011.

In Norway, to increase the production and use of renewable energy and to improve energy efficiency, the government proposed in October 2006 allocating 20 billion NOK (about 2.3 billion €) to

Table 8 Incentive programs offered in IEA Wind Member countries for 2005.

		Australia	Canada	Denmark	Finland	Germany	Greece	Ireland	Italy	Japan	Korea	Mexico	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	United Kingdom	United States	TOTALS 2005	TOTALS 2006
Investment support	Direct capital investment subsides/ grants		X		X		X	NDA	X	X	X			X	X	X			X	X	10	11
	Capital investment write-offs		X					NDA				X	X								3	3
	Soft loans							NDA			X		X							X	3	3
	Others							NDA	X												1	1
Production support	Premium price for generation		X	X		X	X	NDA	X		X		X		X	X		X	X		9	11
	Exemption from energy taxes				X			NDA									X		X		3	3
	Production tax credits							NDA												X	2	1
	Others		X					NDA	X		X	X								X	3	5
Demand creation	Obligation for production from renewables on suppliers	X	X					NDA	X	X						X	X		X	X	7	8
	Free market for green electricity				X			NDA	X				X		X	X		X		X	8	7
	Others					X	X	NDA			X										2	3
Note: see country chapters for more detail																		TOTAL			51	56
NDA indicates no data available																						

a new fund. For renewable power production, the government plans to establish a feed-in system in which accepted projects will receive a fixed support per kilowatt-hour for 15 years.

In some countries, tariffs pegged to retail electricity rates or to inflation reached very high levels in 2006, and policies were changed to limit the cost of incentive programs. For example in Spain, the law allows remuneration to wind farms based on the market price plus a bonus established as a percentage of the named "average reference tariff" (an indicator related to the total cost of the overall electrical system). In 2005 and 2006, the increasing price of electricity in Spain caused the payments determined by this procedure to reach values up to 91 €/MWh. The benefits to investors in wind energy have been remarkably high. In mid-2006, Spanish authorities wrote new draft rules concerning renewable energy sources (wind energy in particular) to limit the price received by wind farm operators. The new law's intent is to guarantee sufficient profit for wind energy investment without a significant increase in the total cost of the electrical system.

In other countries, the premium price for renewable electricity is reduced in future years, and policy audits are included in the laws. For example, in Germany the Renewable Energy Sources Act (EEG) provides that grid operators must pay a starting tariff for at least five years of 83.6 €/MWh to owners for turbines installed in 2006. The EEG requires the starting tariff to be reduced by 2% yearly. A turbine installed in 2007 will therefore receive a starting tariff of 81.9 €/MWh. Special tariffs exist for onshore repowering and for offshore wind farms. The EEG will be audited in 2007 to adapt prices for renewables to new market conditions and technological developments.

Changing the rules governing subsidies can have dramatic effects on the wind energy market. In the Netherlands, the effect of the MEP production subsidy (tariff of 65–77 €/MWh vs. grey energy price of 37 €/MWh) in 2006 was that 350 MW of new wind capacity was installed. 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 July 1, and this resulted in wind projects with a total capacity of 600 MW to be installed up to 2008. The effect of reducing the subsidy to zero in August 2006 was that the markets put the investment decisions for new projects on hold. This stop-and-go effect has been observed previously in several other countries such as the United States and Sweden.

In Portugal, feed-in tariffs have been the main incentive, however, because the tariffs are currently not adjusted for inflation, they were effectively reduced in 2006.

Several countries are moving toward feed-in tariffs as a means of supporting renewable energy development. In Ireland, a change of the price support mechanism for renewable electricity was announced in April 2006. The previous competitive tendering system is to be replaced with a feed-in tariff providing prices of 54 €/MWh for wind projects greater than 5 MW and 57 €/MWh for projects less than 5 MW capacity. Draft details of the scheme have been published, but it had not been launched by the close of 2006.

Denmark's interim policy provides a premium of 100 DKK/MWh (13.42 €/MWh). During 2006, the market price plus premium varied between 330 DKK/MWh and 430 DKK/MWh (44.27–57.69 €/MWh) (except during January, when adjustments were included). The premium becomes zero when the market price exceeds 360 DKK/MWh (48.30 €/MWh), and in 2006 this happened during one month in western Denmark and during five months in eastern Denmark. For these periods, the wind power production actually reduced the market price of electricity.

In Mexico, the GEF approved sponsorship for a first phase of a more extensive project: the Large Scale Renewable Energy Development Project. The World Bank will be the implementing agency. This project focuses on launching an independent power producer renewable energy market by creating a transitory green fund targeted to complement regulated buyback prices for renewable energy.

4.3 Utility Purchase Obligations

At least eight IEA Wind member countries have national and state governments that require utilities to purchase a percentage of their overall generating capacity from renewable resources. Wind energy is the option preferred by most utilities to satisfy this obligation. In the United States, it is estimated that 60% of the wind capacity additions in 2006 (1,472 MW) were motivated in part by state requirements for utilities to purchase renewable energy.

4.4 Green Electricity Market

Wind energy qualifies as green electricity used to meet utility purchase obligations, to trade as certificates, or to meet consumer preferences.

Italy reports higher market prices of green certificates issued for 2006 renewable energy electricity production—around 125 €/MWh. Income from selling green certificates adds to the wholesale market price of wind-generated electricity, which averages around 60 €/MWh. In 2006, the availability term of green certificates was extended from eight to twelve years from the beginning of plant operation.

The Republic of Korea, as a non-annex I Party of the United Nations Framework Convention on Climate Change (UNFCCC), and having ratified the Kyoto Protocol, can host clean development mechanism (CDM) projects. Large-scale wind projects in Gangwon and Yongdeok—representing 98 MW and 39.6 MW, respectively, out of Korea's total installation capacity of 173 MW—have been supported by revenue from the sale of CDM credits, known as Certified Emission Reduction units, or CERs. The Gangwon Wind Farm is the first renewable CDM-supported project in Korea, and its success indicates that installation of a project that uses a renewable source can be supported by the sale of emission reduction certificates associated with the project.

In the United States, both residential and nonresidential customers may support the development of renewable energy resources by purchasing renewable energy certificates (RECs), which represent the unique or green attributes of electricity generated from renewable energy based products. Wind energy is the most commonly used resource for RECs. In 2005, total market sales increased by 37%. Much of this growth was supported by REC sales to nonresidential customers, which more than doubled during 2005. As a result, commercial and institutional REC markets now represent nearly half of total green power market sales in the United States, surpassing sales in competitive electricity markets and utility green pricing programs.

4.5 Other Support Mechanisms

Other kinds of support have accelerated the development of wind energy in the IEA Wind member countries. For example, Canada has created a comprehensive Wind Energy Atlas that allows planners of wind energy projects to generate a detailed picture of wind patterns for any location in Canada. Finland identified the uncertainty in the 1992 wind atlas as a bottleneck to planning for taller multi-megawatt machines along the coastal areas. Italy has updated its wind energy atlas to be posted in 2007. In Germany, Federal authorities have identified suitable areas for offshore wind farms in the North Sea and Baltic Sea, making planning easier for investors.

Clear, consistent programs give the industry a firm foundation. In Italy, some investors have even stated they would be content with lower tradable green certificates prices in exchange for better-defined boundary conditions for their businesses in the long term.

5.0 R, D&D Activities

5.1 Setting Priorities

In 2007, 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 2006 will contribute to such R, R&D planning.

The European Commission launched a consultation process in March 2006 to discuss the medium- and long-term strategy for EU energy policy. The Green Paper "A European Strategy for Sustainable, Competitive, and Secure Energy" proposed the preparation of a "renewable energy roadmap" that would include 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. The Green Paper also foresaw the preparation of a European Strategic Energy Technology Plan to move Europe toward a low-carbon energy system, e.g., "by permitting a sharp increase in the share of lower cost renewables, including the roll-out of offshore wind."

A part of this EU effort, the European Wind Energy Technology Platform (TPWind) was launched on 19 October 2006. It is an industry-led initiative supported by the 6th Framework Programme of the European Union, channeled through the European Wind Energy Association. TPWind will identify areas for increased innovation and prioritize them on the basis of "must haves" versus "nice to haves." The primary aim is overall cost reduction through research and economies of scale (market deployment). The platform will detail specific tasks, approaches, actors, and necessary infrastructure, in the context of private R&D and EU and Member States programs such as the 7th Framework Programme. Finally it will assess the overall funding available from public and private sources to carry out this work.

In 2006, the ExCo approved a new research Task 26 titled Cost of Wind Energy. This task will assess methodologies for estimating COE and establish a method to assess the impact of R&D on COE. 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

Wind energy research is funded in many ways including national, state, and regional programs; cost-shared funding with institutes and corporations; European Union Framework programs; and trade association activities. In national program funding, Denmark, Sweden, and the UK reported R&D budgets that increased significantly in 2006. In Finland and Norway, budgets increased slightly. Budgets in Canada and Germany stayed about the same, and in Italy, Switzerland, and the United States slight decreases for 2006 were reported. Several countries expect budgets to grow in 2007.

In addition to national programs, funds for wind energy research in Europe come from the European Union. During 2006, more than 20 R&D projects related to wind energy were running with the support of the 5th and 6th Framework Programmes of the European Union (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

Test sites for large and small wind turbines and for components are an important part of the national research programs, and several changes were reported this year. 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. 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). The largest turbine being tested in 2006 is the Vestas 4.2 MW originally developed by NEG Micon.

In Germany, the demonstration offshore wind farm Borkum West (which is near the research platform FINO 1 in the North Sea) will be a test site consisting of 12 turbines of the 5-MW class. The demonstration project will be operated by the German Offshore Test Site and Infrastructure Ltd. (DOTI), which was launched by the power companies Vattenfall Europe, E.On, and Energiewerke Weser Ems (EWE). In addition, a test facility for rotor blade manufacturers to conduct static and dynamic tests of multi-megawatt turbine rotor blades was launched at the Fraunhofer Center for Wind Energy and Marine Technologies in Bremerhaven; it will start its work in 2008.

In Mexico, a Regional Wind Technology Centre will be built in early 2007 with the economic support of GEF/UNDP. The center will allow interested wind turbine manufacturers to characterize their products under the local conditions at La Ventosa, Mexico. The modern and flexible installation will enable researchers to obtain hard operational data on the interaction of specific types of wind turbines with the electrical system. And the national technology display will facilitate interaction between wind turbine manufacturers and Mexican industries, thus promoting the identification of possible shared business ventures.

To assist the development of wind energy in Norway, SINTEF Energy Research, the Institute for Energy Technology (IFE), and the University in Trondheim (NTNU) 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.

The Alpine Test Site Gütsch in Switzerland is based on participation in IEA Wind Task 19—Wind Energy in Cold Climates. Its results and recommendations are currently being verified within the context of the EU COST 727 project. Relevant results will be published in a handbook. The Gütsch site, 2,350 m above sea level, is now well equipped with meteorological measurement instruments and with data acquisition systems for power measurements. This location could be a good test site for smaller (<500-kW) wind turbines in alpine conditions.

5.4 Selected R&D News

The country chapters of the 2006 IEA Wind Annual Report contain much information and references to research planned, under way, and recently completed. A few highlights of R, D&D accomplishments for 2006 are presented here.

5.4.1 Offshore wind

March 2006 saw the beginning of the largest ever EU-funded R&D project in the field of wind technology. The UPWIND project is an integrating initiative to look at the design of very large turbines expected for offshore use.

Within IEA Wind Task 23—Offshore Wind Technology Developments, participants formed a working group named Offshore Code Comparison Collaboration (OC3) to focus on coupled turbine/substructure dynamic modeling. The OC3 participants developed dynamics models for an offshore wind turbine with monopile support structure. They made basic model-to-model comparisons of the wind-inflow, wave kinematics, and wind turbine response. They are currently focusing on comparisons of the monopile geotechnical response and are defining a tripod support structure to be used in the next phase of the project. The code comparison work has established a procedure and database that can be used for future code verification activities and analyst training exercises. In addition, the EU-integrated UPWIND research program has adopted the offshore 5-MW baseline wind turbine model, which is used in the OC3 project, as its reference wind turbine. The model will be used as a reference by all UPWIND Work Package teams to quantify the benefits of advanced wind energy technology.

In the Netherlands, some results of the Monitoring and Evaluation program of the Offshore Wind Farm Egmond aan Zee (OWEZ, formerly know as NSW) became available in 2006. In addition to climate data, reports were released detailing analysis methods and results about biological fouling and the projected likelihood and effects of ship collisions, oil spills, and interference with shipping radar of the OWEZ.

On 20 August 2006, the EU DOWNVInD project, which seeks to pioneer cost-effective wind farms in water depths of up to 50 m and approximately 25 km away from the shore, saw the first wind turbine of the project loaded out from Nigg Bay, transported to the location, and lifted onto its substructure. The machine is the first wind turbine in international waters, the farthest from shore (25 km), the biggest (5 MW), and in the deepest water (42 m). DOWNVInD aims to install two demonstration wind turbines adjacent to the Beatrice oil field (east coast of Scotland). The turbines stand about 150 m above sea level.

5.4.2 Large turbine development

In Germany, multi-megawatt turbine development is very active. Prototype turbines were tested by DeWind Ltd. (2-MW) and Fuhrländer (2.5-MW). Work continued on other large turbines: Enercon 6-MW and 4.5-MW, REpower 5-MW, and Multibrid Entwicklungsgesellschaft Ltd 5-MW. A new company, BARD Engineering Ltd., is pushing development of 5-MW turbines with a new "multipile" foundation concept for water depths from 20–50 m.

In the United States, a multi-year development partnership with Clipper Windpower Inc. has resulted in a prototype ready for commercial manufacture. In 2006, the program completed performance and acoustic tests on Clipper's 2.5-MW prototype installed in Wyoming. Other government/industry partnerships in the United States have produced and tested components for large wind turbines including a modular, highly efficient power electronics package; a 1.5-MW single-stage drivetrain with a planetary gearbox and permanent-magnet generator; a new tooth form for gearboxes to improve power density and reduce costs; and a sweep-twist adaptive rotor wind turbine blade that passively reduces loads.

5.4.3 Materials

In Finland, as part of its strategic research program on Smart Machines (2002–2006), VTT has developed technologies, components, and solutions for large wind turbines such as technologies to control the shape of composite structures at laboratory scale.

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 gathered within this project, including results of CRES research in Greece, is available to the public at http://www.kc-wmc.nl/optimat_blades.

5.4.4 Small wind

A new 1.8-kW turbine by Southwest Windpower completed performance tests in 2006. Developed in partnership with U.S. Department of Energy, it has fully integrated electrical components, costs less than comparable sized machines, is easier to install, and operates more quietly.

In Portugal, INETI is developing a small, high-performance, low-cost turbine for urban use–TURBan. This national project, designed and constructed using Portuguese technology, will be completed and operational by mid-2008.

5.4.5 Forecasting and costs

In Finland, the first short-term forecasting project by Foreca, VTT Technical Research Centre, and Cybersoft showed the benefits of grouping wind farms along the coastline; dispersing the sites reduces forecasting errors. Forecast errors from day-ahead forecasts result in deviations in the bid amounts of production to the electricity markets. For these deviations, imbalance costs have to be paid. A study of imbalance costs was paid for by a Finnish wind producer with four sites. The case study showed a price of 1.5 €/MWh (2004 prices) when predicting production without meteorological forecasts and 0.8 €/MWh when predicting production on the basis of meteorological forecasts.

5.4.6 Grid integration

The Republic of Ireland and Northern Ireland began an all-island study in June 2006 to investigate grid issues for renewable energy to 2020. Wind energy will contribute the greatest percentage of renewable energy in Ireland. The study will examine penetrations of renewable energy sources of 15%, 20%, and 30%; determine the cost of various renewable energy mix options; determine technical issues for high renewable energy penetration especially in electrically isolated areas; and inform the government in detail of the implications of renewable energy policy choices.

A study of unit commitment and dispatch in the Netherlands in the presence of future large-scale wind energy production was released in 2006. The results show no ramp rate problems in the Dutch system by 2012. However, base-load problems may arise at high wind penetration levels, and these problems can only be prevented by wasting available wind resources. In a related study, a system model was developed to simulate system balancing including wind power integration under various regimes. The preliminary results demonstrate that the market design for integrating wind power has a major impact on the overall system balance. Most notably, the Area Control Error, being a key parameter for system operation. If wind power has to be balanced by the TSO, some wind power fluctuations may be cancelled out between different wind farms due to geographical spread, but large imbalances are inevitable. In a market-based environment however, the market parties should be responsible for balancing their portfolio in order to keep the imbalance on the system level as low as possible.

A study in the United States gathered the data needed to predict the physical impacts and costs of wind generation on grid operations and to identify transmission constraints. The results showed that the additional operating costs of wind energy would be moderate at the large penetration levels expected in the next five to ten years and that large diverse balancing areas with robust transmission tend to reduce wind's impact and ancillary service cost.

5.4.7 Cold climate

A preliminary study in Switzerland of the use of nano-coatings (antifreeze coatings based on the effect of antifreeze proteins) was carried out. Antifreeze proteins inhibit crystal growth, forcing ice formation to start at much lower temperatures. Unlike traditional antifreeze compounds, the effect of antifreeze proteins is not proportional to their concentration. Synthetically prepared polymers can mimic the effect of antifreeze proteins. So far, the tested coatings have shown a reduction in ice adhesion and formation on surfaces, but this reduction is not yet sufficient to prevent icing. Coatings with antifreeze properties analogous to antifreeze proteins open up new possibilities for reducing ice formation on surfaces.

5.4.8 Storage

In Germany, a new research network is dealing with the storage of wind energy in underground air-pressure storage areas in combination with the energetic deployment of low concentrated North Sea gas resources. Existing underground holes resulting from former salt mines and ore mines are being evaluated concerning their availability as air-pressure storage areas for the intermediate storage of wind energy.

In Ireland, a study of a new electricity storage system is under way: the Vanadium Redox Battery Storage System (VRBESS™) at Sorne Hill Windfarm in Donegal. If successful, the technology would allow wind energy generated at off-peak times to be stored and supplied to the grid at a scheduled time. Another study examined the costs and benefits of integrating a battery-based power storage system with a 6-MW wind farm. The report concluded that the optimum battery is a 2-MW capacity battery delivering six hours of electricity storage.

In Japan, a study of a grid stabilization system with battery backup is under way by demonstrating the system on a wind farm.

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

In Portugal, the most recent public call for grid connection provided incentives to encourage wind farm owners and operators of pumped hydro power stations to store wind energy for use by the power system when needed.

5.4.9 Environmental impact assessment

In a bilateral cooperation between Germany and Denmark, researchers investigated harbor porpoises and birds at the two Danish offshore wind farms, Horns Rev and Nysted. A new project of the German Marine Museum Stralsund and the Danish National Environmental Institute will develop standardized methods for the calibration and signal analysis of porpoise hydrophones (PODs). In related work, temperature measurements at the sea bottom above the 110-kV cables of the Nysted wind farm showed no significant effect on the temperature of the sediment layer above.

In the Netherlands, ECN developed and tested a new method to detect and record bird collisions that is suitable for continuous remote operation in both onshore and offshore wind farms. A prototype was tested on a land-based multi-megawatt turbine at their wind turbine test site. ECN intends to offer a service to wind farm owners and operators in which it is responsible for the installation and operation of the system and reports bird collisions to the customer.

In Sweden, work is under way to accurately model wind turbine interference with military radar. Onshore, models of the interaction between radar and wind turbines have in past years been improved to consider terrain effects. Using these models, onshore wind energy projects have had fewer problems getting approved. For offshore locations, however, the current model in use results in the Defense Administration stopping most projects. To gain knowledge about the real disturbances caused by wind turbines offshore and to develop a new model, the Swedish Energy Agency is funding a project with flight tests over one of the existing offshore wind farms. Plans are for the project to be carried out during 2007.

5.4.10 Long-term measurements

In Germany, final results from the Scientific Measuring and Evaluation Programme (WMEP) were presented in 2006. WMEP has developed 63,000 reports detailing energy output data; operation experiences; and data about damage caused by lightning, storms, ice, and grid failures. The data were collected from 1,500 wind turbines together with wind data at 60 locations. This unique database will be extended to future offshore wind farms.

The German research platform FINO 1 (www.fino-offshore.de) in the North Sea has been in operation for more than three years. Wind, wave, and load data are now available online (http://fino.bsh.de). FINO 2 (www.fino2.de) is located in the Baltic Sea at the borders of the German, Swedish, and Danish EEZ. The monopile foundation was rammed in October 2006. Offshore installation of the deck and the measuring mast will occur in June 2007. FINO 3 (www.fino3.de) will be commissioned in summer 2008 in the northern part of the German EEZ of the North Sea about 70 km west of Sylt Island. A special focus of FINO 3 will be geophysical investigations concerning interactions between sediment and monopile and lightning on the open sea and its possible impact on turbine components.

5.4.11 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

The continued expansion of wind energy capacity and production is projected by all member countries. Due to limited onshore locations in countries with high wind development, activities to begin or expand offshore operations are under way. These include mapping offshore resources, developing hardware and logistics strategies, studying barriers (environmental and radar), and preparing institutional procedures. Increased emphasis on demonstration of large multi-megawatt turbines is coupled with renewed interest in improving the technology of small wind turbines. Reducing costs is a high priority in all of the IEA Wind member countries. On 6–7 December 2007, an IEA Wind Topical Expert Meeting will be held on Long-Term Research Needs. This activity under Task 11 should provide input to the new IEA Wind Strategic Plan for the next 5-year term (7).

References:

1) EWEA, www.ewea.org.

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3) IEA Wind Annual Reports 1995–2005, www.ieawind.org.

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

5) Wind Directions http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WD/WD22vi_public.pdf

6) BWEA report http://www.bwea.com/pdf/planning/planningdelays.pdf

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

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Implementing Agreement

1

1.0 Introduction

IEA's commitment to wind energy dates back to 1977, when the Implementing Agreement began that is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). The past 29 years have seen the development and maturing of wind energy technology. This process 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) The EWEA became a Sponsor member in 2006.

Recently there has been increasing interest in IEA 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. In 2006 the ExCo invited representatives from Brazil, China, India, Russia, and South Africa and others to attend meetings as observers.

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 in 2006 is presented in the Executive Summary of this Annual report. Individual county activities are presented in Chapters 10 through 29.

3.0 Collaborative Research

Participants in the IEA Wind Agreement are currently working 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. 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 2006, 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 pages.

Table 1 Contracting parties in 2006 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

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 signed the 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 the Implementing Agreement 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.

Officers

In 2006, Ana Estanqueiro (Portugal) served as Chair and Sara Hallert (Sweden) served as Vice

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)

Chair. At the 58th ExCo meeting the ExCo elected Morel Oprisan (Canada) and Brian Smith (United States) as vice chairs for the calendar year 2007. Sara Hallert withdrew from her position as vice chair.

Participants

In 2006, the EWEA joined to become the first sponsor member of the Implementing Agreement. (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 57th ExCo meeting was hosted by the European Commission in Brussels, Belgium on 28, 29, and 30 March 2006. There were 24 participants from 13 of the contracting parties, three operating agent representatives of the tasks, the IEA Paris representative, and observers. The ExCo reviewed and approved technical progress reports of ongoing tasks 11, 19, 20, 21, 23, 24, and 25; and approved extension of task 20 through July 2007. The audit report of 2005 accounts of the Common Fund was approved. On 30 March 2006, the ExCo visited the Hansen Transmissions factory at Lommel, Belgium and toured the Renewable Energy House of the European Wind Energy Association in Brussels.

The 29th issue of the IEA Wind Energy Annual Report was published in June 2006.

The 58th ExCo meeting was hosted by the Australian Wind Energy Association (AusWind) in Adelaide, Australia on 21 and 22 September 2006. There were 27 participants from 16 of the contracting parties, five operating agent representatives of tasks, and observers from New Zealand and the Global Wind Energy Council. The completed email ballot to accept the EWEA as sponsor member was announced. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2007. Several ExCo members gave presentations at the AusWind International Wind Energy Conference during the week.

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 2006. (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 for Wind Farm Power Systems	Offshore Wind Energy Technology and Deplyment	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						
Korea					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	
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

Task 11

2

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 pay fees to 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.

The second sub-task is to conduct two types of meetings of experts on topics designated by the IEA Wind Executive Committee (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 2005 Task 25 Power System Operation with Large Amounts of Wind Power was approved by the ExCo after Topical Expert Meeting 44 in 2004 on System Integration of Wind Turbines brought together the interested experts who wrote the Task proposal.

In 2006, a new Task 26 Cost of Energy from Wind Systems, was approved after Topical Expert Meeting 47 in 2005 on Methodologies for Estimating the Cost of Energy from Wind Energy and Methodologies to Estimate the Impact of Research on Cost. Participants in that meeting wrote the task proposal and will participate in the cooperative work to advance understanding in this field.

Over the 26 years since these activities were initiated to promote wind turbine technology through information exchange, 50 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 2006

According to the work plan approved by the ExCo, the following activities were planned for 2006:

48 th Topical Expert Meeting on Operation and Maintenance of Wind Power Stations

49th Topical Expert Meeting on Challenges of Introducing Reliable Small Wind Turbines

50th Topical Expert Meeting on the Application of Smart Structures for Large Wind Turbine Rotor Blades

The fourth meeting of the year "State of the art of Remote Wind Speed Sensing Techniques Using Sodar, Lidar and Satellites" will be arranged early in 2007.

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 Operation and Maintenance of Wind Power Stations (TEM 48)

There is great potential to lower the amount of corrective maintenance and find strategies and methods for preventive maintenance of wind turbines. Doing so will reduce O&M costs. Presently it is quite difficult to develop such general strategies due to the limited number of wind turbines of a specific model and also because fault statistics are only in the hands of the owners/operators.

The attendees of TEM 48 discussed the magnitude of O&M costs. These costs seem to be in the following ranges:

- Offshore 1-2 €/MWh
- Onshore 1 €/MWh

Models to estimate O&M cost are offered by at least two companies: ECN and Garad & Hassan. These tools were considered interesting by the TEM participants, but crucial statistical inputs are difficult to obtain.

3.2 Challenges of Introducing Reliable Small Wind Turbines (TEM 49)

Small wind turbines have great potential to provide electric power, especially in remote locations. Market studies indicate a quickly growing demand for small wind turbines and hybrid power systems, which combine wind and some other generation technology. However, according to meeting

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

Table 2 Topical Expert Meetings held since 1990*			
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	Boulder, Colorado	2000
33	Wind forecasting techniques	Stockholm, Sweden	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
26	Lightning protection of wind turbine generator systems and EMC problems in the associated control systems	Milan, Italy	1994
25	Increased loads in wind power stations	Gothenburg, Sweden	1993
24	Wind conditions for wind turbine design	Risø, Denmark	1993
23	Fatigue of wind turbines, full-scale blade testing	Golden, Colorado	1992
22	Effects of environment on wind turbine safety and performance	Wilhelmshaven, Germany	1992
21	Electrical systems for wind turbines with constant or variable speed	Gothenburg,Sweden	1991
20	Wind characteristics of relevance for wind turbine design	Stockholm, Sweden	1991
19	Wind turbine control systems-strategy and problems	London, England	1990

*For meetings prior to 1990, 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				

participants, small wind turbines have the following issues.

- short operational lifetimes because of technical failures and/or excessive maintenance requirements
- misleading or non-existent power curves, production, and noise data
- lack designs conforming to existing safety standards and have caused accidents
- fail to fulfil legal product requirements in some countries.

While government programs in the early days of wind energy development fostered the manufacturers of medium-sized wind turbines to produce good products, this was not the case for small wind turbines. Contributing to the problems with small wind turbines is also the fact that they are often purchased by private individuals without the professional competence or procurement practices normally used when buying medium and large wind turbines.

The objective of TEM 49 was to find ways to ensure that small wind turbines are reliable in the following areas.

- reliable long life: reduce technical failures and excessive maintenance
- reliable performance: reliable published power curve, production and noise data
- reliable safety: appropriate safety standards followed and accidents avoided
- reliable from a legal point of view: the buyer should not face the risk of buying a product that is illegal to operate.

The participants favored promoting further work in the area. The most important thing would be to develop a label stating that a product is legal and safe. This would allow consumers to avoid unsafe products. One initiative discussed was to develop a recommended practice for labelling small wind turbines. Other initiatives related to such a proposal include the EU-funded study on small wind prepared by a group from France and the Netherlands. The Global Wind Energy Council might also participate in such an initiative. The American Wind Energy Association is presently working in this area, especially on standardization.

The participants agreed to write a proposal for the development of an IEA Wind Recommended Practice on methods for labelling of small wind turbines. An Ad Hoc group was set up with the responsibility to prepare such a proposal in 2007.

3.3 The Application of Smart Structures for Large Wind Turbine Rotor Blades (TEM 50)

3.3.1 Background

Wind turbines and their blades are becoming larger. Modern wind turbines designed for offshore applications are now the largest rotating machines on earth, with the length of one blade almost equal to the entire span of a Boeing 747. This up scaling has so far been accomplished with few changes in the blade structure: all blades are constructed as a single component, with the blade skin as the load carrying element. Until the 1990s, the 'Danish concept' combined constant rotor speed with stall of the flow around the rotor blades; increasing wind speeds automatically induce increasing drag forces that limit the absorbed power. Today, most large wind turbines run at variable rotational speed, combined with the adjustment of the collective pitch angle of the blades to optimize energy yield and to control the loads. Controlling blade pitch angle has led to improved power regulation, significantly lighter blade construction due to the lower load spectrum, and a lighter gearbox due to shaved torque peaks.

The next step in blade load control is almost ready for commercial application: pitch angle adjustment on individual blades instead of on the collective. This will further reduce rotor loads, especially the periodic loading due to yaw and wind shear. Not only blades will benefit from this, but also the drive train and nacelle structure.

As wind turbines become even larger more detailed and faster control of the loads will be necessary. Control should be possible for each blade at any azimuthal position and any spanwise station. This will be accomplished by aerodynamic control devices with embedded intelligence distributed along the span. The similarity to control devices used for airplane wings (flaps at leading and trailing edge, ailerons) is apparent, but the requirements for wind turbine blade control devices are probably much more severe. Modern blades are very reliable and require only limited maintenance at the blade pitch bearing. Future blades with distributed control devices should be as reliable, without adding maintenance requirements. The development of this kind of technology, often named in popular terms 'smart structures' or 'smart technology', is an interdisciplinary development par excellence.

3.3.2 Discussion

The objective of TEM 50 was to report and discuss progress of R&D on these topics. During the final discussion, the general attitude was that this new area in the wind turbine research may result in more effective ways of controlling power production and thus lower the cost of electricity produced.

However, the following challenges related to "smart structures" were identified.

- Costs are difficult to determine for these new technologies. Designers should aim for 30% (substantial) load reduction to compensate for the risks. Reliability is most important.
- Shape Memory Alloy (SMA) materials have an on/off characteristic, but the need in wind turbines is to have variable amplitude.
- Control issues related to SMA are cooling, temperature range, and loads.
- Damage from lightning strikes in SMA materials and conductors must be handled. Helicopter blades, for example, are certified and have solved the problem of lightning strike.
- It is important to try to damp edge-wise oscillations in blades and this must be handled by the new "smart" structures. Necessary damping figures of 0.5–1.5 % were mentioned.
- Bending/torsion coupling in the blades may be introduced to control power. This has been used in the small scale but has not been

used commercially because the tools are not sufficient to claim efficiency increase. The structure will cost more so trade off cannot be made accurately.

• Missing in the discussion was the need for sensors and energy supply to the actuators. For information, there is a national Danish program on using sensors.

• Efficiency of actuator depends on airfoil. An airfoil designed specifically for these actuators may be needed. Both Risø and University of Stuttgart are developing such airfoils.

• Aerodynamicists are beginning to understand effects caused by non-stationary phenomena, which were thought to be stationary. Non-stationary, high-frequency phenomena should be investigated.

The participants were very enthusiastic about having another Topical Expert Meeting on this subject. The suggestion was to have annual meetings on smart structures with some added topics like new structural and 3-D aerodynamic concepts.

4.0 Plans for 2007 and beyond

Task 11 has been extended through 2007 and a new workplan was approved to continue coordinating Topical Experts Meetings and Joint Action Symposia. Four meetings of this type will be arranged every year. Examples of meetings include, but will not be limited to the following.

• State of the Art of Remote Wind Speed

• Sensing Techniques Using Sodar, Lidar and Satellites

• Wind and Wave Measurements at Offshore Locations

• Radar, Radio, and Wind Turbines

• Social Acceptance of Wind Energy Projects

• Noise and Noise Propagation Models

All documents produced under Task 11 are available to organizations within the countries that participate in the Task: Canada, Denmark, Finland, Germany, Ireland, Italy, Japan, Mexico, the Netherlands, Norway, Spain, Sweden, the United Kingdom, and the United States. Organizations within these countries can receive the newest documents from the Operating Agent representative, listed in Appendix B.

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

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 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. A continuation of Task 19 was approved by the ExCo in autumn 2005. The work of the second term began in 2006 and will continue through 2008. Table 1 lists the participating countries in 2006.

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 locate on 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- 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

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
Switzerland	ENCO (for Swiss Federal Office of Energy)
USA	NREL

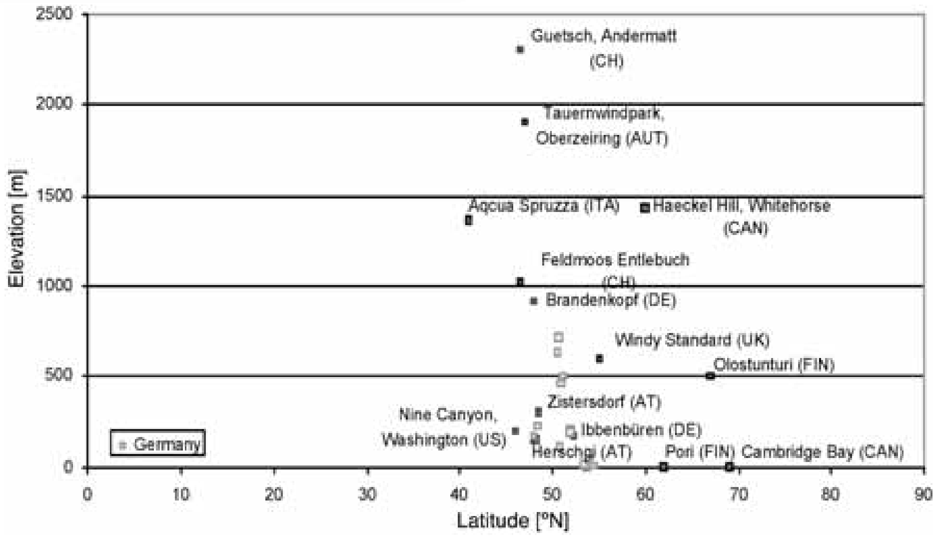

Figure 1 Location of selected cold climate sites that experience cold climate conditions annually

- 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)
- Update the Task 19 state-of-the-art report and update the 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 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 (Figures 2 and 3).

The participants have agreed to a cost-shared and task-shared arrangement to carry out specific activities necessary to achieve the objectives. In addition to financial support for the Operating Agent, participants supply information and attend task meetings.

Participants of the 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 2006

In the two meetings organized by Task 19, the second term of the task was planned in detail. National activities in the participating countries were presented. The ongoing and planned national activities, which contribute to the objectives of Task 19 include:

- Characterization of icing, wind speed, air temperature, duration, correlation including sensor comparison and testing in test sites in eastern Canada, Finland, Norway, and Switzerland
- Development of meso-scale modeling for icing risk (Norway with test data from Finland)
- Collection of operational experience from turbines operating in cold climates (Finland, Germany, Switzerland, and the United States)
- Modeling of wind turbine performance and loading in icing conditions (Finland and Italy)
- Research on the physics of icing and de-icing technologies in an icing wind tunnel (Canada)

The project website at http://arcticwind.vtt.fi has been updated and serves as an extranet among the participants of Task 19. During 2006, the common efforts towards the end of the task were planned. These include:

- Cold climate issues in standards
- Dissemination of the results to utility and operator interest groups
- Market study

The cold climate related requirements in the present IEC61400-standards will be reviewed in order prepare a set of recommendations to be presented to IEC TC88.

Towards the end of the task it was agreed that the results will be disseminated to interested utilities and operators in specific seminars.

4.0 Plans for 2007 and beyond

The Task 19 activities for the year 2007 period include:

- Review of cold climate issues in present IEC-61400 standards and proposals for continuation
- Market study
- Update of the Task 19 State-of-the-Art Report

The activities will solve the most common issues that are causing uncertainty regarding cold climate wind development. These activities are intended to match well with the national activities that the participants have planned for the next two years.

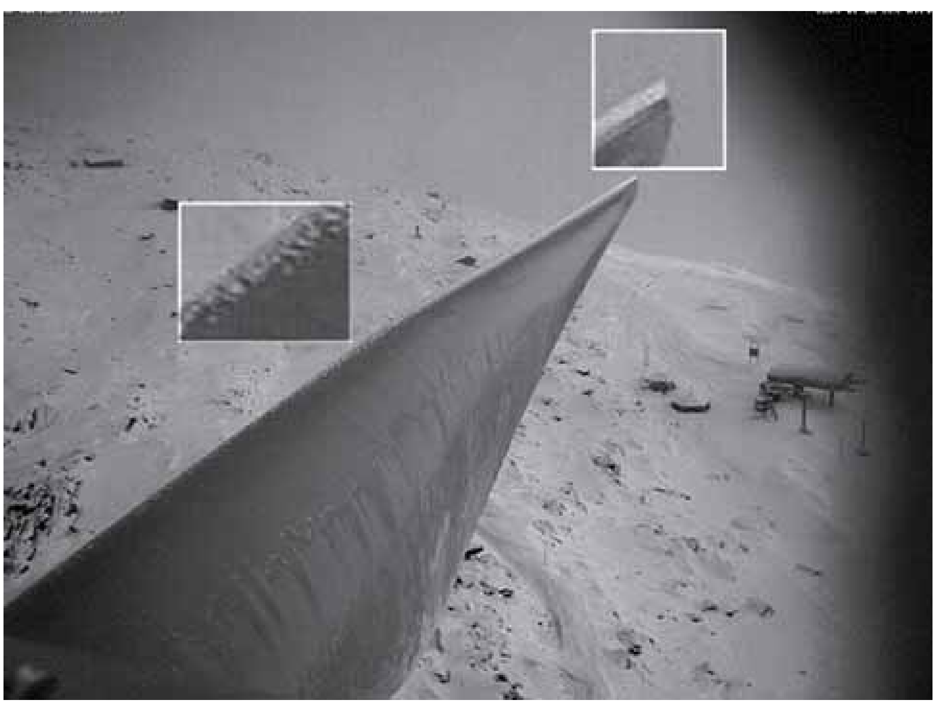

Figure 2 Wind turbine within walking distance from a ski lift in Gütsch. Turbine is equipped with a de-icing system. Photo: ENCO AG, Switzerland.

Figure 3 Wind measurements with video monitoring of icing in Norway. Photo: Kjeller Vindteknikk, Norway.

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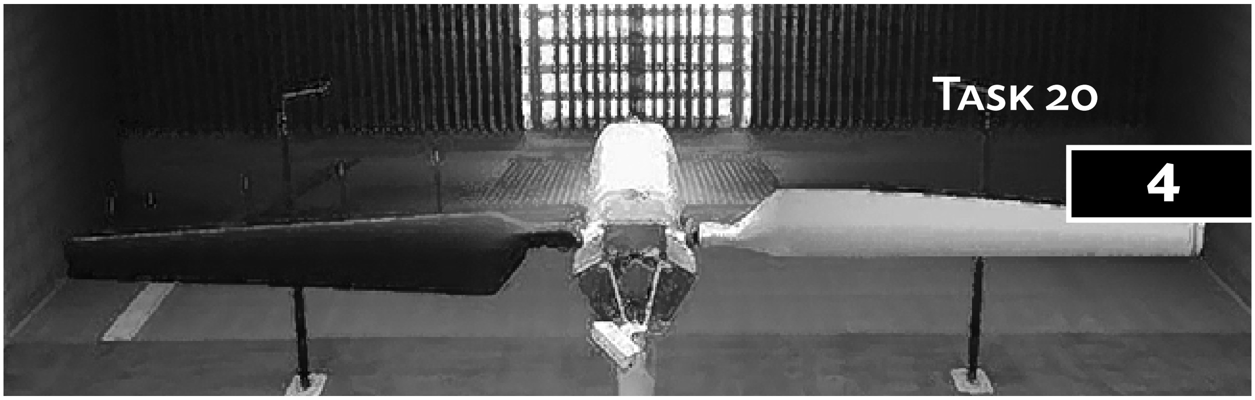
Authors: Esa Peltola, VTT Processes, Finland and Timo Laakso, Pöyry Energy, Finland



HAWT Aerodynamics And Models From Wind Tunnel Measurements

1.0 Introduction

Wind energy continues to expand worldwide, and wind turbines continue to grow larger. In this environment, sustained technological innovation will require aerodynamics models of greater accuracy and reliability. To achieve these goals, theoretical and computational models must evolve alongside high-quality experimental measurements. Over the past decade, turbine aerodynamics instrumentation and data quality have improved substantially as a result of efforts like IEA Wind Task XIV, "Field Rotor Aerodynamics," and Task XVIII, "Enhanced Field Rotor Aerodynamics Database."

In these efforts, turbine sizes and configurations were comparable to state-of-the-art turbines, and recorded aerodynamic phenomena that 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.

To acquire aerodynamics data representative of full-scale turbines, under conditions of steady uniform inflow, the NREL (National Renewable Energy Laboratory) UAE (Unsteady Aerodynamics Experiment) wind turbine was tested in the NASA Ames 80 foot by 120 foot (24.4 m by 36.6 m) wind tunnel (Figure 1). This test was designed to provide accurate and reliable experimental measurements, having high spatial and temporal resolution, for 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 over 2,100 data files containing nearly 100 GB (gigabytes) of high-quality data.

Shortly after test completion, select data were employed as a reference standard in a blind comparison designed to evaluate wind turbine aerodynamics code fidelity and robustness. In this exercise, participants were given the UAE geometry and structural properties, and then attempted to predict aerodynamic response for a modest number of test cases representing diverse 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. Represented in the field of models were blade element momentum models, prescribed wake models, free wake models, and Navier-Stokes codes. Results generally showed unexpectedly large margins of disagreement between the predicted and measured data. Notably, 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 research task 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 aerody-

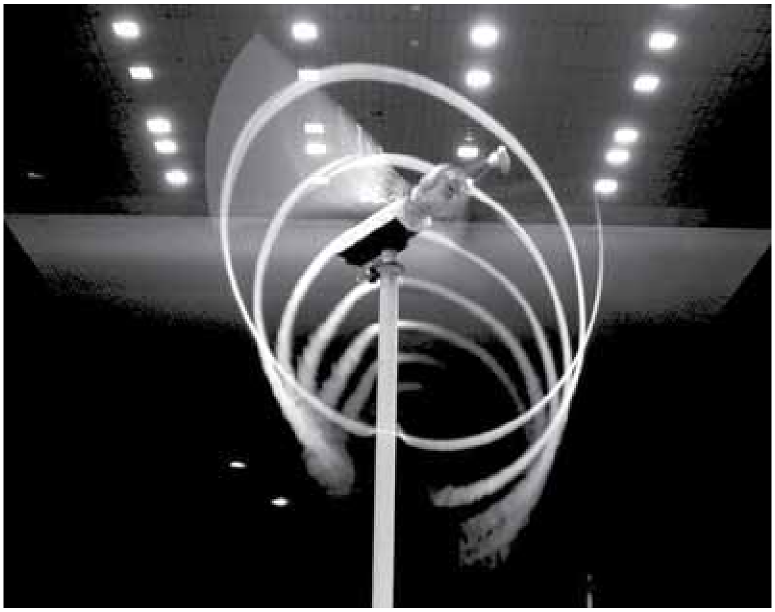


Figure 1 NREL UAE wake flow visualization in NASA Ames 80 foot by 120 foot wind tunnel

namics 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

2.1 Objectives

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
- 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.

2.2 Participants

In 2006, eleven organizations representing eight Task 20 member countries are participating in Task 20. In addition, three organizations from three other IEA member countries participate in conjunction with Task 11 during Joint Action on Aerodynamics meetings.

- 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
- Gotland University, Sweden
- Institutt for Energiteknikk, Norway
- Kyushu University, Japan
- National Renewable Energy Laboratory (NREL), United States
- Risø National Laboratory, Denmark
- Royal Institute of Technology, Sweden
- Seoul National University, Republic of Korea
- Technical University of Delft, The Netherlands
- Kiel University of Applied Sciences, Germany

2.3 Resources

In the initial stages of Task 20, data acquired during the UAE wind tunnel test were hosted on the Unsteady Aerodynamics Experiment (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 Operating Agent Representative. Currently, nearly 30 user accounts have been set up, and over 50 users have acquired data for diverse applications. If unique 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 2006

During 2006, 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 the Kiel University of Applied Sciences, 25–27 April 2006. As with the previous three Task 20 meetings held in 2003 through 2005, the 2006 Task 20 meeting was conducted in collaboration with the Task 11 Joint Action on Aerodynamics of Wind Turbines meeting.

At the April 2006 Task 20 annual meeting, researchers representing their respective countries reported on work carried out during the preceding year. Summarized below are the 13 presentations given at the 2006 meeting, including titles, authors, and affiliations.

"Aerodynamics of Darrieus Rotors," A. P. Schaffarczyk, Kiel University of Applied Sciences, Germany – Previous vertical axis turbine designs were prone to under-performance and early structure failure. As interest in vertical axis machines is renewed, a full spectrum of physics-based, validated design tools, ranging from theoretical approaches to CFD models, will be needed. These design tools will be enabled by fundamental aerodynamic research, and will play a key role in avoiding errors made in early vertical axis turbine designs.

"Renaissance of Vortex Generators," K. Kaiser, Aero & Structural Dynamics, Germany – In the past, vortex generators were used to optimize the power curve of stall regulated turbines running at fixed speed. At present, state of the art turbines use blade pitch control and variable rotor speed. However, some current control algorithms allow blade angle of attack to vary through a broad range in which aerodynamic performance varies substantially. Vortex generators could be used to optimize aerodynamic performance of blades, in combination with pitch control and variable speed.

"Navier-Stokes Computation of Rotor-Tower Interactions," F. Zahle, Risø National Laboratory, Denmark – A newly implemented overset grid method was shown to successfully model the interaction between the tower wake and rotor on a downwind turbine. At certain flow conditions where the tower shedding frequency and the rotor blade passage frequency were sufficiently close to being multiples of each other, vortex lock-in was observed. It was hypothesized that this phenomenon was responsible for unexplained high levels of low frequency noise observed on downwind turbines (Figure 2).

"Aerodynamic Investigation of Winglets on Wind Turbine Rotors," J. Johansen, Risø National Laboratory, Denmark – The aerodynamic benefits of adding a winglet to a wind turbine blade were investigated using computational fluid dynamics. Results showed that adding a winglet increased the force distribution over the outer 0.14R, increasing power production by 0.6% to 1.4% for wind speeds higher than 6 m/s, but increasing thrust by 1.0% to 1.6%. A family of geometry configurations was examined, and suggested that winglets could deliver even greater benefits if properly optimized.

"Experimental and Computational Fluid Mechanics at Vattenfall Utveckling," J. Westin, Vattenfall Utveckling AB, and S. Ivanell, Gotland University, Sweden – The Vattenfall Group is now the fifth largest electricity generator in Europe. It maintains a corporate research and development center, where computation and testing are used to address technical issues in several disciplines, including fluid dynamics. Current fluid dynamics activities do not include wind energy, but a desire exists to expand in this direction. Participation in IEA Task 11/20 activities represents a key step in attaining this goal.

"Wake Measurements in ECN's Wind Turbine Test Site," G. Schepers, Energy Research Centre of The Netherlands, The Netherlands – ECN's Wind Turbine Test Field Wieringermeer (EWTW), test assets, and data are summarized. The north row

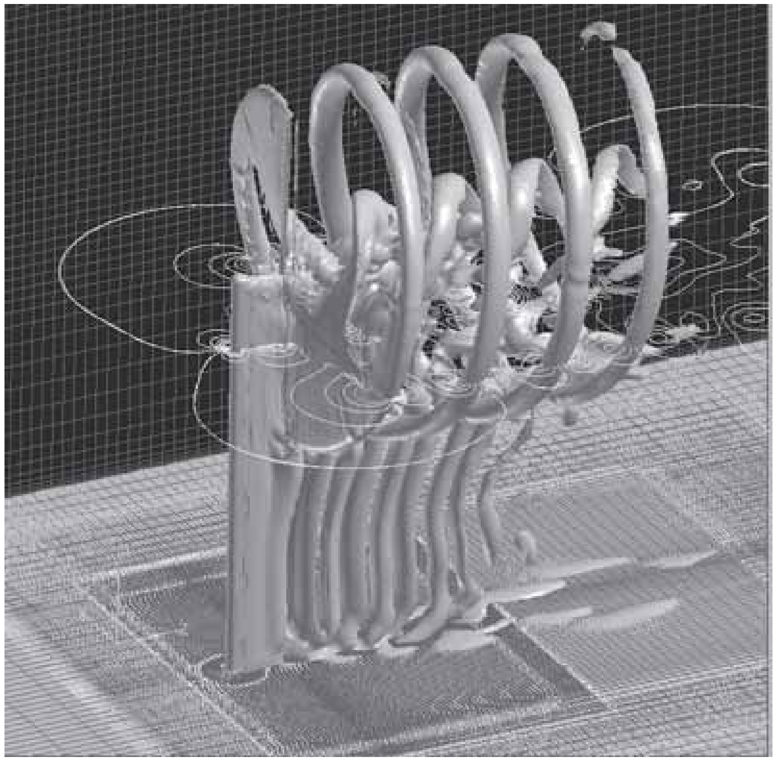


Figure 2 Computed iso-vorticity surfaces for a downwind turbine, showing rotor and tower wake structures. (F. Zahle, et al., Riso National Laboratory, Denmark)

consists of five Nordex N80 2.5 MW machines. All are equipped with nacelle sonic anemometers and other instrumentation, and one is instrumented to measure blade root and tower base bending moments. A 108 m meteorological mast instrumented at three heights captures wake data from the five N80's, which are 2.5D to 12.8D upstream of the mast, depending on wind direction. Diverse data for turbine operation have been acquired and analyzed.

"Wind Turbine Wake Subject to Thermally Stratified Atmospheric Boundary Layer," C. Masson, École de Technologie Supérieure, Canada – This work is concerned with the behavior of wind turbine wakes under the influence of various thermal stratifications of the atmospheric boundary layer. Specifically, a numerical model is formulated to simulate turbine aerodynamics, including the wake, in an atmospheric boundary layer under varying thermal stratifications. This model represents the rotor as an actuator disk and exerts blade influences on the flow via blade element theory. Incompressible 3-D RANS is employed to compute the wake flow field, using a modified k-ε model.

"The Near Wake of a Model Rotor: Measurements and Modeling," W. Haans, Delft Technical University, The Netherlands – An experimental campaign produced a comprehensive and consistent set of measured data for a model rotor wake. The near wake was characterized for a range of yawed flow conditions, including the baseline axisymmetric condition. Data included rotor thrust, tip vortex trajectory, phase locked mean velocities, and dynamic stall locations, but did not include blade loads. These data have been modeled with an actuator line code. Initial comparisons are promising, and will improve understanding of near wake aerodynamics under yawed conditions (Figure 3).

"Actuator Line Computations on Wakes of Wind Turbines in Wind Farms," N. Troldborg, Denmark Technical University, Denmark – Wake dynamics of a single wind turbine and three turbines aligned in a row are compared, using a 3-D Navier-Stokes method combined with an actuator line technique. Computations for the single turbine exhibit low frequency wake fluctuations, and show that blade tip vortices may be preserved several rotor diameters downstream. Results for the three turbine row demonstrate that tip and root vortices from downstream turbines dissipate near the rotor. Results also show that placing turbines too densely can significantly reduce power.

"Towards the Optimal Loaded Actuator Disc," R. Mikkelsen, Denmark Technical University, Denmark – The optimally loaded actuator disc was considered, including tangential velocities loaded to give constant axial induction. Instead of BEM theory, analyses were done with a vortex model and a Navier-Stokes method. The computed axial loadings were found to increase toward the root section. The analytic solution reveals that the increase is due to the low wake pressure caused by centrifugal acceleration of increasing tangential velocities at inboard radii. Some local Cp levels exceeded the Betz limit, but integration over the disc yielded Cp consistent with Betz.

"The Steady State Parked Configurations," R. van Rooij, Delft Technical University, The Netherlands – NREL UAE lift and drag data at high angles of attack for parked blade conditions were analyzed, with these 3-D data being compared to data that would be obtained under 2-D conditions. Lift and drag characteristics at five span locations (30%, 47%, 63%, 80% and 95%) showed that 3-D loads in parked condition were different than would be produced under 2-D conditions. Detailed analyses of segment lift showed a possible offset in inflow angle at the 47% and 63% span locations, probably caused by flow probe measurements.

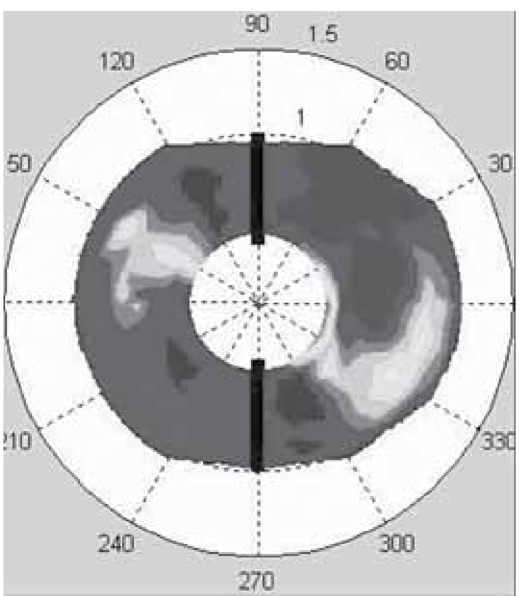


Figure 3 Standard deviation contours of measured near wake velocity. (W. Haans, et al., Delft University of Technology, The Netherlands)

"Identification of Flow Structures on a Rotating Blade Using the NREL UAE Phase VI Data and Frequency Analysis," A. Gonzales and X. Munduate, Centro Nacional de Energías Renovables, Spain – Data acquired by the UAE Phase VI wind turbine under parked and zero yaw rotating conditions were compared to ascertain the effects of rotation on blade aerodynamics. Data employed in the comparison consisted of local inflow angles, surface pressure distributions, and force coefficient data, all of which were studied at multiple radial locations. For both parked and rotating conditions, trailing and leading edge separation movement were tracked with respect to incidence angle, and pronounced flow field modifications were observed in response to rotation.

"Unsteadiness in Rotationally Augmented Blade Flow Fields," S. Schreck, National Renewable Energy Laboratory, United States – Means, standard deviations, and spectral decompositions were computed from time records of UAE Phase VI surface pressure coefficient and sectional normal force. These data were correlated with separation/impingement movement data from previous work. While separated flow fields were steady or pseudo-steady, rotationally augmented flow fields were found to be substantially unsteady. Magnitude and spectral content of time variation in rotationally augmented flow fields changed significantly with wind speed and radial location.

4.0 Plans For 2007

The 2007 Annual Progress Meeting will be the fifth and final meeting for Task 20, and will be held at Denmark's Risø National Laboratory on June 14-15. As in previous years, the Task 20 meeting will be held in collaboration with the Task 11 Joint Action on Aerodynamics of Wind Turbines meeting.

Following this final technical progress meeting, the participants will spend six months documenting their Task 20 research. It is anticipated that the Task 20 final report will be delivered to the IEA Wind Secretary near the end of 2007.

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

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. Such assessment is commonly conducted using commercially available software packages for simulation and analysis of power systems. These packages normally facilitate a set of well-developed models of conventional components such as fossil-fuel-fired power stations and transmission network components. However, models of wind turbines or wind farms represent new features with, in many cases, unknown accuracy. This at best leads to uncertainty in the market, and at worst it leads to an erroneous design jeopardising the power system stability.

The challenge is twofold. First, the technology in modern wind farms is fairly complex, and the dynamic behavior of these wind farms may differ significantly depending on the wind turbine type and manufacturer-specific technical solutions. Second, model validation must be transparent and adequate for providing confidence. Thus, for a coordinated effort aiming to enhance progress, Task 21 under the IEA Wind Agreement was proposed and approved in April 2002 with SINTEF Energy Research of Norway as the Operating Agent.

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 they carry out activities, supply information, and join meetings as required to meet the task objectives.

The overall objective is to assist 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

Task 21 has participants from nine countries (Denmark, Finland, Ireland, the Netherlands, Norway, Portugal, Sweden, the United Kingdom, and the United States). In these countries, research institutes and universities carrying out work to develop and test wind farm models. They also perform grid studies in cooperation with wind turbine manufacturers and electric utilities. In total, participants of the task are expected to contribute more than 20 person-years of work effort.

Cooperation within the task comes from sharing measurement data, model descriptions, and discussions at meetings. A total of eight task meetings have been arranged. In 2006, a meeting was held in Athens, Greece at the venue of the European Wind

Energy Conference. A workshop dedicated to Task 21 was organized as part of this conference with presentations by all participants of the task. This proved to be an excellent opportunity for disseminating results and getting feedback for final reporting. Continuous communication for preparing the Task 21 final report is by e-mail and phone.

Model developments are ongoing among participants. They include both fixed- and variable-speed technologies and use 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 mainly from fixed-speed wind turbines, but also a small collection of measurements from variable speed wind turbines is included.

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. 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, more than 10 models have been tested, including models of both fixed-speed and variable-speed wind turbines.

A topic of high interest is the ability of wind turbines to ride through temporary grid faults. If they can ride through faults they will contribute 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 will continue in 2007, and a Committee Draft for Voting of IEC

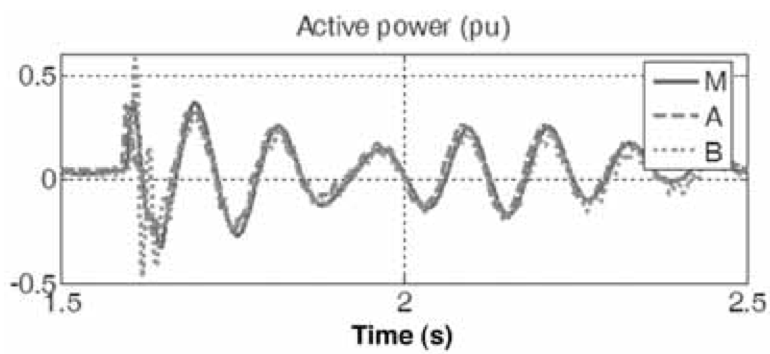


Figure 1 Time-series plot of measured and simulated active power output from a fixed-speed, stall-controlled wind turbine with squirrel-cage induction generator during a voltage dip on the grid. M is measurement, A and B are simulations.

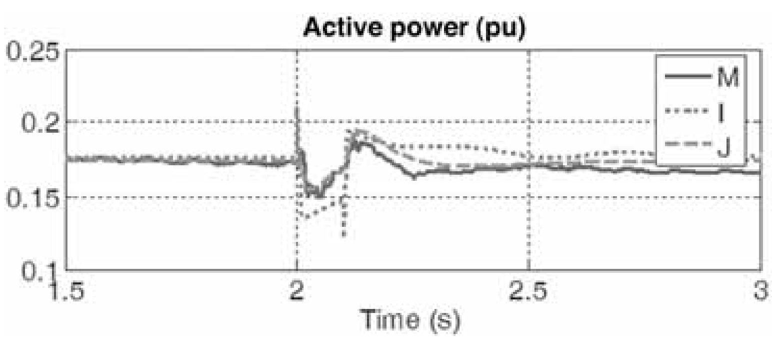


Figure 2 Time-series plot of measured and simulated active power output from a variable speed wind turbine with doubly-fed induction generator during a voltage dip on the grid. M is measurement, I and J are simulations.

61400-21, ed. 2 was prepared at the end of 2006. Hence, in the future, wind turbine manufacturers may refer to standard test certificates for demonstrating performance under grid transients. 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.

Additional information about Task 21 can be found on the Internet at http://www.energy.sintef.no/wind/IEA.asp.

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Offshore Wind Energy Technology Development

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 tend to blow faster and smoother at sea than on land yielding more electricity generation per square meter of swept rotor area. On shore, larger 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 relative shorter transmission lines, yet far enough away to reduce visual and noise impacts.

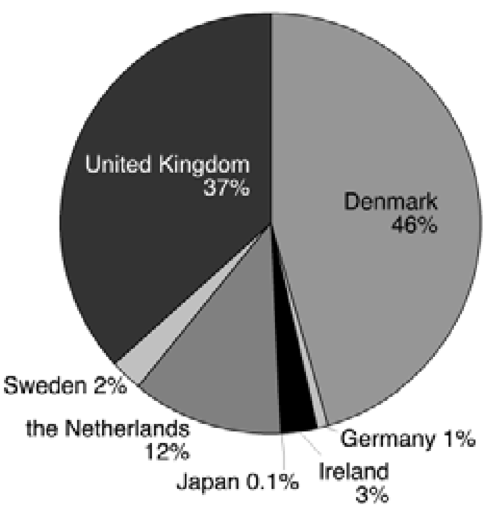


Figure 1 Offshore wind projects installed through 2006, based on a total of 927 MW

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 2006, there were 927 MW of offshore wind power operating in Denmark, Germany, Ireland, Japan, the Netherlands, Sweden, and United Kingdom. Figure 1 shows how the current capacity is distributed among the European countries. China, Finland, Germany, Italy, Norway, Republic of Korea, Spain, and the United States all have plans to install their first offshore wind farms within this decade.

Challenges for offshore development include higher initial investment costs for large machines, 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. In Europe, the space available for offshore wind turbines in many countries is larger than 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.

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 March 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 Denmark, Finland, the Netherlands, UK, and the US.

In addition to challenges relevant to all offshore development, it became clear that some nations with long coastlines but without shallow seas within their continental shelf were interested in exploring technology relating to installing wind turbines in deeper water. EU countries such as Ireland, Italy, Portugal, and Spain have a relatively small sea area with water depths less than 30 m. Countries outside the EU like Brazil, China, Japan, and the United States also have high potential for wind power development in deeper waters.

In October 2003, and again in October 2004, workshops on deep-water technologies were held in Washington, D.C. with participants from the US, Europe, and Asia (See: http://www.nrel.gov/wind_meetings/offshore_wind/). It was clear from these workshops that opening vast windy areas of deep-water ocean for electric power generation will require development of new technologies and strategies. Work is underway in many countries to address the many issues surrounding wind development offshore. Both of these meetings on aspects of offshore development recommended the IEA Wind Implementing Agreement as a framework for sharing information on these activities.

In May 2004, the IEA Wind ExCo approved Annex 23 to the Implementing Agreement, as a framework for holding focused workshops and developing research tasks directed at understanding issues and developing technologies to advance the development of wind energy systems offshore.

The task activities are now underway and eight countries have joined as shown in Table 1. Several additional countries are still considering joining. Each country may have several participating organizations for a single membership fee; more participating organizations will lead to more robust results. It is the responsibility of each country to determine how the cost of membership is distributed among the individual organizations.

Table 1 Participating countries and organizations in Task 23

Country	Membership Status/ Contracting Party	Organization
Denmark (OA)	Committed/RISØ National Laboratory	• RISØ National Laboratory • Vestas • Siemens • Elsam •Carl Bro • DNV
Germany	Committed/Ministry for Environment, Nature Concervation and Nuclear Safety.	• University of Stuttgart • GE Energy • GL Windenergie
Netherlands	Commitment/Wea@sea	• Wea@sea • ECN
Norway	Committed/Enova SF	• NTNU-BAT
Republic of Korea	Commitment/	• KEMCO
Sweden	Commitment/Chalmers	• Chalmers
United Kingdom	Committed/ Department of Trade and Industry	• Garrad Hassan • Ceasa
United States (OA)	Committed/ US Department of Energy	• NREL • MIT • University of Massachusetts • GE Energy

2.0 Objectives and Strategy

The overall objectives of Task 23 include:

- Conduct R&D activities of common interest to participants to reduce costs and uncertainties
- Identify joint research tasks among interested countries based on the issues identified at the TEM 43 on Critical Issues Regarding Offshore Technology and Deployment
- 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.

This task has been organized as two subtasks with Risø National Laboratory (Risø) in Denmark and the National Renewable Energy Laboratory (NREL) in the United States serving as joint operating agents, each leading one subtask.

Subtask One "Experience with Critical Deployment Issues" is lead by Risø and Subtask Two "Research for Deeper Water" is led by NREL. The Task 23 structure showing the Research Areas with respect to the subtask is shown below in Figure 2.

3.0 Progress In 2006

3.1 Subtask One: Experience with Critical Deployment Issues

The work in subtask one has been divided into three research areas. Workshops have been held for the Research Area 2: Electric System Integration and the Research Area 3: External Conditions, Layouts and Design of Offshore Wind Farms.

3.1.1 Research Area 1: Ecological Issues and Regulations

The first workshop for Research Area 1 Ecological Issues and Regulations was planned to be hosted by the Netherlands sometime in 2006. However, a delay has set back plans to organize workshop and identify activities.

The following basic areas for potential collaboration will be discussed at the first workshop:

- Baseline data and research methods
- Develop methods to share baseline data and research methods for pre- and post-construction studies
- Impacts on the environment (assessment criteria)
- Summarize preliminary conclusions from environmental impact assessments among nations that have offshore facilities. This area is similar to one of the objectives of Concerted action for Offshore wind energy Deployment (COD)
- Evaluate potential cumulative effects to the marine ecology
- Compare methodologies and preliminary conclusions from avian and mammal surveys
- Permitting process
- Evaluate streamlining of planning and approval procedures
- Educate the regulators and facilitate interagency cooperation

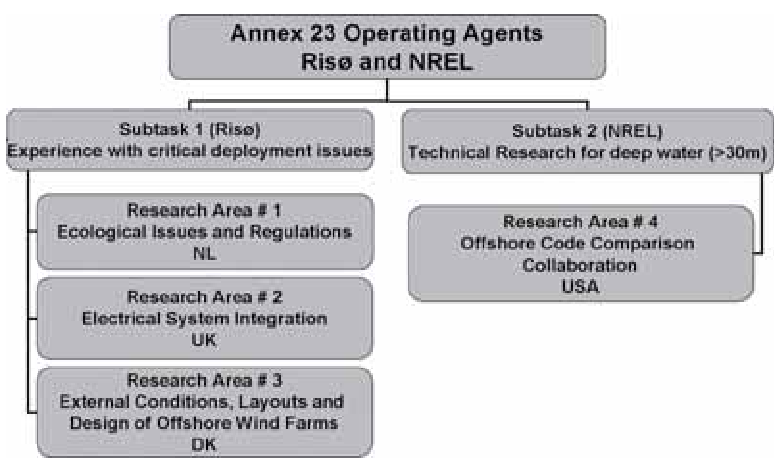


Figure 2 Annex XXIII organizational flow chart

• Pre- and post-construction monitoring of operating wind facilities
• Public (stakeholder) involvement and acceptance
• Decommissioning processes and procedures.

3.1.2 Research Area 2: Electric System Integration

At the first workshop at Manchester University, UK on 12–13 September 2005 it was decided to focus the work program on five issues covering subjects related to connection of Offshore Wind Farms to Onshore Grids. These are:

• Off shore wind meteorology and impact on power fluctuations and wind forecasting
• Behavior and modelling 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 off shore grid systems and enabling technologies.

In 2006, a planning meeting was held at Risø on 16 August and a consensus was reached to organize three meetings: two in 2007 and one in 2008. The five original issues would be work items for the three meetings. However, following the meetings, the need may appear to organize additional workshops and meetings on modified subjects as compared with those in the workshop plan (Table 2).

At the working group meeting, participants specified the national projects that would supply information as part of the IEA Wind Task 23 collaboration (Table3). Initial project data collected show many interesting member country projects that will be included in the collaboration. A format for the survey and data collection is shown below. The projects for collaboration between member countries will continue to be coordinated at the workshops mentioned above.

3.1.3 Research Area 3: External Conditions, Layouts and Design of Offshore Wind Farms

The first workshop for Research Area 3 External Conditions, Layouts and Design of Off shore Wind Farms was held on 12–13 December 2005 at RISØ National Laboratory. The workshop covered the topics #1 and #5 previously defined in the annex text. At the workshop, three important issues were identified to be included in the future work program for External Conditions, Layouts, and Design of Off shore Wind Farms: wake modelling and benchmarking of models; marine boundary layer characteristics; and met-ocean data and loads.

Regarding wake modelling and benchmarking of models several activities took place in 2006 and are planned for 2007. A workshop held at the Danish Test Station for large wind turbines, Høvsøre and Billund in Jutland, Denmark indicated a great need for further collaboration and exchange of data to develop and verify computational models and to understand the physics of wakes and meteorological backgrounds. The EU R&D project UPWIND includes similar activities and coordination activities will take place between the members of IEA Wind Task 23 and partners of UPWIND. A format has been agreed to for collecting and benchmarking data related to offshore wind farms and onshore farms in cases when it is considered relevant. The format will be suggested to the participants in the workshop and member countries of Task 23. The collaboration will be focussed on data which are important for power calculations as well as design loads. During 2007, the benchmarking experience

Table 2 Workshop plan - Electrical System Integration

Category (issue)	Work item	Who takes the initiative	Action
I A	Technical architecture	UK	Workshop early 2007
I B	Grid codes		
II A	Offshore meteorology and electrical power	Denmark	Workshop late 2007
II B	Connection and control system		
III	Transient behaviour	Netherlands	Workshop in 2008

Table 3 Collaboration projects: Offshore Wind Farms to Onshore Grids

Project title	Description	Category (issue per Table 1)	Period, value (USD), effort, country
Handling of sudden disconnection of a DFIG wind turbine cluster feeder and its reconnection	Designing a model of a DFIG wind turbine with ride through system; comparing with measurements	III I A	2007-2008 210,000 2½ person-year Sweden
Analysis of wind park high-frequency electrical transients	Modelling of transients in offshore turbine and transmission system	III I A	2007-2008 210,000 2½ person-year Sweden
DC/DC-converters in wind farms	Identifying the most cost effective converter design, construction and test of ea prototype	II B III	2005-2007 210,000 2½ person-year Sweden
Study on the development of the offshore grid for connection of Round II farms	Assessing costs of offshore connection of farms Thames Estuary, Greater Wash, and off coast North West of England	I A	2004-2005 65,000 5 person-month UK
Methodology for the Development of Network Design Standards for Offshore Transmission Networks	Economically efficient offshore networks are designed and proves to be very different to onshore cabling	I B	2006 260,000 20 person-month UK
Grid integration options for offshore wind farms	Analysis of design of offshore grid networks based on a cost-benefit methodology. Radial designs are suggested	I A	2006 25,000 3 person-month UK
Grid codes for offshore grids	Investigation of appropriate grid code requirements offshore, assessment of influences and needs for consistency with onshore networks	I B	2007-2008 130,000 1½ person-year UK
Switching transients and harmonics in offshore networks	Investigation of faults, switching transients and harmonics from long lengths of EHV cable offshore	III	2008 130,000 1½ person-year UK
Power fluctuations of large offshore wind farms	Development of simulation models for offshore wind farms as a planning tool for calculating the regulating power and ramp capability necessary in the grid system	II A	2005-2007 525,000 3 person-year Denmark
Meso-scale meteorology	Providing improved predictability of short term power variations due to local wind speed variability (time and spatial scales 10-30 minutes and 2-20 km, respectively	II A	2007-2010 395,000 2½ person-year Denmark

and the results obtained from the continued collaboration, also with UPWIND, will be analysed and discussed at a second workshop planned for the fall of 2007.

Regarding marine boundary layer characteristics and met-ocean data and loads, Task 23 collaborated with Task 11 to plan a topical expert meeting (TEM) for January 2007. The meeting will concern 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. Another Task 23 meeting will be held in Berlin in February 2007 together with a German Offshore Conference and the EU policy seminar on offshore wind.

For Research Area 3, work programs will include the following activities. For wake modelling and benchmarking of models, a second workshop will be organized late in 2007 focusing on power calculations and design tools. Also, a format will be developed for collecting and benchmarking offshore data and a format will be developed for onshore data when judged necessary. For marine boundary layer characteristics and met-ocean data and loads, new collaboration initiatives will be taken. A significant research area dealing with operation and maintenance issues offshore was also considered as a high priority topic but a workshop for this area has not yet been planned.

3.2 Subtask Two: Research for Deeper Water

Subtask 2 was oritinally intended to focus on technical issues associated with deeper water implimentation of offshore wind energy. To maximize the benefit to the research community and to take advantage of experience with current turbine modeling efforts in shallow water, it was decided to include both shallow and deepwater modeling in the subtask. Uncertainties associated with load prediction increase the risk for offshore machines, and the development of accurate dynamic models for load prediction is the best way to reduce these uncertainties. Participants have compared assumptions, model fidelity, and the results of model outputs for controlled cases determined by the group. Through this type of rigorous sharing and subsequent validation efforts, offshore researchers will accelerate the development of codes for modeling a wide range of offshore wind turbine systems.

This task 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 Collaboration (OC^3). The group is led by researchers at NREL's National Wind Technology Center in the United States.

This group is focused on benchmarking structural dynamics models used for estimating offshore dynamic loads. Because this effort requires intense collaboration, periodic Internet meetings have been established as the main form of collaboration with several fac-to-face meetings scheduled at key points in the project. To help with exchanging information, an IEA web site has been set up for the subtask (http://www.ieawind.org/Annex%20XXIII/Subtask2.html). A complete project plan can be found on this web site. Parts of this website are only available to members.

Currently conservative offshore design practices adopted from marine industries are enabling offshore development to proceed, but if offshore wind energy is to be economical, 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. Thus the OC^3 group has identified the following objectives.

- Identify and verify model capabilities and limitations
- Establish confidence in predictive capabilities
- Establish analysis methodologies
- Identify areas needing further research and testing

This project should 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, Japan, Norway, the Republic of Korea, 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. The scope includes:

- Water Depth: 5 m to greater than 200 m
- 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, and controls.

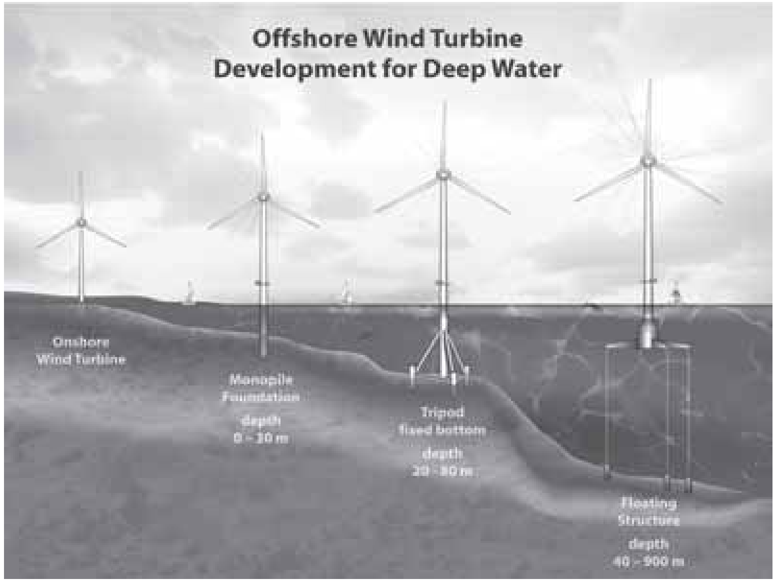


Figure 3 Strategies for offshore wind installation on land and in various water depths

A multiphase project has been outlined in a project work plan. The first phase would be strictly analytical with the goal of verifying the analytical capabilities and differences of the codes of the participants. The second and third phases would compare codes with various support structures and foundation models respectively.

3.2.1 Project Status

- There have been five face-to-face meetings: Denmark 1/05, Trondheim 6/05, Denmark 10/05, Pittsburg 6/06, and Stuttgart 1/07.
- There have been multiple Internet meetings. These net meetings continue to be productive and significantly reduce the need for travel.
- All participants have completed and tested their baseline turbine models.
- Wave and turbulence inputs have been run.
- Foundation models have been defined and modeled.
- Dynamic response comparisons for full wave loading on a monopile support structure is complete.
- Foundation models have been compared under wave/turbulence dynamic loading.
- Tripod support structure modeling and comparisons have begun and should be complete by June 2007.
- The United States has completed preliminary modeling of a floating platform under dynamic wave and turbulence loading.
- Floating platform modeling is scheduled for completion by fall of 2007.

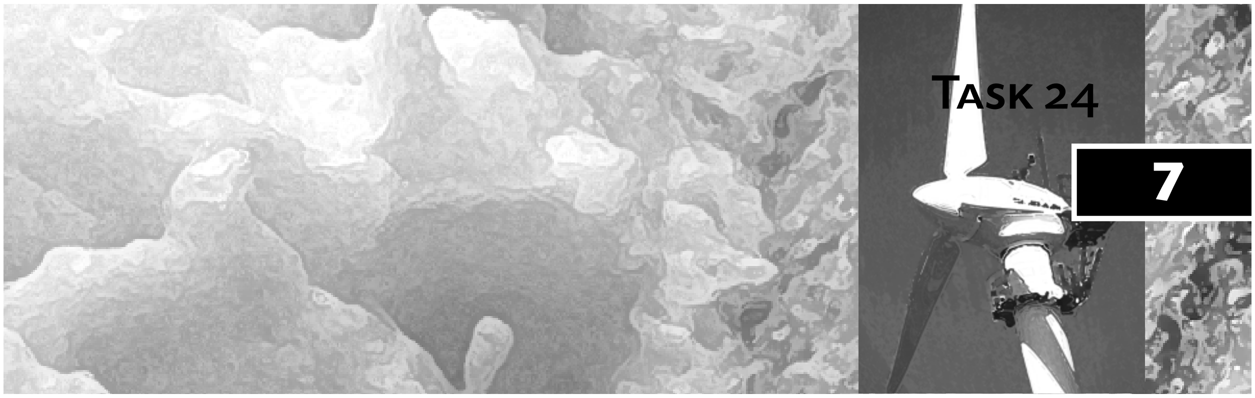
3.2.2 Early Benefits

The OC3 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 Work Package calls for the development of a reference turbine as well as procedures for verifying models and codes. OC3 has provided a basis for both of these goals.

4.0 Plans For 2007 And Beyond

Task 23 will continue for four years beginning October 2005. The plans for 2007 within each area are described above. The task may be extended for such additional periods as determined by two or more participants, with approval from the ExCo.

Authors: Jørgen Lemming, Risø National Laboratory, Denmark and Walter Musial and Sandy Butterfield, NREL, United States.



Integration of Wind and Hydropower Systems

1.0 Introduction

Within IEA Wind member countries, there is about 450 GW of hydropower capacity and approximately 62 GW of wind power capacity. Several of the member countries are pursuing integrating these two renewable resources for the benefit of consumers and the electrical generation system. Attendees at an IEA Wind Topical Experts Meeting in 2003 expressed the desire for conducting cooperative research on the integration of wind and hydropower technologies under the auspices of the IEA Wind agreement. In response, a proposal for Task 24 Integration of Wind and Hydropower Systems was approved by the ExCo in May 2004. This cooperative research effort, which will operate for four years, ending in May 2008, offers participating organizations 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, the IEA Wind Task 24 works in cooperation with the IEA Hydropower Implementing Agreement, which is investigating integration of hydropower and wind through a complementary set of investigations.

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
- To document case studies pertaining to wind and hydropower integration, and create an Internet report library.

The outcomes of the work conducted under Task 24 include:

- The identification of practical wind/hydro system configurations
- A consistent method of studying the technical and economic feasibility of integrating wind and hydropower systems
- 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

Table 1 Task 24 Member Countries, Contracting Parties, and Participants		
Country	Contracting Party	Participant
Australia	Australia Wind Energy Assoc.	Hydro Tasmania
Canada	Natural Resources Canada	Natural Resources Canada Manitoba Hydro
Finland	TEKES National Technology Agency in Finland	VTT Processes
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 GE Global Research Sacramento Municipal Utility District

• A database of reports describing case studies and wind-hydro system analyses conducted through cooperative research of the Annex.

2.0 Research Activities

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 topics, some studies may only address and share information related to one. 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, and balancing areas, 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 annex is planning to contribute at least one case study. Participants of the task are contributing a wide variety of case studies, 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. There is also a wide variety of hydropower facilities, with some being essentially run-of-the-river 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 Hydrologic 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 integrating with wind power. Thus, study of the impacts of wind integration on hydropower facilities and hydrological 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 hydrological 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. It is worth noting that 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 hydrologic impact studies may demonstrate the technical feasibility of integrating wind and hydropower systems, implementation will depend on the economic feasibility of a given project. Such economic feasibility will depend on the type of electricity market for which the wind-hydro integration project is 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 the key factors driving the 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 to the electricity customer during low-hydro years and extended droughts may also be investigated. 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

Simplified methods for approximating the amount of wind power that can be physically or economically integrated with existing hydropower generation should be devised based on the characteristics of the local transmission control area loads, hydropower facilities, and the wind power resource. 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. Four of the participating countries expect to contribute to the simplified modeling (Australia, Finland, 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 control area along with "surrounding" issues.

3.0 Status And Plans

By the end of 2006, three meetings of the Task participants had been held. The first was a kickoff meeting, held in February 2005, at Hoover Dam near Boulder City, Nevada, United States. At this meeting, the general work plan for participating countries was defined. The first R&D Meeting was held in conjunction with the IEA Wind ExCo 56 meeting in Lucerne, Switzerland, in September

2005. Several participants reported on their case studies. The work of the task over these first two years was focused on initiating participant case studies and finding how best to collaborate.

In defining how to best collaborate, it was seen early that due to the differences in terminology and techniques inherent in an international collaboration, that 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 coming during 2006.

In 2006, two 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. The purpose of this meeting was to discuss the matrix and details of the upcoming R&D meeting #2.

R&D meeting #2 was held 25–26 September 2006, in Launceston, Tasmania (Figure 2). Excellent progress was reported on all case studies. In learning of the progress on these projects, 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. Another key outcome of the meeting was the enhancement of the expected results of Task 24. 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 annex was defined. Focused working groups will create content for each section of the report, roughly corresponding with the case study categories listed above.

A final "working" version of the matrix was adopted at the end of 2006. Each task participant

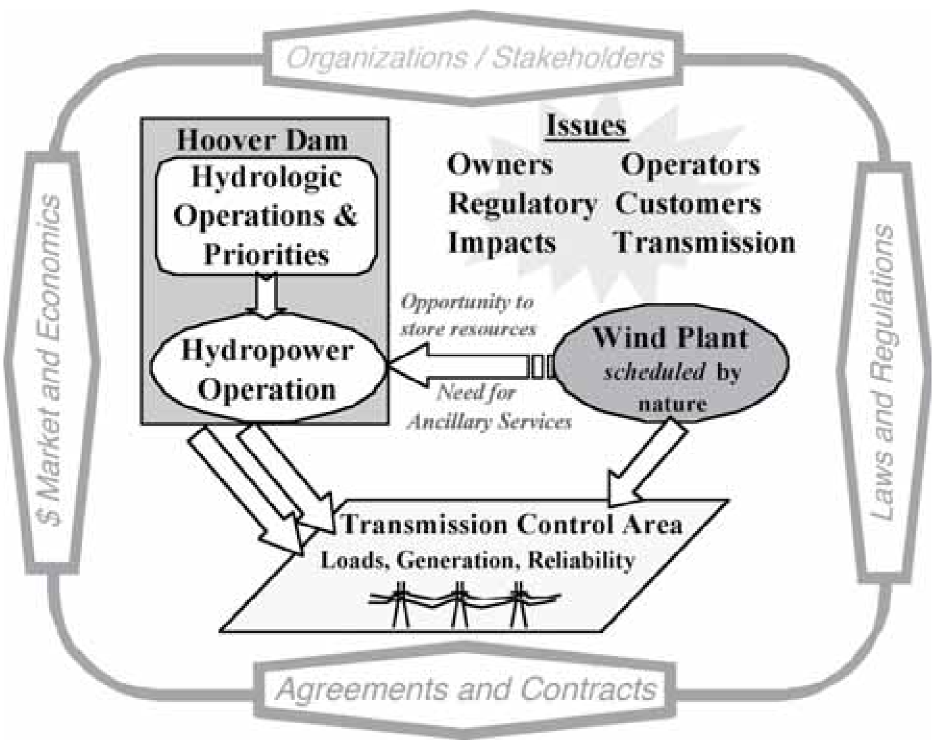


Figure 1 A conceptual view of the relationships between wind power, hydropower, and the transmission control area, and the issues surrounding their integration


Figure 2 Photograph of meeting attendees at the Task 24 R&D Meeting #2 in Lanceston, Tasmania

will complete a version of the matrix to describe their case study projects, with submission due in early 2007. This will then facilitate comparing and reporting the results. It is anticipated that the final report of the task will be completed in the summer of 2008.

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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 of wind power 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 in many countries investigating the power system impacts of wind power. However, the results on the costs of integration differ substantially and com-

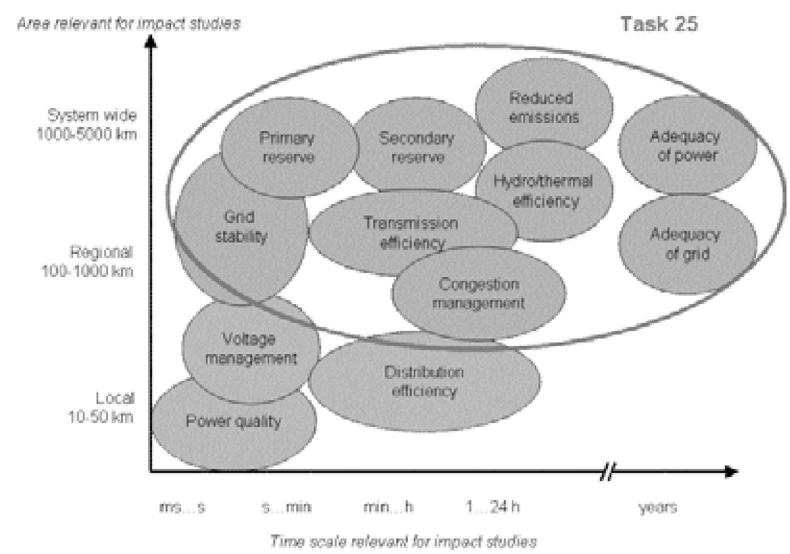

Figure 1 Impacts of wind power on power systems, divided in different time scales and width of area relevant for the studies. Primary reserve is here denoted for reserves activated in seconds (frequency activated reserve; regulation) and Secondary reserve for reserves activated in 5–15 minutes (minute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

parisons are difficult to make due to using different methodology, data and tools, as well as terminology and metrics in representing the results. Estimating the cost of impacts can be too conservative 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 related to these issues.

2.0 Objectives and Strategy

The ultimate objective is to provide information to facilitate the highest economically feasible wind energy 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. The Task 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 other R&D Task work.

The participants will collect and share information on the experience gained and the studies made up to and during the task. The 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 the 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 has started with a state-of-the-art report collecting the knowledge and results so far. The task will end with developing 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.

The 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 countries that have officially committed in 2006. Spain, France, and Australia are still considering participating in the task.

3.0 Progress in 2006

The meetings organised by Task 25 have established an international forum for exchange of knowledge and experiences. In the three meetings organised in 2006, all countries have presented the national results so far and the work on-going and also the first report gathering the results has been discussed. Two meetings have been organised in conjunction with wind integration workshops: Nordic Wind Power Conference in May in Finland and

Table 1 Countries that have joined Task 25 of IEA Wind

Country	Institution
Denmark	Risø National Laboratories; Energinet.dk
EWEA	European Wind Energy Associations
Finland	VTT Technical Research Centre of Finland
Germany	ISET; RWE; E.ON Netz
Ireland	To be confirmed
Netherlands	ECN
Norway	SINTEF; Statkraft
Portugal	INETI; REN
Sweden	KTH
UK	Centre for Distributed Generation & Sustainable Electrical Energy
United States	NREL; UWIG

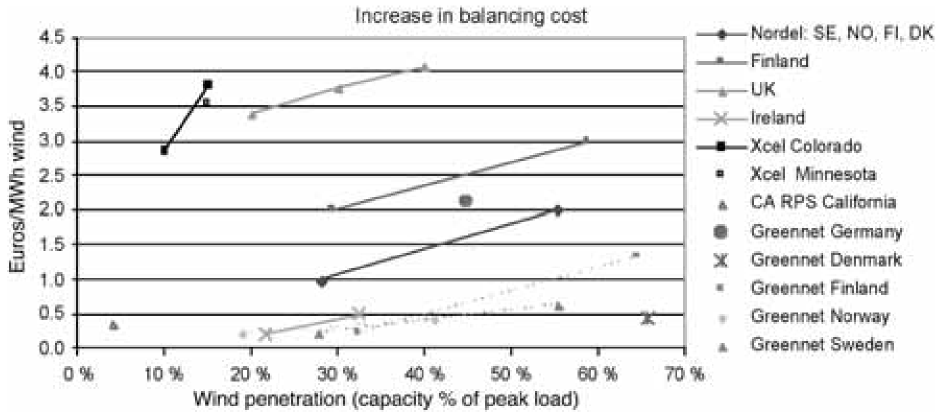

Figure 2 Results from estimates for the increase in balancing and operating costs due to wind power. The currency conversion used here is 1 € = 0.7 £ and 1 € = 1.3 USD.

Utility Wind Integration Group UWIG fall workshop in Oklahoma City, United States. The system operators of Denmark, Germany, Ireland, and Portugal have joined the meetings. Also the TSO organisations CIGRE and ETSO have been contacted and informed of Task 25 work. In addition to Task 25 overall presentations, case studies from Denmark, Finland, Norway, Portugal, Sweden, and the United States were presented in special sessions for Task 25 in NWPC and in UWIG conferences.

The Task 25 web site has been opened at www.ieawind.org gathering the Task 25 publications as well as literature related to system integration.

A poster outlining the task objectives and strategy was presented in EWEC'06 conference, March 2006 and Nordic Wind Power Conference NWPC in May, 2006.

A paper collecting experience on wind integration issues was presented in NWPC, with experience from Denmark, Germany, and Sweden. It was further expanded to a journal article with added experience reported from Ireland and New Mexico in the United States and was submitted to IEEE Transactions on Energy Conversion.

Work on the state-of-the art report started in spring 2006, analysing the existing results. This report was the main subject of the two R&D meetings in Helsinki and Oklahoma City. A draft version of the state-of-the art report was distributed to participants in December 2006.

The first results were presented at the Global Wind Power Conference GWPC2006 18–22 September 2006 and at the fall seminars on wind integration: UWIG seminar 24–25 October, Delft workshop for offshore and large scale integration 25 October and EWEA Grid Conference 7–8 November 2006.

Drawing from the first results of Task 23, Figure 2 illustrates the difficulties in comparing the results from existing studies. The range for integration costs due to increased balancing needs is large. This is due to different power systems in question, different time scales for reserve allocation, and different methodologies applied in the studies.

4.0 Plans for 2007 and beyond

The second year, 2007, will see the publication of the state-of-the-art report in the spring. It has been agreed with EWEA that a special session for Task 25 will be made for EWEC'2007 in Milan. National case studies will be worked on; more results will be collected, and work with analysing the results will be continued. The library in the web pages of Task 25 will be complemented and updated. Journal articles from some of the issues in the state-of-the-art report will be written.

The spring meeting will take place in May in Milan in conjunction with EWEC'2007. A joint meeting with Task 24 Integration of Wind and Hydropower Systems has been suggested for Norway in fall 2007.

The results will be drawn together during the last year, 2008. 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.

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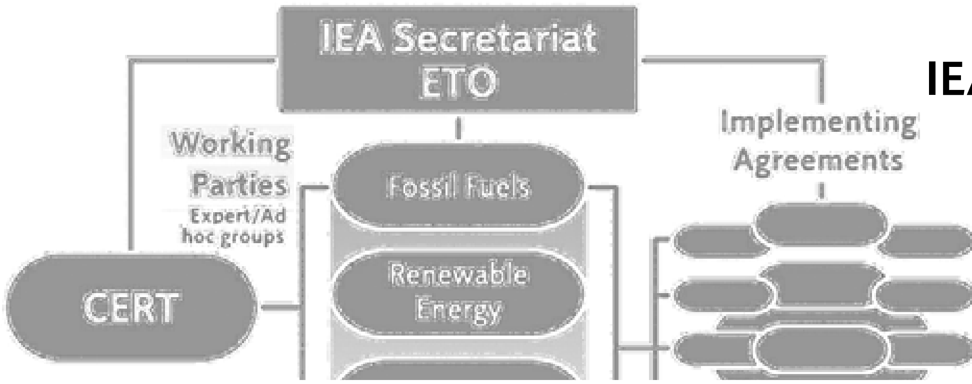

1.0 Global Renewable Energy Markets and Policies

Because of their heavy non-commercial biomass use, non-OECD regions emerge as the main renewables users, accounting for 78.2% of world total primary energy supply (TPES). On the other hand, OECD countries supply only 21.8% of world renewables while consuming 49.8% of world TPES. However, when looking at "new" renewables, OECD countries account for most of the production, producing 86.3% of wind, solar, and tidal energy in 2004.

The principal constraint in advancing renewable energy over the last few decades has been cost-effectiveness. With the exception of large hydropower, combustible biomass (for heat) and larger geothermal projects (>30 MWe), the average costs of renewable energy are generally not competitive with wholesale electricity and fossil fuel prices. On the other hand, several renewable energy options for specific, small-scale applications can now compete in the marketplace, including hot water from solar collectors and electricity from small hydro and other technologies.

Renewables accounted for almost 18% of global electricity production in 2004, after coal (40%) and natural gas (close to 20%), but ahead of nuclear (16%), and oil (7%) and non-renewable wastes. Almost 90% of electricity generated from renewables comes from hydropower plants while close to 6% comes from combustible renewables and waste. Geothermal, solar and wind have now reached 4.5% of renewable generation.

The IEA has continued to work on the identification and inventory of existing national policies and measures related to renewable energy. In 2006, the IEA expanded its Global Renewable Energy Policies and Measures Database to include policy and statistical information on 78 countries. The database is freely accessible online at http://renewables.iea.org. Visitors can search for information according to country, policy instrument, renewable energy technology, renewable energy target, and other criteria. (Figure 1)

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.

The database distinguishes among 24 specific policy types. It has now developed to the extent that some low-level analysis of findings can be carried out. Before a technology is deployed in a given country's energy portfolio, extensive research and development is usually carried out to prove the technology and if necessary to adapt it to the country's needs and the resources it has available. The corollary of this is that research and development policies are among the first to appear in a policy portfolio. Not every country implements such policies however as, after an initial period, the technology need not be developed 'from scratch' but can simply be imported.

Investment incentives appear subsequently as technologies leave the fundamental research phase, and prototypes are deployed, followed by the first operational plant. Tax measures and incentive tariffs represent additional methods of encouraging development. In more recent years quota systems have become common, and most recently, tradable certificates.

2.0 Grid integration of renewables

As part of the Gleneagles Plan of Action (GPOA) the IEA has embarked on a comprehensive program of work to identify best practice and policy options for working towards a "clean, clever, competitive, energy future.

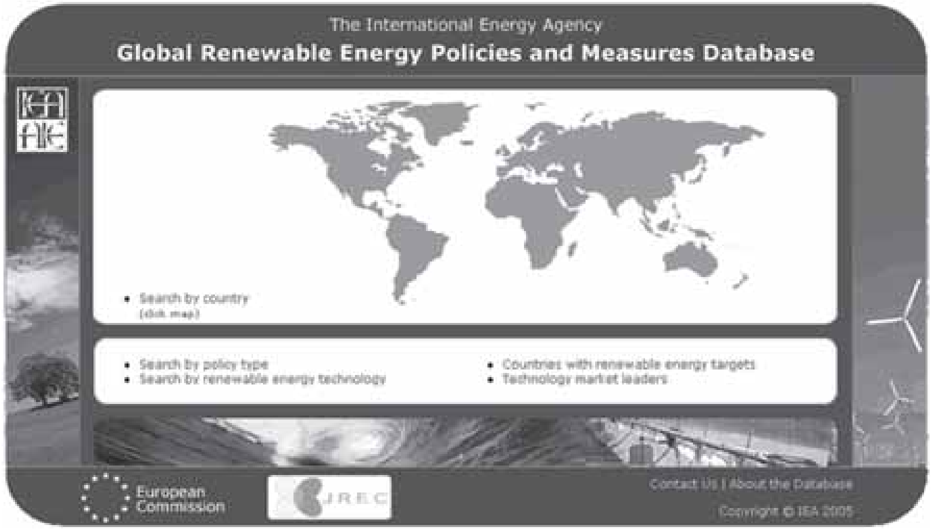

Figure 1 A screen view of the Global Renewable Energy Policies and Measures Database.

The GPOA has the following major programmatic elements:

- Launched a Dialogue on Climate Change, Clean Energy, and Sustainable Development with advice on strategies from the IEA and World Bank
- Transforming the way we use energy: appliances, buildings, indicators, industry, and surface transport
- Cleaner fossil fuels: activities in support of cleaner coal and carbon capture and storage
- Renewable Energy: activities to improve integration of renewables into electricity grids
- Electricity Grids: role of technology in electricity grids
- Promoting networks for research and development: activities to support enhanced R&D cooperation.

The IEA Secretariat will organize two topical workshops in 2007 to discuss the role of renewables in liberalized electricity markets. The workshops will be aimed at evaluating and promoting means to overcome technical, regulatory, and commercial barriers. The outcomes may be incorporated into a publication on grid integration of renewables. This work may draw together all the findings of research and workshops into a report on the challenges of integrating renewable energy sources into networks and optimizing the efficiency of grids.

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Renewables in Global Energy Supply – An IEA Fact Sheet, IEA/OECD, Paris, January 2007

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

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Australia

10

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. The growth of the industry in the period 2003–2005 demonstrated this potential and how quickly it can be tapped when investment conditions are right.

A stable and growing economy, established finance sector, strong manufacturing sector, and increasing demand for energy add to the attractiveness of Australia as a base for businesses related to wind energy. About one thousand Australians are currently employed by the industry.

At the end of 2006, the total installed capacity was 817 MW, after a somewhat disappointing year during which just 109.2 MW was installed (Figure 1). However, developments in the second half of 2006 created renewed enthusiasm and confidence, to the extent that projects totaling more than 1,500 MW either received final planning approval or were confirmed for construction.

For operators already established in Australia, capacity factors above 35% are commonly achieved. At least one wind farm recorded an average capacity factor of about 50%. Wind farming is becoming an increasingly attractive option for many landholders as Australia endures one of the worst droughts in recorded history and farm incomes become less dependable each year.

Opinion polling carried out in October 2006 on behalf of Auswind by A. C. Nielsen showed overwhelming acceptance of wind energy by the broader Australian community. Key findings included the following:

- Nine out of 10 Australians are aware of climate change and concerned about environmental issues.
- Seventy-eight percent say Australia should be a world leader in greenhouse gas reduction.
- Nearly three out of four Australians recognize coal-fired power stations as a major contributor to climate change.
- Three out of four believe the federal government should do more to support wind energy to reduce carbon emissions.
- Sixty-eight percent are willing to pay more for environmentally friendly energy sources.
- Just 6% say any form of electricity is acceptable as long as the waste can be buried.

2.0 Progress toward national objectives

2.1 Industry growth in 2006

For the Australian wind energy industry, 2006 was a year of consolidation following advances made during the previous three to four years thanks to the boost provided by the federal government's Mandatory Renewable Energy Target (MRET) scheme. With MRET all but reaching its target of

Table 1 Key Statistics 2006: Australia	
Total installed wind generation	817 MW
New wind generation installed	109.2 MW
Total electrical output from wind	2.505 TWh
Wind generation as % of national electric demand	1.2%
Target:	The Mandatory Renewable Energy Target, 9,500 GWh from renewables by 2010, has been met. New targets introduced by state governments:Victoria - 10% by 2016 New South Wales - 10% by 2010, 15% by 2020

9,500 GWh of renewable energy four years before its target date of 2010, the industry experienced a considerable slowdown. Attention was largely focused on preparing new projects for implementation once the investment outlook improved. This is precisely what happened in the second half of the year thanks to the announcement of several state-based schemes (see Section 4 below), which sparked an almost unprecedented rush of project approvals and commencements.

After the addition of 328 MW of capacity in 2005, just 109.2 MW was added in 2006. However, capacity is expected to increase sharply in the coming years, with at least 163 MW predicted to come online in 2007 and considerably higher numbers in the years heading toward 2010.

Figures in January 2007 show the Australian wind energy industry offsetting 3.26 million tonnes of CO_2 per year (Figure 2), the equivalent of taking 752,000 cars off the road or planting 4.86 million trees.

2.2 Progress toward national global targets

Australia is a party to the United Nations Framework Convention on Climate Change. However, the federal government's consistent position is that it would not ratify the Kyoto Protocol as long as the major emerging economies were not included and adherence to its dictates would act against Australia's economic interests. Despite this stance, the government has maintained a position that it would meet the Kyoto target of 108% of 1990 emissions over the period 2008–2012. The latest projections were released late in 2006 in a report titled "Tracking to the Kyoto Target" (www.greenhouse.gov.au/projections). The report forecasts Australia's emissions to be 109% of 1990 levels by 2008–2012.

When the report was released, Senator Ian Campbell, who was environment minister said: "Australia is experiencing strong economic and employment growth and has a booming resources sector. This in turn means emissions levels go up." Unfortunately, this has also been coupled with an overall reduction in the proportion of Australia's power supplies coming from renewable sources over the past two decades. This latest projection of emissions is lower than the projection of 110% released in 2003. However, the decreases measured so far have largely been achieved by reductions in land clearing rather than by reductions in emissions in other areas of the economy.

The Australian government has committed itself to:

- Playing a role in the Asia-Pacific Partnership for Clean Development and Climate (AP6)
- A fund of 500 million AUD to support low-emissions technology largely focused on carbon capture and storage
- Plans to build the word's biggest solar power station in northwestern Victoria

2.3 Task Group on Emissions Trading

On 10 December 2006, the prime minister announced the establishment of a joint government-

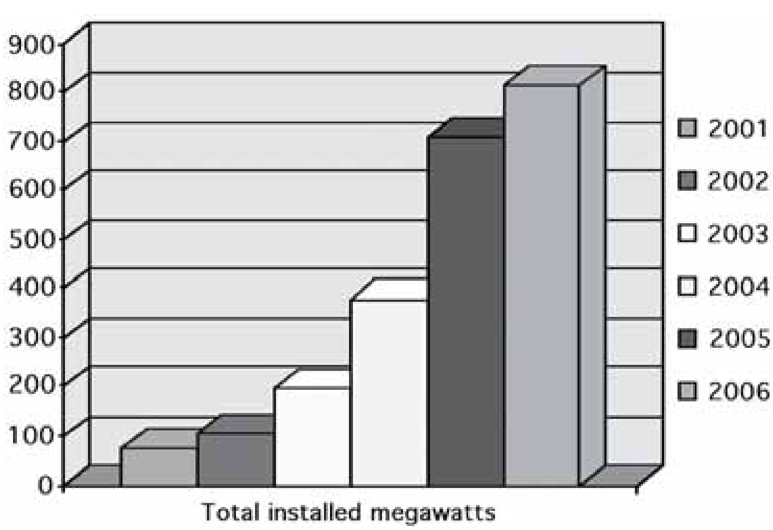


Figure 1 Australian wind energy capacity: Cumulative growth 2001–2006.

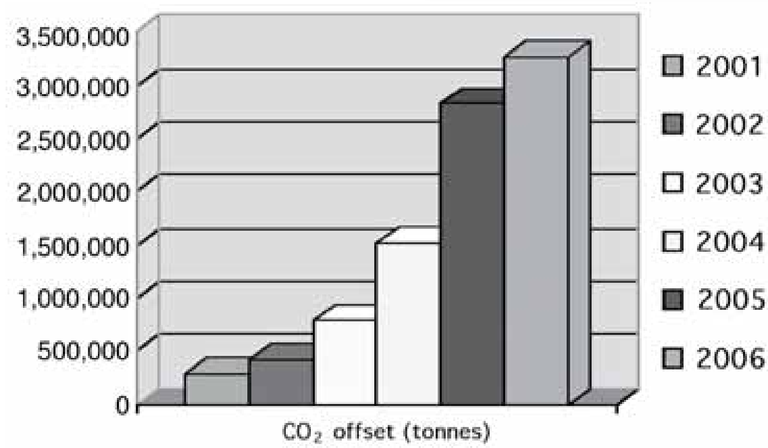


Figure 2 Cumulative tons of CO_2 offset by Australian wind energy production: 2001–2006.

business Task Group on Emissions Trading, to report by 31 May 2007. The task group is primarily made up of representatives of large energy-consuming corporations, wholesale energy producers, and senior public servants. The terms of reference are as follows:

> Australia enjoys major competitive advantages through the possession of large reserves of fossil fuels and uranium. In assessing Australia's further contribution to reducing greenhouse gas emissions, these advantages must be preserved.
>
> Against this background the Task Group will be asked to advise on the nature and design of a workable global emissions trading system in which Australia would be able to participate. The Task Group will advise and report on additional steps that might be taken, in Australia, consistent with the goal of establishing such a system.

The task group will be seeking contributions from stakeholders and will provide a response to the prime minister by 31 May 2007.

The wind energy industry views this review as important but also warns against total reliance on an emissions-trading-only response to achieve emission reduction. To transform Australia's stationary energy sector to make clean energy technology available to the economy, implementing additional measures that immediately commence the greater deployment of zero emission energy technology is critical. So too is the need to ensure that policy deliberations are also focused on mature clean energy technologies that are available today.

3.0 Benefits to national economy

3.1 Market characteristics

With the lapsing of the major national incentive scheme for the establishment of new renewable energy projects (MRET), output by the Australian wind energy industry has been reduced, but major players are actively readying themselves for improved conditions ahead. This period has tested the patience of some, but it illustrates the robustness of the Australian wind energy industry and its member companies, which are willing to ride out the tough times.

The industry is already making a significant contribution to the Australian economy, particularly in rural and regional locations (Table 2). 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, and some areas are looking to renewable energy generally as a source of future prosperity. A good example is the Ararat Rural City in western Victoria. Already home to the Challicum Hills Wind Farm, it is now looking to establish a renewable energy business precinct, capitalizing on its potential as a manufacturing and transport hub for southeast Australia.

Australia's manufacturing industry experienced significant growth in 2004 and 2005. Despite the closure of the Vestas nacelle assembly plant in Burnie, Tasmania, 2006 was a positive year overall for the manufacturing sector, with strong demand from domestic and external operators.

Manufacturing operations exist in three states: Tasmania, Victoria, and South Australia. Tasmania is home to the turbine tower manufacturer Haywards Engineering. Victoria has a manufacturing plant building wind towers and components (Keppel Prince) and a new blade manufacturing plant, both based in the southwestern coastal town of Portland. South Australia boasts the major steel fabrication company Air-Ride Technologies.

4.0 National incentive programs

The major incentive scheme for the wind energy industry reached its effective conclusion in 2006. The federal government's MRET scheme achieved its target of 9,500 GWh of new renewable generation four years ahead of its original schedule, leaving developers with no active incentive scheme until the states came to the rescue in the second half of 2006.

4.1 State-based incentive programs

The combination of national and state-based incentive schemes have resulted in six states (Figure 3). First Victoria with its VRET scheme (10% of all retail electricity sales to be sourced from renewables by 2016), then New South Wales with its NRET scheme (10% by 2010 and 15% by 2020) gave the industry the kick start it had been waiting for. The major difference between VRET and NRET is that Victoria requires its quota of renewable electricity to be generated within the state, while New South Wales allows generation outside its borders as long as the electricity is consumed within NSW.

Further incentive came from South Australia, already home to almost half of the nation's installed wind energy capacity, with a pledge to source 20% of its power from renewables by 2014. However, at this writing no mechanism has been revealed to achieve this. Starfish Hill wind farm is an example of the installations taking place in South Australia (Figure 4).

Meanwhile, the WARET legislation in Western Australia proposes 8.3% of the state's power to come from renewables by 2010, growing to 20% by 2020. This legislation, introduced by the Greens, has passed the upper house but has not yet achieved a majority in the lower house of parliament.

4.2 National Greenhouse Strategy

The development and growth of the renewable energy industry in Australia is primarily supported by the strategic initiatives that have flowed from the federal government's 1998 National Greenhouse Strategy (NGS), the strategic framework for advancing Australia's domestic response to greenhouse gases. The Australian government, through the Australian Greenhouse Office, delivers the majority of these initiatives under the 1.8 billion AUD climate change strategy. The initiatives include a wide range of measures focusing on the energy, transport, and agricultural sectors. The most

Table 2 Australian wind energy industry 2006: Economic, environmental, and social benefits*

Installed megawatts	817
Average number of Australian households powered by wind energy	347,906
Number of wind energy projects (two or more turbines)	30
Annual greenhouse gas emissions displaced	3,256,399 tonnes CO_2/yr
Equivalent number of cars taken off the road	752,055/yr
Landholder lease payments	2.54 million AUD/yr
Operations and management costs	20.54 million AUD/yr
Total capital investment	1.4 billion AUD
Manufacturing jobs	300
Construction jobs	374
Operations and management jobs	120
Other jobs (project development, engineering, and finance)	175

*All figures are estimates only based on available information obtained by Auswind.

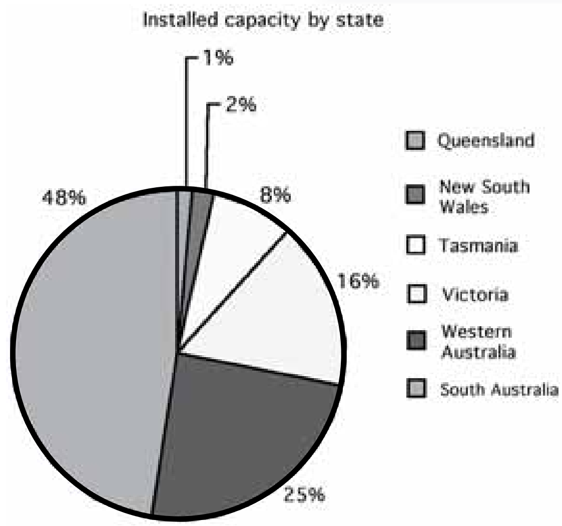


Figure 3 Australian states: installed wind energy capacity 2006.

significant NGS initiative for the renewable energy sector has been the MRET scheme discussed earlier. Other NGS initiatives are outlined in the following sections.

4.3 NGS initiatives

The NGS provides direct support to the renewable energy industry through programs including these:

- The 26.5 million AUD Renewable Energy Equity Fund, which provides venture capital to high-growth and emerging companies commercializing direct or enabling renewable energy technology services.
- The 54 million AUD Renewable Energy Commercialisation Program (RECP), which provides the potential for a strong commercial contribution to the renewable energy industry, with a focus on reducing greenhouse gas emissions.
- The Renewable Energy Showcase, which provides funding and/or promotion of leading-edge technologies that are approaching commercialization.

4.4 White Paper on Energy and the Environment

The federal government's most recent comprehensive response to energy and environmental issues was released in June 2004 and framed within the White Paper on Energy and the Environment, "Securing Australia's Energy Future." The existing MRET (9,500 GWh by 2010–2020) was retained, although the processes associated with its administration and operation were refined.

The white paper included funding for the following support incentives:

- A renewable energy development initiative—100 million AUD over seven years.
- Low emissions technology and abatement—27 million AUD over four years.
- Advanced electricity storage technologies—20 million AUD over four years.
- Wind forecasting capability—14 million AUD.
- Improved electricity grid accessibility through federal and state government relations.

The white paper also included a 500 million AUD Low Emissions Technology Demonstration Fund to support industry-led projects that can reduce the cost of large-scale, low-emission technologies with significant potential for long-term abatement. However, it is anticipated that this fund will be predominantly focused on the fossil-fuel industry.

4.5 Green Power national accreditation program

Renewable energy development is 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

Figure 4 Starfish Hill Wind Farm, South Australia. Photo courtesy of Tarong Energy

commercial customers have contributed to reducing greenhouse gas emissions by buying green power across Australia, resulting in savings of more than 2.5 million tonnes of greenhouse gas emissions.

4.6 Australian Greenhouse Office initiatives

The Australian Greenhouse Office (AGO), established in 1998, remains the principal federal government agency on greenhouse matters. The AGO is providing up to 6 million AUD over four years to foster the industry and guide the development of industry standards. The key AGO programs of benefit to wind energy projects are the Renewable Energy Commercialisation Program, Renewable Energy Industry Development Program, and Renewable Remote Power Generation Program.

5.0 R, D&D activities

5.1 Auswind best practice guidelines

In 2002, Auswind, with funding from the Commonwealth Department of Environment and Heritage, developed best practice guidelines for wind farm developments in Australia. These guidelines document best practice processes from site selection and preparation for development application through construction, operation, and decommissioning at the end of the development's life. A review of the guidelines was undertaken in the second half of 2006 to ensure that they continued to reflect best practice (by benchmarking them against international and national standards) and could support the Auswind Accreditation Scheme (see next section).

5.2 Auswind accreditation scheme

In June 2006, Auswind received funding from AGO's Department of Environment and Heritage to develop an accreditation scheme for the wind energy industry in Australia. This project is now under way. Documentation for the planning phase of a wind farm development has been drafted, and scheme guidelines and specifications are being established.

5.3 Wind Farms and Landscape Values project

The Wind Farms and Landscape Values–National Assessment Methodology project is a joint project of the Australian Council of National Trusts (ACNT) and Auswind. It is funded by the Department of the Environment and Heritage under the Low Emission Technology and Abatement Program. The objective of the project is to provide a sound, transparent, nationally applicable framework for identifying and assessing landscape values, assessing the potential impacts of wind farms on landscape values, and assessing site impact and mitigation and community consultation procedures. This project was born from the recognition that the long-term sustainability of the wind energy industry depends on appropriately sited and sensitively developed wind energy projects.

Stage one of the three-stage Wind Farms and Landscape Values project, the issues paper, was released in June 2005. The paper effectively addresses the complexities associated with wind farm siting issues, largely because it is the result of an extensive consultation process that gives all stakeholders the opportunity to assist in formulating an agreed upon set of national landscape issues for the Australian wind energy industry. More than fifty organizations and many more individuals were consulted in the first stage of the project. This set the scene for stage two, which will involve a series of public meetings and forums throughout Australia during 2007. These meetings will seek the views of the public and relevant organizations as to how a landscape assessment methodology should work.

Funding from the AGO Department of Environment and Heritage will support this process in every Australian state. The goal is an agreed upon set of national landscape methodologies to be adopted by the Australian wind energy industry and promoted by the ACNT.

5.4 Other government R, D&D funding

The federal government's White Paper on Energy and the Environment has devoted significant R&D funding to clean energy technologies through its Low Emissions Technology Development Fund. However, it is anticipated that most of this funding will go toward advancing geosequestration technology for Australia's coal industry. The white paper also included 14 million AUD to improve Australia's wind forecasting capability through research being undertaken within the AGO.

The federal Department of Industry, Science and Resources and the Australian Taxation Office foster renewable energy innovation with a 1.25 AUD tax deduction for every dollar spent on eligible R&D activities.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's premier scientific organization, makes its major contribution to wind energy research through its Wind Energy Research Unit (WERU). The WERU has primarily focused on developing capabilities for regional wind assessment tools and modeling wind flow over complex topography.

There are several additional R&D funding programs in the AGO, the CSIRO, and Australian universities.

5.5 Collaborative links

Auswind continues to be the Australian participant for the International Energy Agency (IEA) Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems. Auswind also has strong ties with the Global Wind Energy Council (GWEC); it presented GWEC's largest international event of 2006 in Adelaide, South Australia, in the form of the Global Windpower 2006 conference and exhibition. With nearly five hundred delegates, almost half of them from outside Australia, Global Windpower 2006 was an overwhelming success. Australia's national wind-power conference, Auswind 2007, is expected to follow on from this success when it is held in September 2007 in Melbourne, Victoria.

Auswind also maintains strong ties with industry associations across the world, particularly in the Asia-Pacific region. The industry's co-operative international relationships strengthen Australia's information and research base. They also provide the Australian industry with best practice examples from more established wind energy industries.

6.0 The next term

6.1. Priorities for industry growth

Auswind has identified several key priorities for supporting progress in the wind energy industry in Australia. The most urgent priority is the binding establishment of a new or extended federal industry development mechanism (or multiple state mechanisms) to increase the market capacity for the deployment of wind energy projects in Australia. Auswind 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.

6.1.1. Industry development mechanisms

The most urgent requirement for further expansion of the wind energy industry in Australia is an increased market for renewable energy projects. Auswind has been working extensively with related organizations, such as the Business Council for Sustainable Energy (BCSE), to develop clean energy policy proposals for consideration by the federal government. At the same time, liaison continues at the state level to ensure that schemes both in place and proposed reflect the realities of the electricity market and create conditions in which the wind energy industry can thrive.

Auswind representatives have also played an active role as official observers of the AP6, providing access to the highest level of decision-making on energy policy in Australia and in the broader Asia-Pacific region. Participating in such forums as an independent and autonomous industry is a significant step forward for the Australian wind energy sector.

6.1.2 Grid integration and market categorization

The Australian energy market is one of the most flexible in the world and could easily adapt to incorporate larger amounts of wind energy. However, some Australian regulatory authorities are requiring wind energy projects to be subject to the same market rules that govern fossil-fueled power stations. To enforce these rules without altering the mechanics of the NEM will unnecessarily reduce the amount of energy that can be delivered from clean energy projects.

6.1.3. Addressing community concerns with wind energy projects

As has been the case in many other countries around the world, wind energy projects in Australia have attracted considerable media attention and vocal community debate. Auswind completed several initiatives in 2005 that address some of the most common concerns associated with wind energy projects in Australia (Section 5). In Australia, wind energy projects come under the jurisdiction of state or local authorities. Most states are now moving toward state government approval for the larger wind energy projects while involving local governments in the consultation process. Victoria, South Australia, and New South Wales have developed extensive planning guidelines for wind energy projects.

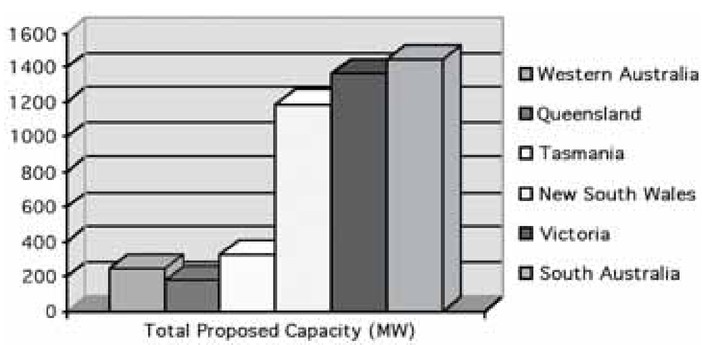
6.2. Australia's development potential

The year 2007 shapes up as a crucial year for Australia's energy sector, with big decisions soon to be made about the structure of the sector in coming decades (Figure 5). The wind energy industry is poised, ready to fill a substantial portion of the nation's future energy requirements. Auswind estimates that, given appropriate policies, Australia's installed wind energy capacity could realistically reach triple its 2006 figure (817 MW) by the end of 2010. The pivotal decisions will be made not at the corporate level, but by government. Auswind is well placed to contribute to and influence these decisions.

A report commissioned by the Australian Greenhouse Office in 2003 found that the NEM is already able to support an installed wind capacity of more than 8,000 MW, provided that the progressive development of wind energy projects is enabled in a dispersed fashion, commercial wind output forecasting is in place, and interstate connectivity continues to be enhanced. This amount of wind energy would equate to approximately 10% of Australia's electricity needs and is attainable without significant wind-specific modifications to existing electrical infrastructure. Given a stronger political commitment to the deployment of clean energy technologies, the future role for wind power in Australia could be even more substantial.

After six years of strong growth, the Australian wind energy industry demonstrated its resilience in 2006, surviving a protracted slowdown. It is now once again preparing to show its full potential thanks to the introduction of policies that encourage the deployment of clean energy technologies. The full extent of this potential should become apparent in the years ahead.

Author: Rob Clancy, Auswind, Australia.



* Includes projects with planning approval but excludes projects undergoing construction

Figure 5 Proposed Australian wind energy projects by state: 2006*

Canada

11

1.0 Introduction

Canada's large landmass, long coastline, and relatively cool air mass combine to provide a wind resource of large potential. Canada has significant potential for wind energy development, and Canadian wind energy has grown exponentially over the past ten years. Canadian wind power had a record year in 2006, with installed wind energy generating capacity growing to 1,460 MW. Several federal and provincial programs, including the recent commitment to a new incentive program for low-impact renewable energy projects, the ecoENERGY for Renewable Power program, are setting the stage for continued growth.

Wind energy in Canada still requires policy, financial, and technical support to make it consistently appealing and competitive with conventional energy sources. Support measures are also needed to stimulate domestic manufacturing and assembly operations.

While current wind capacity represents less than 1% of total capacity at present, 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 ensure the provision of economic incentives for accelerated introduction of new capacity. In January 2007, the federal government announced a new ecoENERGY for Renewable Power program to pursue the efforts that began with the Wind Power Production Incentive program. The new program will permit funding of an additional 3,000 MW of wind capacity by 2011. This program is currently the main driver for future wind energy deployment in Canada. Other levels of government provide support for the development and expansion of the wind energy industry to varying degrees, and installed capacity is set to grow quickly.

By December 2006, a total of 1,460 MW of wind power had been installed in Canada, making it the thirteenth country to reach the 1,000-MW milestone and the twelfth nation in terms of amount of installed wind energy capacity. In 2006, Canadian wind installed capacity was increased by 113% with the addition of 776 MW of installed capacity. (Figure 1)

At 414 MW, Ontario has the highest installed capacity, followed by Alberta at 385 MW and Québec at 322 MW (Figure 2). Although British Co-

Table 1 Key Statistics 2006: Canada	
Total installed wind generation	1,460 MW
New wind generation installed	776 MW
Total electrical output from wind	3.8 TWh*
Wind generation as % of national electric demand	0.7%*
Target:	N/A

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

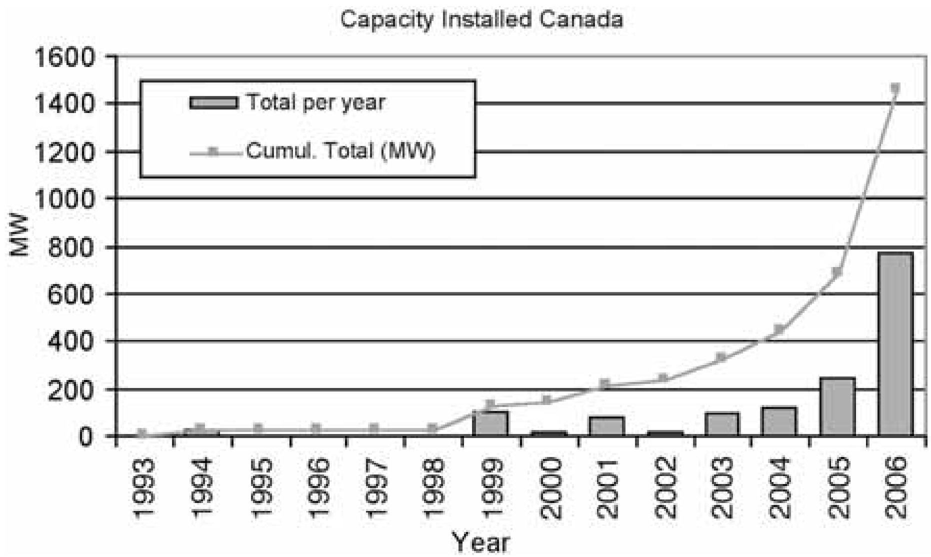


Figure 1 Installed capacity per year in Canada. Source: Natural Resources Canada 2007.

lumbia still does not have any wind capacity, this will change during the next few years, as in 2006 it approved power purchase agreements (PPAs) for 325 MW to be built by 2010.

New installations in 2006 include the Prince Wind Energy Project located near Sault Ste. Marie in northern Ontario. At 189 MW, this is the largest wind farm in Canada. Also in Ontario, the Erie Shores Wind Farm (99 MW), the Kingsbridge Phase 1 Wind Farm (39.6 MW), and the Melanchton Phase 1 Wind Farm (67.5 MW) were commissioned in 2006. In Québec, the Baie-des-Sables Wind Farm (109.5 MW) is the first commissioned installation that was part of the 1,000-MW bid awarded in 2004 by Hydro-Québec. In Saskatchewan, the Centennial Wind Farm was the largest wind farm for part of the year at 150 MW (Figure 3). In Manitoba, the second phase of the St. Leon Wind Farm (84 MW) (Figure 4) was completed in early 2006. In Alberta, the Soderglen Wind Farm (70.5 MW) and the ChinChute Wind Farm (30 MW) were also commissioned at the end of 2006. Finally, several projects representing a total of 15 MW were commissioned in Nova Scotia in late 2006.

2.1 Rates and trends in deployment

Installed wind-power capacity in Canada has experienced an average annual growth rate of 51% over the past five years. Annual growth rates have steadily increased, reaching 113% in 2006 from a low level of 8% growth in 2002. Although 2007 is expected to be a very good year, the uncertainty of the federal incentive for wind during 2006, coupled with the renewal of the production tax credit in the United States and overall competition for equipment, will most probably slow this growth rate. Still, industry experts estimate that more than 500 MW of new capacity will be installed in 2007.

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

2.2 Contribution to national energy demand

In 2005, Canadian national electrical energy generation totalled 551 TWh (Energy Statistics Handbook 2006 File: 57-601-XWE) and was estimated to reach about the same level in 2006. Total installed generation capacity, which includes hydropower, coal, nuclear, natural gas, oil-fired, woodfired, tidal, and wind plants, was projected at 125 GW at the end of 2006. The installed wind capacity was 1,460 MW at the end of 2006, producing an estimated 3,800 GWh of wind energy per year (about 0.7% of total electricity production).

Figure 2 Canada's installed wind capacity. Source: Canadian Wind Energy Association Web site, January 2007.

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 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 baseload 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, in particular visual impacts, noise pollution, and potential effects on wildlife such as birds and bats. Community acceptance of wind projects depend on these challenges being addressed.
- Codes and standards need to be developed for local interconnection and safety issues. These are usually harmonized with inter-

Figure 3 Centennial Wind Farm (150 MW) in Rushlake Creek, Saskatchewan. (Photo Credit: Jimmy Royer 2006)

national standards and should be adapted to ensure Canadian conditions are addressed.

The issue of variability does not 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. 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. However, the lack of grid transmission availability can be a problem in regions where wind resource is promising but grid capacity is inadequate because it is in a remote area or because production capacity has grown faster than anticipated.

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 industry also includes wind resource assessment firms and wind farm developers. As an indication of the level of industrial expertise, CanWEA comprises more than 290 companies involved in wind turbine and component manufacturing, wind energy project development, and other related services.

Figure 4 Vestas NM 82 turbines at the St. Leon Wind Farm, Manitoba. Source: Jimmy Royer 2006.

Currently, the majority of equipment used in Canadian projects is procured outside of the country. The Canadian content of most current and planned projects involves mainly project management, engineering services, and site-related costs. With increasing markets and investments, there is an opportunity to increase Canadian content, particularly for equipment supply. Figure 5 shows the typical distribution of costs for installing a wind farm.

3.2.2 Manufacturing

The Canadian industry mainly comprises of developers backed by large energy firms and industrial corporations that bring with them financial resources and commercial credibility. SaskPower and other leaders such as VisionQuest (TransAlta), Suncor, and Canadian Hydro Developers have significant operations behind them. In addition, heavy hitters have invested in emerging wind independent power producers (IPPs). For example, TransCanada with Cartier Wind Energy Group, Epcor, Nexen, and Brookfield Power purchased Superior Wind Power in 2005. 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. As a result of the Québec RFP process, GE Wind Energy has established facilities in the province to enable 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, and in Matane, Marmen is manufacturing towers and Composites VCI is manufacturing nacelles. Elsewhere, DMI Industries (U.S.) acquired a manufacturing plant in Fort Erie, Ontario, to expand its heavy steel wind tower fabrication operations. As well, AAER has started a blade and tower manufacturing unit in Bromont, Québec. The nascent market also includes a few notable foreign entrants such as Spanish wind Acciona/EHN that has joined with developers Suncor and Enbridge in Alberta. Also, AAER Systems has licensed Fürhlander technology and plans to manufacture in Bromont, Québec.

Canada also has small wind turbine manufacturers, among which are 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, and Atlantic Orient Canada Inc. are offering turbines in the size range of 50 kW to 60 kW.

3.3 Economic details

No fuel costs are associated with wind energy; therefore, capital costs and operating and maintenance costs largely determine generation costs (Figure 5). 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 Prince Edward Island

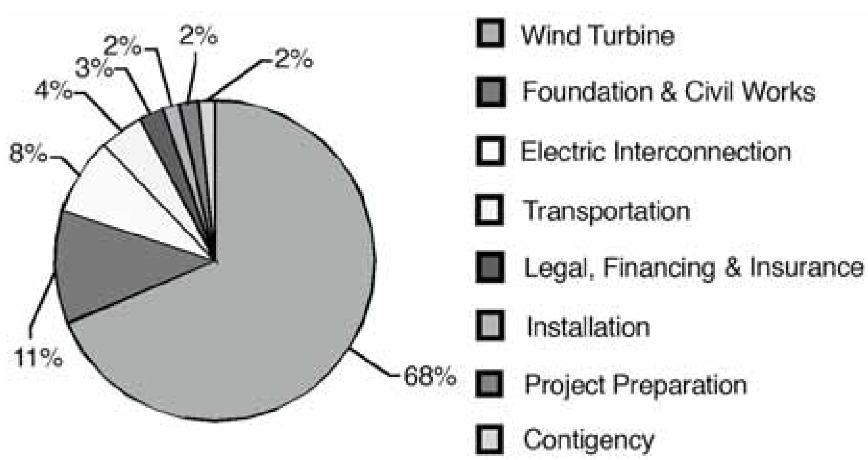


Figure 5 Capital cost breakdown for a typical 30-MW onshore wind farm. Source: NRCan 2007.

resulted in electricity prices from wind energy in the range 0.0775 CAD/kWh to 0.096 CAD/kWh. 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%. 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 CanWEA estimates, Canada's wind energy industry contributed 736 million CAD to the country's gross domestic product in 2005. That same year, there were 1,200 full-time-equivalent jobs in the wind energy industry, an increase of 65% over 2004.

Financing does not constitute a significant barrier as long as wind developers are backed up by long-term PPAs with utilities and benefit from a steady stream of revenue. However, policy stability and long-term incentives are essential for reducing the perceived risk of developing new wind farms.

In Alberta, full retail competition between power generators began on 1 January 2000. This process has allowed wind generators freer access to the electrical grid. In Ontario, a similarly deregulated system commenced on 1 May 2002. However, a few short months later, the provincial government, under political pressure because of rising electricity prices, capped the generation component of the cost to small consumers, effectively freezing the rates for four years. This is viewed as a setback to private generators, some of which have been considering wind power projects. Nevertheless, incentives for renewables, now being finalized, are expected to offset the impacts of the rate cap.

In all other Canadian jurisdictions, the buy-back price is generally set by the local utility and is based on avoided costs.

4.0 National incentive programs

4.1 Main support initiatives and market stimulation incentives

The most influential market stimulation instrument so far has been the federal government's Wind Power Production Incentive (WPPI) program for wind energy developers. Qualifying wind energy facilities receive 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 was intended to help address climate change and improve air quality. Originally slated to build 1,000 MW by 2007, the program has funded a total of 924 MW by the end of 2006. The recently announced ecoENERGY for Renewable Power program will provide the same incentive under similar terms and conditions for an additional 3,000 MW to be built by 2011.

Currently, Class 43.1 of the federal Income Tax Act provides 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. Recently, the tax write-off has been increased from 30% to 50% per year on a declining-balance basis.

As well, the government has legislated the extension of the use of flow-through share financing for intangible expenses in certain renewable projects, through the Canadian Renewable and Conservation Expense (CRCE) category in the income tax system. With CRCE, the Income Tax Act allows the first exploratory wind turbine of each section of a wind farm to be fully deducted in the year of its installation, in a manner similar to the one in which the first exploratory well of a new oil field can be written off. Table 2, compiled by CanWEA, shows the level of commitment per province.

In parallel, various agencies are working to provide tools needed by industry to address the market created by these incentives. The following are a few examples of these activities:

The Canadian Wind Energy Atlas is a massive database of high-resolution wind statistics for the entire country, making Canada one of the large-area countries in the world to have a comprehensive wind energy atlas across its entire territory. The atlas

Table 2 Federal and provincial objectives for wind energy

Jurisdiction	Initiative	Status
Federal	Announced the ecoEnergy for Renewable Power program in January 2007 to support the deployment of 3,000 MW of wind energy between 2007 and 2011	Program scheduled to be launched in April 2007
British Columbia	Fifty percent of new generation to come from clean energy sources	2006 Call for Power awards 325 MW of power purchase agreements (PPAs) for wind projects
Alberta	An initial "threshold" of 900 MW of wind energy development established; work under way on policies (e.g., wind energy forecasting) to allow an increase in the threshold	Alberta will pass 500 MW of installed wind energy capacity in 2007.
Saskatchewan	Current initiatives will result in wind energy meeting 5% of electricity demand in Saskatchewan (about 200 MW).	Small-projects RFP has led to recent awarding of 25-MW PPA.
Manitoba	Manitoba government seeking 1,000 MW of wind energy within a decade	More than 100 MW in place; 300-MW RFP to be issued in early 2007
Ontario	Renewable Portfolio Standard (5% by 2007; 10% by 2010)—potentially four-fifths of this will be wind energy—2,100 MW by 2010	More than 1,200 MW in place and/or contracted; 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 RFP to be awarded in 2007.
New Brunswick	NB Power seeking 400 MW of wind energy by 2016	Ninety-five MW of wind energy contracted—seeking to have 200 MW in place by 2008
Nova Scotia	Regulations mandate that almost 20% of electricity must come from renewable sources by 2013.	Fifty MW of wind energy in place; 130-MW RFP for renewable energy to be released in 2007
Prince Edward Island	Government target of 15% of electricity coming from wind power in 2010 (60 MW); notional goal of 100% by 2015	Sixty-plus MW of wind energy now installed or contracted
Newfoundland	Draft energy paper calls for 150 MW of wind energy	Fifty-one MW now contracted

was created with WEST (the Wind Energy Simulation Toolkit), a sophisticated computer modeling program developed by scientists at the Meteorological Service of Canada (MSC) of Environment Canada in partnership with their colleagues at Natural Resources Canada (NRCan). WEST allows planners of wind energy projects to look both backward and forward in time to generate a detailed picture of wind patterns for any location in Canada. This means wind farms can be situated with greater precision and, by reducing the need for extensive field studies to verify wind conditions in a given area, development of new projects can move much more quickly. The atlas can be found on the Internet at http://www.windatlas.ca.

MSC developed the AnemoScope Wind Energy Simulation Toolkit as a complement to its Wind Energy Atlas. AnemoScope provides a fully integrated solution, combining state-of-the-art mesoscale and microscale wind models with advanced visualization, pre- and postprocessing, and analysis directly on a Microsoft Windows environment. It allows users to locate the ideal place to install wind turbines by providing the science and technology to perform pinpointed wind energy studies. It includes dynamic modelling of all scales down to the wind-farm level and integrates more than 50 years of global historical meteorological data. AnemoScope's ability to assess an area of 1 square kilometer down to an area as small as 100 square meters allows wind location studies to be made much more rapidly, with greater confidence and certainty, and at a lower cost than had been previously possible (Figure 6). Instead of using older-generation tools, AnemoScope uses two advanced meteorological models, Environment Canada's MC2 and MS-Micro, to calculate and predict wind flow patterns over a given landscape.

NRCan recently funded CanWEA to examine the interconnection requirements for wind technologies in Canada. The resulting report by Garrad Hassan proposes a base code that incorporates the existing codes developed in Alberta, Ontario, and Québec and includes the collaboration of the American Wind Energy Association. It proposes a structure allowing variability in requirements to accommodate both provincial differences and site-specific differences. The report will be studied by the various provincial bodies responsible for grid interconnection.

5.0 R, D&D activities

5.1 National R, D&D efforts

The fiscal year 2006/2007 budget for the Wind Energy R&D (WERD) group of Natural Resources Canada (NRCan) is about 2.5 million CAD, with contributions of about 1.5 million CAD from contractors, research institutions, and provinces.

The Canadian government's Technology Early Action Measures (TEAM) program provides funds for activities falling under the Climate Change Initiative, which include renewable energy deployments. The funds from this program can be accessed 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 group 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 newly-formed national wind institute. Since 1981, the

Figure 6 AnemoScope's micro-scale wind energy level for Montreal region, Québec. Source: MSC Environment Canada, 2007.

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. The national Wind Energy Institute of Canada (WEICan) evolved from the regionally-based AWTS and will focus on four strategic areas: testing and certification, research and innovation, training and public education, and technical consultation and assistance. WEICan will support the development and implementation of wind power generation and wind energy products and services for Canada and export markets.

NRCan's WERD group supports 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, and the development of a wind/diesel control system for remote communities.

5.2 Collaborative research

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

- Task 11–Base Technology Information Exchange;
- Task 19–Wind Energy in Cold Climates;
- Task 20–HAWT Aerodynamics and Models from Wind Tunnel Measurements;
- Task 24–Integration of Wind and Hydropower Systems.

Canada participates in the International Electrotechnical Commission's technical committee on Wind Turbines with status as a full participant.

6.0 The next term

Canada's wind research and development priorities over the next five years are as follows:

Technology Development: Canada will continue to focus on the design, development, testing and demonstration of small and large wind turbine technologies. This includes offshore technologies with a special focus on the great lakes. Technology and standards development will emphasize adaptation 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's Wind Implementing Agreement, the Wind Energy Institute of Canada, and through a newly-formed network of Canadian university researchers, should this network receive funding in the upcoming year.

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

Environmental Impact & Mitigation: A new focus area for NRCan, techno-environmental impact and mitigation studies will shed some light on turbine / wildlife interaction as well as noise and radiofrequency interference assessment and mitigation.

Although a sustained effort is required to address both technical and non-technical issues, cost of generation in Canada remains the most important barrier to increased wind deployment in this country. 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 by a combined effort on 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 is helping bridge the gap.

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Denmark

12

1.0 Introduction

Today, more than 15% of Denmark's energy supplies come from renewable sources. Seventeen percent of the electricity demand was produced by wind turbines in 2006. Twenty-three percent of energy supplies come from natural gas and 20% from coal. Dependence on oil has been reduced to about 40%. In total, the degree of self-sufficiency is more than 150%, and Denmark is a net exporter of oil and natural gas from its resources in the North Sea.

The installation of new wind power capacity in Denmark has been low during the past three years, and in 2006 only 8 MW net new capacity was installed. The key statistics for 2006 are shown in Table 1. However the Danish wind turbine manufacturers have been able to maintain a very substantial export in 2006 of more than 5,000 MW/yr, which corresponded to a global market share of the Danish wind turbine industry of more than 35%.

The international sustainability targets such as reduction of CO_2 emissions and economic considerations have played significant roles in recent years. The tools of the Danish energy policy have included subsidies for energy savings, green energy taxes, liberalization of the electricity and gas markets, and introduction of CO_2 quotas.

Toward the end of 2006, the Danish government undertook new initiatives that emphasize globalization and improved use of renewable energy sources, including stronger support for energy research, development, and demonstration.

2.0 Progress toward national objectives

At the end of 2006, the Danish government undertook new political initiatives to promote further use of renewable energy sources to reduce CO_2 emissions. For wind energy, these initiatives aim at supporting the national objectives based on the political agreement from 2004—construction of new offshore wind farms and a second repowering scheme for the replacement of unfavorably located wind turbines with new wind turbines in other places. The agreement also introduced a market-oriented pricing system for wind power and increased research, development and demonstration of advanced energy technologies. Information about the agreement was reported in the 2004 IEA Wind Energy Annual Report and can also be downloaded from the Danish Energy Authority's Web site (www.ens.dk). The 2004 energy policy agreement was followed by the long-term strategy on energy policy called Energy Strategy 2025. This was published in June 2005 and was reported on in the 2005 IEA Wind Energy Annual Report.

The current initiatives are more ambitious and more specific about the use of renewable energies in the Danish energy system. By 2025, the goal is set to double from 15% to 30% the share of renewable energy in the Danish energy supply, at the

Table 1 Key Statistics 2006: Denmark	
Total installed wind generation	3,137 MW
New wind generation installed*	8 MW
Total electrical output from wind	6.108 TWh
Wind generation as % of national electric demand**	16.8 %
Target:	N/A

* 12 MW installed; 4 MW removed
** Actual for 2006. (In Denmark the mean energy content in the wind was very low in 2006. In some years, the same production capacity would have resulted in more than 20% of the same electricity demand.)

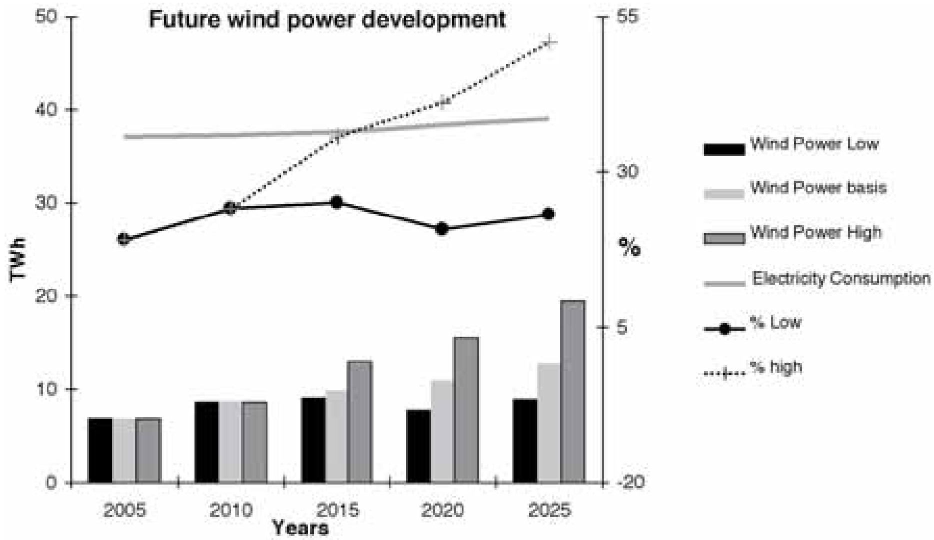

Figure 1 High and low scenarios showing possible wind-power development in Denmark.

same time reducing the use of fossil fuels by 15%. To stabilize the overall Danish use of energy as it is today, the level of energy savings will be increased to 1.25% annually. New technologies and saving opportunities will be made available as a result of a decision to double the total Danish investments in energy R, D&D before 2010. One of the important contributions to the increased use of renewable energy in the Danish energy system will be an estimated wind energy share of 50% for electricity production in 2025.

To reach these goals and fulfill Energy Strategy 2005, several priorities have been set. These include additional support for R, D&D in fuel cells; development of second-generation bioethanol 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 has prepared projections to 2025 on the production of electricity and district heating; these projections were also reported in the 2005 IEA Wind report. With the new initiatives–and if the price of oil remains high (above 50 USD/barrel)–both wind energy and biomass will become so advantageous that they could amount to as much as 80% of Danish electricity consumption, with wind power expected to cover more than 50% and biomass 30% (Figure 1).

2.1 Siting of the new wind turbines in Denmark

The government intends that new wind energy capacity, both onshore and offshore, should continue to be established on an economically healthy basis. In this context, the physical location of new offshore wind farms; the various considerations relative to nature, environment, and landscape; and related challenges will all be assessed and updated periodically.

In December 2005, the Danish Energy Authority undertook a new plan for siting the next generation of offshore wind farms between 2010 and 2025. A working group was formed to propose future Danish offshore wind turbine development. Two other working groups were set up, one to identify sites for future turbines on land and one to position new industrially developed turbines (0-series) for testing by manufacturers and developers. All three groups will limit their considerations to wind turbines above 150 m in height. The working group for siting on land has finished its task. 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.

The two working groups for offshore siting and positioning of test turbines did not finish their work in 2006, but it is expected that their final reports will be published early in 2007. These groups identified the following important issues:

• Manufacturers have a strong need for test sites with realistic wind conditions so they can conduct measurements and test technology landmarks before they introduce new turbine developments to a truly commercial market.
• Testing of turbines on land is very important and is cost-effective for many phases of offshore turbine development.
• In Denmark, turbine testing is of great importance, because Denmark exports a considerable number of wind turbines to many different markets that have varying requirements.
• The number of test sites on land for very large turbines is limited, and therefore the sites must be used continuously with different turbines. The testing period may vary from a few months to several years.

The working group that is identifying offshore sites is considered to be an update of a group formed by Denmark's 1997 Action Plan for Offshore Wind Power. However, since 1997, many conditions have changed. The working group must identify several sites that have the potential for more than 4,000 MW of offshore wind power to be installed from 2015 to 2025. It is estimated that this amount of wind power can supply about half of Denmark's future electricity consumption.

The working group must take into account all offshore constraints in Danish waters: sailing routes, military use, interests of the fishing industry, and preservation of nature, including many visual characteristics. Also, it must evaluate grid connection possibilities, including considerations for and consequences of the transmission system to transport the power produced by the turbines.

2.2 Installed capacity and production in 2006

The total capacity of wind power in Denmark increased by only 8 MW in 2006, which brought the end-of-year total to 3,137 MW. The total number of turbines was reduced to 5,274. During 2006, only 9 new wind turbines were installed, and 28 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. See Figures 2, 3 and 4 for detailed history of installed capacity and production in Denmark.

As was shown in Table 1, in 2006 electricity from wind energy covered 16.8% of the electricity consumption in Denmark, which was less than the 18.5% in 2005. Both figures are relatively low because mean wind speed in Denmark in 2005 and 2006 was lower than the average. The wind energy development has been shown graphically as a wind index that varies over the years. Recently, after discussions about the accuracy of the index, a new statistical basis for such an index was proposed, and a new index is under development. The total electricity production from wind energy in 2006 was 6,108 GWh, a drop of about 8% from 2005.

In 2004 and 2005, observed CO_2 emissions decreased by 9.4% and 6.4%, respectively, relative to the year before. The drop was primarily due to decreasing electricity production and warmer weather. During these years, a large electricity export changed into a net import. CO_2 emissions adjusted for export/import and temperature variations showed a decrease of 1.5% in 2004 relative to 2003, and there was no change from 2004 to 2005. Relative to 1990, the adjusted CO_2 emissions in 2005 showed a fall of 16.2%.

The shift from coal to natural gas, renewable energy, and other measures has meant that, year by year, less CO_2 is linked to each unit of fuel consumed. Thus, in 2005 each gigajoule (GJ) of adjusted gross energy consumption was linked to 60.3 kg CO_2, against 74.2 kg in 1990. This corresponds to an 18.7% reduction. Electricity production in 2005 in Denmark caused 522 grams of CO_2 emissions per kWh. In 1990, CO_2 emissions were 937 g/kWh of electricity produced. This corresponds to a reduction of 44.2%. This large reduction is attributable to fuel conversions in electricity production and to the growing significance of CHP production and wind power.

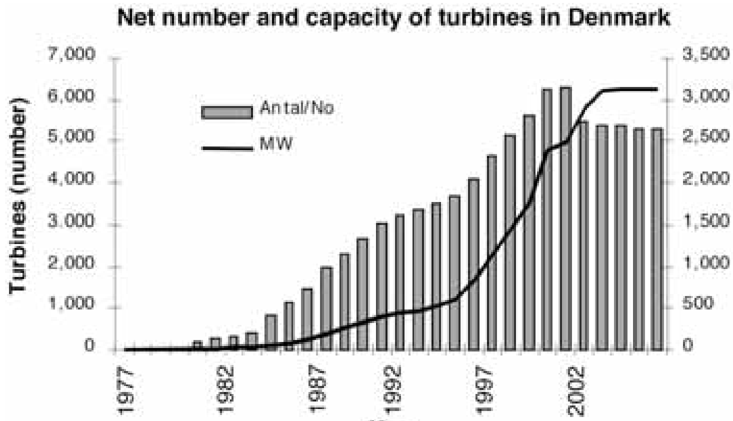

Figure 2 Net number and capacity of turbines in Denmark.

Denmark's largest turbines installed on land remain the five 3-MW turbines and five 2.75-MW turbines, which were installed in 2002 at special sites. At the Risø test site at Høvsøre, one 3.6-MW turbine and one 4.2-MW turbine are still being tested. The two largest offshore wind farms are 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 from 2004, two more offshore wind farms of 200 MW will be established. Contract notices were published in 2004 for two sites, one for an area at Horns Rev and one for an area 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 5). The wind farm will cover a total area of about 35 km^2, and the wind farm will be commissioned during 2009. Energinet.dk is responsible for extending the electricity grid to the wind farm. The energy company Energi E2 (DONG Energy) submitted the lowest tender for the Horns Rev II farm in 2005. The price to be paid is 0.518 DKK /kWh for the first 50,000 full-load hours, corresponding to about twelve years of electricity production. The DONG Energy company, DONG Renewables, conducted feasibility studies and prepared an environmental impact assessment (EIA) report that clarifies environmental and natural conditions.

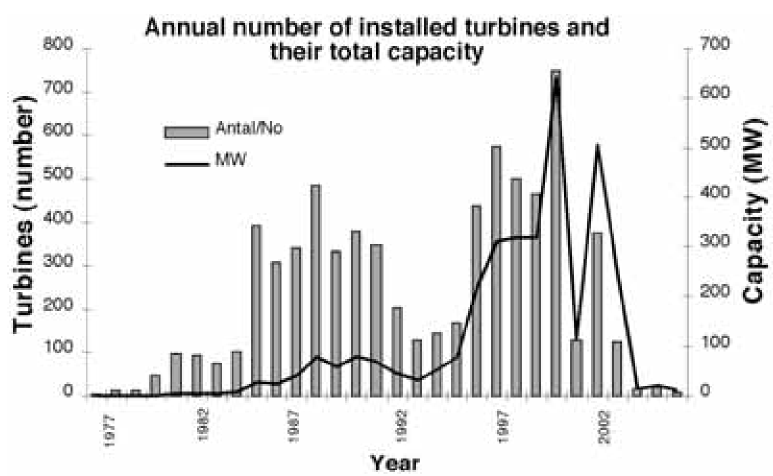

Figure 3 Annual number of installed new turbines and their total capacity.

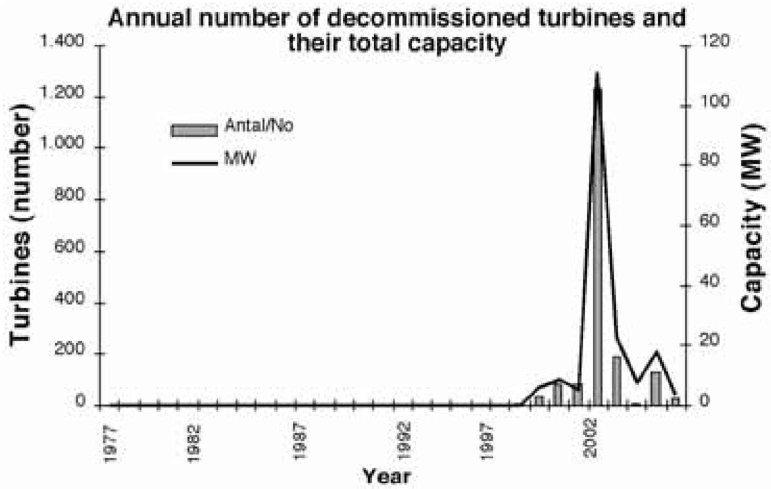

Figure 4 Annual number of decommissioned turbines and their total capacity.

During the fall of 2006, the EIA report was distributed for a public hearing.

2.4 Rødsand II

At the end of 2005, the Danish Energy Authority received three tender bids for a 200-MW offshore wind farm concession at Rødsand. The tenders are (1) a group consisting of two Dutch companies: Ballast Nedam Infra BV and Evelop BV, (2) Rødsand II A/S (with Vattenfall as the main shareholder), and (3) a group consisting of DONG Vind A/S, Sydkraft AB (now E.ON Sweden), and Energi E2 A/S.

The Danish Energy Authority evaluated the tendering information and in April 2006 selected the group comprising Energi E2 A/S, E.ON Sweden, and DONG Vind A/S to establish the new offshore wind farm neighboring Rødsand I (Nysted Offshore Wind Farm). The group submitted the lowest tender–0.499 DKK /kWh for the first 50,000 full-load hours, corresponding to about fourteen years of electricity production.

The offshore wind farm is to be located about 3 km west of the existing wind farm at Rødsand. The wind farm will cover a total area of about 35 km^2. It has been agreed that the wind farm will be commissioned during 2010. Together with SEAS Transmission, Energinet.dk is responsible for extending the electricity grid to the wind farm. The next steps are to conduct feasibility studies and prepare an EIA report.

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/).

3.0 Benefits to national economy

3.1 Market characteristics

Sales by Danish wind turbine manufacturers Vestas Wind Systems and Siemens Wind Power were 3,800 MW in 2005, which was higher than the figure for 2004 (3,290 MW). The figure for 2006 was 5,300 MW. The Danish home market in 2006 amounted only to 12 MW, about the same as in previous years. Therefore, nearly all turbines manufactured are exported, contributing more than 30 billion DKK per year to the national economy. In 2006, the two large manufacturers Vestas and Siemens together had a world market share of more than 35%. More than 25,000 people are employed in the Danish wind sector.

The market for onshore wind power in Denmark has not changed since the last annual report. It is still characterized by a low 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. Future inland market development will therefore mainly be tied to the second repowering scheme that will replace smaller

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

wind turbines with new, larger machines, which will be paid an extra premium of 0.12 DKK/kWh.

Offshore, the future market will be driven by political decisions based on the update of the Action Plan for Offshore Wind Power from 1997 (described earlier).

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 megawatts 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 microturbines.

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.

In 2006, the new generation of 3-MW turbines has been produced to supply the emerging offshore wind farms. Vestas, especially, on the basis of experiences at Horns Rev, made a strong effort in 2005 and 2006 to improve the quality of its offshore wind turbines.

The two major organizations in Denmark that represent the owners and manufacturers, respectively, are the Danish Wind Turbine Owners' Association (www.dkvind.dk) and the Danish Wind Industry Association (www.windpower.org).

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 nearshore farms is also high. In 2004, though, the availability on Horns Rev was low because the gears and transformers on all the Vestas turbines were undergoing comprehensive repair. During 2005 and 2006, all turbines operated at nearly 100% with an availability of about 95% and 97% respectively, whereas the Siemens (Bonus) turbines at Nysted reached about 97% and 95%.

3.3 Economic details

Operation and maintenance costs (service, consumables, repair, insurance, administration, lease of site, and so on) for new large turbines have seldom 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 new scheme is based on the IEC WT01 System for Conformity Testing and Certification of Wind Turbines. Implementation of the IEC system means a higher degree of mutual recognition of certificates among countries and therefore easier access for all manufacturers to sell their products internationally. Certification bodies providing services according to the new scheme now can operate after they have been accredited by any recognized accreditation body worldwide. During 2006, a supplementary set of rules was developed for microturbines up to 2.5 m^2 in rotor diameter. This is expected to come into force in the beginning of 2007. The Danish Energy Authority is responsible for the administration of the scheme. Risø National Laboratory acts as secretariat and information center. All documents related to the certification scheme can be found on the Web site: www.wt-certification.dk.

4.0 National incentive programs

Denmark continues to follow incentive programs adopted by the parliament in June 2004 that specify the cost for access and connection of wind turbines to the grid and the premium paid on top of the market price. According to the original bill from December 2003, renewable energy certificates should be issued for electricity produced from renewable energy, but the introduction of these certificates has been postponed and the certificates temporarily replaced by a premium of 0.10 DKK/kWh. All wind turbines except those installed by the utility sector before 2000 can obtain certificates or the premium for twenty years. Details about the purchase prices were listed in the 2004 IEA Wind Energy Annual Report.

During 2006, the market price plus premium varied between 0.33 DKK/kWh and 0.43 DKK/kWh (except during January, when adjustments were included). The premium becomes zero when the market price exceeds 0.36 DKK/kWh, and in 2006 this happened during one month in western Denmark and during five months in eastern Denmark. For these periods, the wind-power production actually reduced the market price of electricity.

5.0 R, D&D activities

5.1 National R, D&D efforts

A positive change in the funding of renewable energy R&D began in 2005. A major increase in funding of wind R, D&D was introduced in 2006, and another increase is planned for 2007. Prior to the political agreements of 9 May 2003 and 29 March 2004, public funds (including funds financed by consumers) reserved for energy R, D&D in 2005 amounted to approximately 273 million DKK. In 2006, energy R, D&D funds totaled 337 million DKK, and the budgets for 2007 show an increase to 448 million DKK. Additionally, the national research councils and the newly established High Technology Foundation may also provide funds for energy research. The programs and available funds are shown in Table 2.

The Danish Energy Authority is responsible for the administration of the Energy Research Programme (EFP), which covers research in both con-

Table 2 Programs and available funds for renewable energy R&D projects including wind energy (million DKK)

Program	2003	2004	2005	2006	2007
Energy Research	41.0	72.0	73.0	74.0	76.0
Energy Development and Demonstration Program	–	–	–	–	110.0
PSO*—electricity production	100.0	130.0	130.0	130.0	130.0
PSO*—electricity utilization	25.0	25.0	25.0	25.0	25.0
Renewable energy R&D—Danish Agency for Science Technology and Innovation	35.0	45.0	45.0	108.3	107.1
Total	201.0	272.0	273.0	337.3	448.1

*PSO = public service obligation

ventional energy and renewable energy. The EFP is intended to establish technological foundations necessary for the practical implementation of Danish energy policy. It is also meant to help strengthen exports of Danish energy technology and know-how. Additionally, 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 2006 EFP budget was maintained at the level reached in 2004 and 2005 due to the political agreement of 9 May 2003.

The total grants to wind energy projects supported by EFP in 2006 was 11.3 million DKK (9.5 million DKK in 2005). The projects are listed in Table 3 together with projects funded by other Danish programs.

Two million DKK is allocated to the secretariat of the Danish Wind Turbine Certification Scheme 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. Standardization work has high priority and is supported through R&D funds.

5.2 The PSO program of transmission system operators

Transmission system operators have PSO-subsidized R&D programs for noncommercial projects concerning new and environmentally friendly

Table 3 Important wind energy projects funded by Danish R&D programs in 2006*

Project title (Funding source)	Applicant	Support (million DKK)
Program for Research in Applied Aeroelasticity (EFP)**	Risø	2.9
Simulation for Generalization of Wind Loads (EFP)	Risø	2.0
Improved Performance Measurements; Characterization of the Wind Field (EFP)	Risø	2.6
Mesoscale Atmospheric Variability and the Variation of Wind and Production for Offshore Wind Farms (PSO***)	Risø	2.5
Noise and Optimization of Wind Farms (PSO)	Delta	2.0
Low-Frequency Noise from Large Wind Turbines (EFP)	Delta	2.9

* In addition to these projects, two other EFP projects were funded with a total amount of 0.9 million DKK.
** EFP = Energy Research Programme
*** PSO = public service obligation

energy technologies. PSO stands for public service obligation. 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 2006 totaled 4.5 million DKK. The corresponding figure in 2005 was 15.9 million DKK.

5.3 Danish Council for Strategic Research

For 2006, the budget for energy and environmental research of the Danish Council for Strategic Research was increased to 108 million DKK, and this level will be continued in 2007. However, in 2006 no wind energy projects were funded, whereas in 2005, 13.8 million DKK was granted to wind projects.

5.4 Riso National Laboratory

Risø National Laboratory is the largest research institution for wind energy in Denmark. Risø has formed a consortium with the Technical University of Denmark (DTU), Aalborg University (AAU), and the Danish Hydraulic Institute (DHI). This builds on Risø's existing close cooperation with DTU on aeroelastic design and with AAU on electrical design. The cross-disciplinary consortium is intended to improve the network and coordination among research, education, and industry. The research is planned and implemented around the following four themes: (1) climatic conditions; (2) wind turbine design; (3) electrical systems, control, and integration; and (4) society, markets, and energy systems. Many of the R&D projects listed in Table 3 are carried out by partners in the consortium.

Risø still 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. 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 largest turbine being tested is the Vestas 4.2 MW originally developed by NEG Micon. The test site is shown in Figure 6.

On 1 January 2007, Risø National Laboratory, the Danish Institute for Food and Veterinary Research, the Danish Institute for Fisheries Research, the Danish National Space Center, and the Danish Transport Research Institute merged with DTU as the continuing unit.

5.5 Collaborative research

A possible constraint on the future deployment of wind energy in the Danish energy system is the issue of maintaining the power balance or dealing with surplus electricity. Due to the high share of electricity from CHP (about 50%) and the high share from renewable electricity, mainly wind power (about 25%), a substantial part of Danish electricity production is influenced by weather conditions (outdoor temperature and wind speed). This limits the system's ability to adapt to quickly changing electricity prices on the market. On cold, windy nights, an electricity surplus may arise. On one hand, this is a successful demonstration of how far CHP and

Figure 6 Test site at Hovsore.

electricity from renewable energy can be developed. On the other hand, it poses a new challenge, to the electricity system in general and the system operators in particular, to handle fluctuating electricity production.

Electricity surplus is generally exported. If it is not physically possible to export the entire surplus, a critical situation arises in which wind capacity must be reduced. This is happening with increasing frequency in the western part of Denmark. The economical benefit of using, rather than exporting, the surplus depends on the power-market price of electricity and on the environmental value of electricity exported from Denmark. In general, more flexibility in power production and demand means a more appropriate response to market conditions. Wind-generated surplus electricity is advantageous, lowering consumer prices. Tax reductions on future production of heat from surplus electricity will open up new market possibilities for wind energy electricity.

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

Denmark participates in IEA Wind Tasks 11, 20, 21, and 25. In Task 23, Risø National Laboratory serves as one of the subtask operators.

- Task 11 – Base Technology Information Exchange. The participation is important because Denmark exports a great deal of wind turbine technology and know-how.
- Task 20 – HAWT Aerodynamics and Models from Wind Tunnel Measurements. Participation is important for research, because Denmark does not have access to large national wind tunnel installations.
- Task 21 – Dynamic Models of Wind Farms for Power System Studies. Modeling Danish power systems that are occasionally dominated by wind power is necessary to develop the concept of a wind turbine as a wind-power station, not just a decentralized production unit.
- Task 23 – Offshore Wind Energy Technology Deployment. It is important to consider cost reductions and environmental considerations when establishing deployment strategies. Participation in this task will benefit partners of the EU UpWind project mentioned previously.

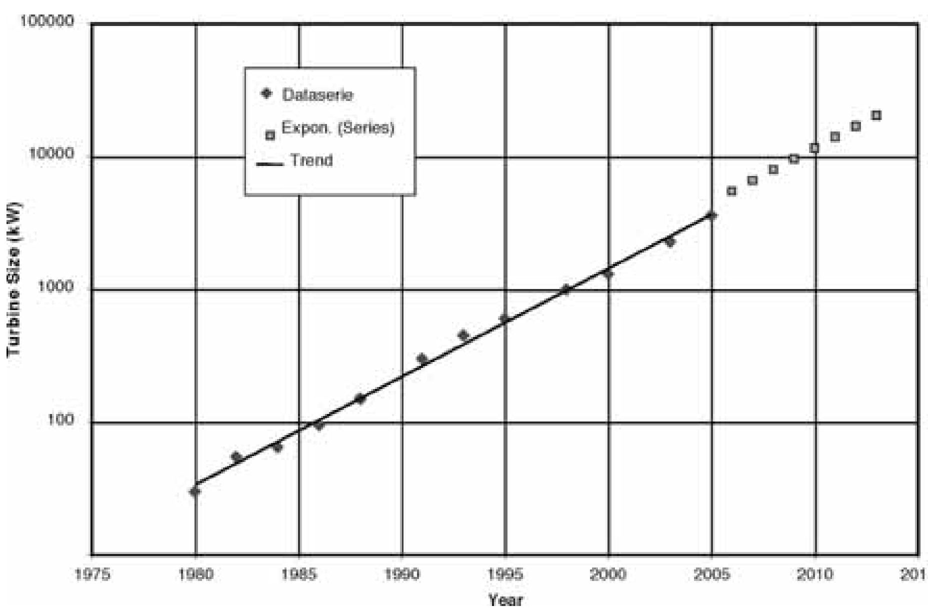

Figure 7 Expected size of future wind turbines From the presentation "Why not just make a 5 or 10 MW wind turbine?" Henrik Stiesdal, Siemens Wind Power. Danish Society of Wind Energy, Wind Energy Conference, Ebeltoft, Denmark, October 2004.

• Task 25 – Power System Operation with Large Amounts of Wind Power. Danish participation is important because critical issues for the Danish power system are balancing, increased flexibility through DSM/storage, and grid stability.

6.0 The next term

With the Danish turbine market in 2006 at nearly zero and the new, large offshore projects only in the planning process, new information on investment costs is unavailable. For the recent megawatt-scale machines, the ex-works cost might be slightly higher per kilowatt of generation capacity. But as the wind resource at rotor height is greater and the amount of wind energy harvested is therefore better, the total economy of megawatt-scale projects will be better.

The production cost for wind-generated electricity per kilowatt hour is still decreasing, and the trend is that production from large-size turbines is approaching competitiveness on equal terms with electricity production from conventional power stations.

The new initiatives taken recently that aim to fulfill the Energy Strategy 2025 will strengthen wind energy R, D&D in Denmark. It is expected that focus will be shifted to increased demonstration of new technologies, and development of future offshore wind will depend strongly on political decisions made on the basis of working group recommendations on siting turbines.

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European Commission

13

1.0 Introduction – wind energy deployment in the EU during 2006

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The market for European wind power broke new records in 2006. According to the figures released by the European Wind Energy Association 7,588 MW of wind power capacity, worth some 9 billion €, was installed last year in the EU, an increase of 23% compared to 2005 (1). Figure 1 shows the distribution of wind capacity across the countries of Europe.

The cumulative wind power capacity operating in the EU rose by 19% and now exceeds 48,000 MW. In an average wind year, this will produce approximately 100 TWh of electricity, equal to 3.3% of total EU electricity consumption. For the seventh consecutive year, wind power is second only to gas-fired capacity (approximately 8,500 MW in 2006) (2) in terms of new electricity generating installations.

Germany and Spain continue to attract the majority of investments. In 2006, these two countries represented 50% of the EU market. With 2,233 MW installed during 2006, a 23% increase compared to 2005, Germany passed the 20,000 MW mark. Spain was the second largest market in 2006, with 1,587 MW.

However, the figures confirm a trend in the European market towards less reliance on the German and Spanish markets and that a second wave of Member States is heavily investing in wind energy. Thus France moved up to the third place, with a record installed capacity of 810 MW in 2006 – more capacity than has previously been commissioned in the entire history of that country.

The performance of Portugal has also been outstanding, with 694 MW of new capacity. The United Kingdom, with 634 MW installed in 2006, has witnessed a record year (47% increase). Other remarkable markets are those of Italy (417 MW) and Ireland (250 MW, an increase of 50% compared to 2005).

New wind power installations in the new EU Member States tripled from 60 MW in 2005 to 183 MW in 2006, mainly driven by Poland, Lithuania, and Hungary. Bulgaria installed 22 MW, while Romania connected 1.3 MW. Eight EU countries now have more than 1,000 MW of wind power capacity installed.

2.0 The EU legislative framework for wind energy

2.1 The RES-E Directive

An important contributor to the growth of the European market for wind energy technology has been effective EU framework legislation combined with legislation at the national level, aimed at reducing barriers to the development of wind energy and other renewables. For electricity, the EU aims at having renewable sources provide 21% of EU electricity consumption by 2010. This target was established by the EU Renewables Directive (77/2001/EC), which sets out differentiated national indicative targets for each Member State. The Renewables Directive has been a historical step in the delivery of renewable electricity and constitutes the main driving force behind new policies being implemented.

According to its last progress report (3), in the past two years 50% additional renewable electricity (non-hydro) has been generated, which implies that Europe will, in all likelihood, come close to its target by 2010. This positive overall trend should not dis-

Wind power installed in Europe by end of 2006 (cumulative)

EU CAPACITY (MW)	End 2005	Installed 2006	End 2006
Austria	819	145.6	965
Belgium	167.4	26.3	193
Bulgaria*	10	22	32
Cyprus	0	0	0
Czech Republic	28	22	50
Denmark	3,128	11.5	3,136
Estonia	32	0	32
Finland	82	4	86
France	757	810	1,567
Germany	18,414.9	2,233.1	20,622
Greece	573.3	172.5	746
Hungary	17.5	43.40	61
Ireland	495.5	249.9	745
Italy	1,718	417	2,123
Latvia	27	0	27
Lithuania	6.4	49.05	55.5
Luxembourg	35.3	0	35
Malta	0	0	0
Netherlands	1,219	356	1,560
Poland	83	69.3	152.5
Portugal	1,022	694.4	1,716
Romania*	1.69	1.3	3
Slovakia	5	0	5
Slovenia	0	0	0
Spain	10,028	1,587.16	11,615
Sweden	509.5	62.15	572
UK	1,332	634.4	1,963
EU-15	40,301	7,404	47,644
EU-10	199.2	183.7	383
EU-25	40,500	7,587.9	48,027
EU-27	40,511	7,611	48,062

	End 2005	Installed 2006	End 2006
Other countries (MW)			
Faroe Islands	4	0	4
Ukraine	77.3	8.3	85.6
Total	81.3	8.3	90.6
EFTA countries (MW)			
Iceland	0	0	0
Liechtenstein	0	0	0
Norway	267	47	314
Switzerland	11.6	0	11.6
Total	278.6	47	325.6
Accession countries (MW)			
Croatia	6	11.2	17.2
Turkey	20	30.85	51
Total	26	42.05	68.2
TOTAL EUROPE	40,898	7,708.4	48,545

Note: Due to previous-year adjustments, project decomissioning of 61 MW and repowering, and rounding, the 2006 end-of-year cumulative capacity total does not exactly match the year-end 2005 total plus the 2006 additions.

* Bulgaria and Romania are members of the European Union from 01/01/2007

Figure 1 Cumulative wind power installed in Europe at the close of 2006. SOURCE: European Wind Energy Association, 2007. Available at http://www.ewea.org.

guise the insufficient performance of many Member States. In relation to wind, the progress report highlights that still one third of EU countries do not lend enough support to wind energy. The main cause of the slow development in some Member States is not deliberate policy but delays in authorization, unfair grid access conditions, and slow reinforcement of the electric power grid (4).

2.2 Political support mechanisms for wind energy

In the pursuit of the overall target of 21% from renewable electricity by 2010, the Renewables 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 graph below gives an overview of renewable electricity support systems in the EU-25.

2.3 Long-term planning

In a broader context, the European Commission launched in March 2006 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" (5) 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. The Green Paper also foresaw the preparation of a European Strategic Energy Technology Plan that aims at moving Europe towards a low carbon energy system, e.g. "by permitting a sharp increase in the share of lower cost renewables, including the roll-out of offshore wind." The Energy Package released 10 January 2007 is the Commission's follow up from the consultation.

3.0 R&D wind energy projects funded by the European Commission

During 2006, more than 20 R&D projects were running with the support of the Fifth and Sixth Framework Programmes of the European Union (the Framework Programmes are the main EU-wide tool to support strategic research areas).

The management and monitoring of projects is divided among two Directorate-Generals of the European Commission: 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 2006.

3.1 DG Research Activities

The projects running in 2006 can be divided into the following thematic categories:

1. Wind turbines
2. Blades and rotors
3. Wind resources forecasting and mapping

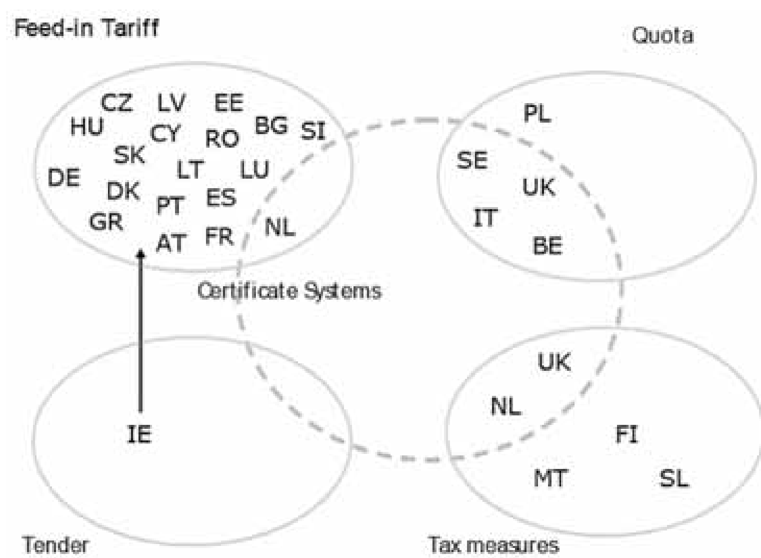

Figure 2 Overview of renewable electricity support systems in EU-25, and Bulgaria (BU) and Romania (RO) (2005). SOURCE: "Monitoring and evaluation of policy instruments to support renewable electricity in EU member states;" Final report; Fraunhofer, ISI, EEG, 2006.

4. Wind farm development and management
5. Integration of wind power

In the descriptions below, the projects are named through their acronym.

3.1.1 Wind turbines

The Integrated Project UPWIND started on 1 March 2006 and aims at developing design tools for future very large wind turbines (8-10 MW) standing in wind farms of several hundreds of MW, both onshore and offshore. Coordinated by the Risø National Laboratory (Denmark), this large long-term research effort involves 42 partners and will run for five years.

3.1.2 Blades and rotors

The KNOW-BLADE project aims at reducing uncertainties in the aerodynamic and aero-elastic analyses by applying Navier-Stokes solvers in place of today's more common BEM (Blade Element Momentum theory) solvers. The areas looked into in detail include 2-D and 3-D modeling, blade tip problems, and aerodynamic accessories such as vortex generators and stall strips.

Another important issue in this field is the verification and qualification of aerodynamic design tools. In order to enable the wind community to improve, qualify, and verify their aerodynamic design tools, an experimental database obtained under controlled and well-established conditions is needed. The MEXICO project seeks to provide such a well-documented database through a set of detailed wind-tunnel measurements in the German-Dutch DNW wind tunnel.

An area closely related to this is the production of aerodynamic noise from wind turbines, which is still one of the major hindrances for the onshore exploitation of wind energy. In the SIROCCO project, an aerodynamic/acoustic design method is being developed with which silent airfoils can be planned. The airfoils will be applied to existing turbines and will be subjected to extensive measurement campaigns.

The STABCON project is intended to improve knowledge in the field of aero-elastic stability and control of large wind turbines. Through the formation of a European Network on aero-elastic stability, this project aims to develop reliable design tools for aero-elastic stability analyses and the optimization of large wind turbines.

Another key area where progress is being made is in the understanding of the material behavior of blades. In particular, the static and fatigue properties of fiber-reinforced blades is being investigated. As a part of this research, the OPTIMAT BLADES project is progressing with a detailed parametric study, which will result in a comprehensive and consistent database for fiber reinforced materials to be used by the industry. Besides this database, design guidelines ready to be implemented into the design standards will be formulated.

3.1.3 Wind resources forecasting and mapping

The ANEMOS project seeks to substantially improve methods for short-term wind power forecasting. It responds to the needs of different end-users through the development of approaches for single wind farms, for regional or national forecasting, and for different time scales ranging from a few hours to a few days ahead. Emphasis is given to challenging situations such as complex terrain and extreme weather conditions, as well as to offshore prediction for which no specific tools currently exist. New methods are being developed to estimate on-line the level of uncertainty of the predictions and the expected risk based on ensemble weather forecasts.

Currently, a good number of research projects are underway on the European and national level in the fields of short-term forecasting of wind power, offshore wind and wave resource prediction, and offshore wakes in large wind farms. The purpose of the POW'WOW project is to coordinate the activities in these related fields, to spread the knowledge gained from these projects among the partners and colleagues, and to start work on some roadmaps for the future. Therefore, the leaders of research projects are assuming the function of a multiplier towards the larger research and user community. Additionally, in the fields of short-term forecasting and offshore energy resource, Expert Groups will be formed to act as the central focus point for external stakeholders. The liaison with other groups will also include groups outside of Europe.

3.1.4 Wind farm development and management

To investigate whether a cost-effective, integrated condition monitoring system could be realized in practice, the project CONMOW (Condition Monitoring for Off-shore Wind Farms) has extensively instrumented a single turbine, a GE 1.5S located at Zoetermeer (Netherlands), not only with condition monitoring techniques but also with the more "traditional" measurement systems. The main objective of this project is to improve monitoring systems and to develop data processing techniques to create an early warning system for component failure.

3.2 DG TREN (Energy and Transport) activities

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

HISP aims at installing three pilot modified 2-MW wind energy converters on Bockberget-Högsara Island (Finland) in a semi-offshore arctic environment. The objective of this project is to gain experience and to build up a track record of small wind farms with multi-megawatt wind turbines built on island, to demonstrate high availability and to verify the low cost foundation design with as little alteration on the nature and inhabitants of the islands as possible.

The aim of the STANDICE project is to contribute to the development of an international standard for the design of marine structures such as OWECS (Offshore Wind Energy Converters) against ice loads with special emphasis on European sub-arctic ice conditions, such as in the Baltic Sea. The project should help to develop the ISO TC67 SC7 WG8 "Arctic Offshore Structures Standard" and especially the Sub-Arctic Supplement. The project should also provide the industry and government authorities in Europe with internationally standardized ice load design criteria.

The DOWNVInD project seeks to pioneer cost-effective wind farms in water depths of up to 50 m and approximately 25 km away from the shore. On 20 August 2006, history was made when the first wind turbine of the DOWNVInD project was loaded out from Nigg Bay, transported to the location, and lifted onto its substructure. The machine is the first wind turbine in international waters, the furthest from shore (25 km), the biggest (5 MW), and in the deepest water (42 m). DOWNVInD is the flagship project for offshore wind energy development in Europe. It aims to install two demonstration wind turbines adjacent to the Beatrice oil field (east coast of Scotland). The turbines stand about one hundred and fifty meters above sea level.

The NEWGEN project aims at the development of a new direct drive generator, which has the potential to reduce the weight and thus the cost of the generator installation by 70%. This is mainly achieved by applying a novel mechanical solution, which drastically reduces the stiffness requirements and therefore permits a larger diameter generator. In this way both the amount of electrically active material and the amount of construction material are reduced. Thus the total wind turbine cost should decrease by roughly 20%. The project aims to develop and test a commercial size (3 MW) NewGen generator, and to demonstrate this generator in a large wind turbine, based on an existing wind turbine design. The work will use the just finished development and laboratory testing of a pilot scale (140 kW) generator. A preliminary study reveals that a 20 MW generator is feasible and compatible.

In the project SIWT, the participants plan to develop a novel offshore wind turbine concept using a suction pile foundation. The subject concept allows installation of the complete wind turbine, substructure, and suction pile foundation offshore in one piece. The concept is virtually independent of the water depth because it uses floating equipment. This allows offshore wind farms to be installed in deeper waters out of sight from the coastline. The unit will be fastened to the barge and is then ready to sail away to the offshore location. The complete duration including tow and offshore installation is anticipated to take only 2-3 days subject to the distance to port. In the field, the barge will be moored and the unit will be lowered to the seafloor. The suction piles will be installed using suction pumps. This operation occurs in only 3-6 hours without noise, i.e. there is limited disturbance to marine life. For the installation of a large wind farm involving say 50-100 turbines, two complete spreads could be mobilized to make installation feasible in one season. The complete wind turbine including foundation can be removed by reversing the installation procedure. No structural elements will be left in or on to the seabed. If required, the complete unit can be re-installed at another location.

3.3 Future R&D projects

Several new wind projects are expected to start in 2007 under the 6th Framework Programme. The new demonstration projects will address site development and operation of large wind turbines in complex terrain, development of a toolbox for the design of wind farms (focus on off-shore application) in order to reduce wind power generation costs, and secretariat activities of the new Wind Energy Technology Platform (see the next section).

In addition, the project "EWIS" (European Wind Integration Study), which gathers 15 Transmission System Operators representing 13 countries, aims at bringing common pan-European recommendations relating to wind energy penetration at large scale.

A new framework programme – FP7 - for the period 2007 to 2013, was negotiated and approved in December 2006, and a first call for proposals (6) is underway. The 7th Framework Programme will have a total budget of 50.2 billion euros over its seven years of functioning. In relation to energy research, renewables and energy end-use efficiency will receive more than half of the budget for non-nuclear research, meaning at least 1,175 million euros over the seven years. The theme "Energy" includes six topics related to wind under the "Renewable Electricity" activity. First contracts should start at the end of 2007.

3.4 European Commission contacts

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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 European Commission 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, channeled through the European Wind Energy Association. Its objective is to identify areas for increased innovation, new and existing research, and development tasks, and to prioritize them on the basis of "must haves" versus "nice to haves." Their primary aim is overall cost reductions through research and economies of scale (market deployment). The platform will develop coherent recommendations detailing specific tasks, approaches, actors, and necessary infrastructure, in the context of private R&D and EU and Member States programs such as FP7. Finally it will assess the overall funding available to carry out this work from public and private sources.

The TPWind thus seeks to become the indispensable forum for the crystallization of policy and technology research and deployment pathways for the wind energy sector, as well as a new opportunity for informal collaboration and coordination between Member States, including those less developed in wind energy terms.

Historically, the principal drivers for wind energy cost reductions have been R&D, for approximately 40%; and economies of scale, for around 60%. The scope of TPWind mirrors this duality. TPWind will focus not only on short- to long-term technological R&D but also on the potential market development "showstoppers" through a number of policy working groups.

The following diagram reflects the structure of the European Wind Energy Technology Platform, which will be fully operational during the course of 2007. The secretariat of the platform will be funded by FP6.

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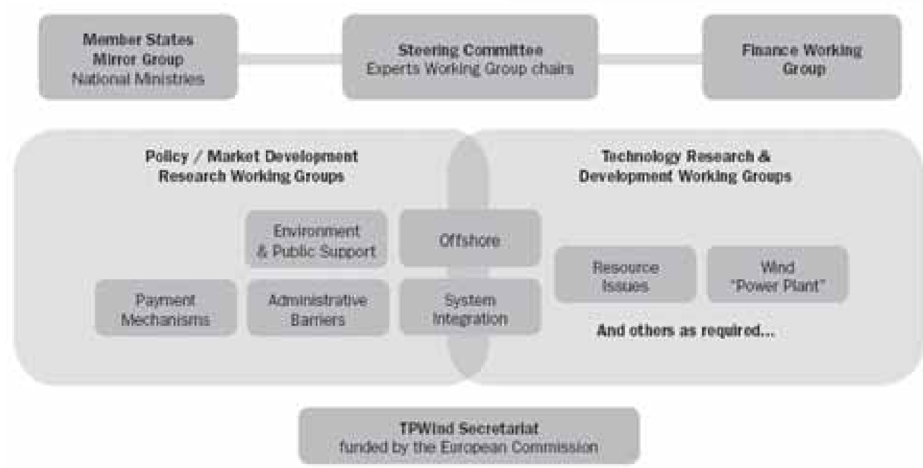

Figure 3 Proposed structure of TPWind. SOURCE: European Wind Energy Association. Available at http://www.windplatform.eu.

References and notes:

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

2) According to Platts PowerVision, March 2007

3) COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT, Green Paper follow-up action report on progress in renewable electricity, COM (2006) 849, http://www.cdep.ro/docs_comisii/IE/CE/COM_2006_849_EN_ACTE_f.pdf

4) Page 10 of the Communication.

5) COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT, A European Strategy for Sustainable, Competitive and Secure Energy, COM (2006) 105

http://ec.europa.eu/energy/green-paper-energy/doc/2006_03_08_gp_document_en.pdf

6) PROVISIONAL* COOPERATION WORK PROGRAMME 20071, EUROPEAN COMMISSION: C(2006) 6839, http://rp7.ffg.at/upload/medialibrary/cooperation_intro_wp_200701_en44564.pdf

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14 Finland

1.0 Introduction

Energy in Finland is generated using a high share of renewables, mainly hydropower and biomass. Finland's generating capacity is diverse: In 2006, 26% of gross demand was produced by nuclear, 13% by hydropower, and 31% 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 sites available. In the existing distribution network, the short-term potential on the coastal areas of Finland is more than 300 MW. 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 2001 National Climate Strategy, targets for wind-power deployment in Finland were set at 500 MW in 2010. In the new energy and climate strategy approved in 2006, only the target for RES was set: 31.5% of the total electricity consumption in 2010. The parliament required that RES-specific programs be made, so targets for wind power may be expected in the future. No major changes in measures to achieve the targets were suggested by the new national energy and climate strategy. A feed-in law for peat production was passed in 2006, so a feed-in tariff system for wind-, solar-, and wood-based electricity production will probably be discussed more after the parliamentary election in spring 2007.

Progress in wind-power capacity has been slow compared with the goals. The funds available for investment subsidies are inadequate to achieve any large increases in wind-power capacity. With the existing support mechanisms, only 200 MW to 300 MW of wind-power capacity is foreseen for 2010.

The development in wind-power capacity and production is presented in Figure 1. Two new turbines totaling 4 MW were installed, bringing the total capacity to 86 MW at the end of 2006. Total wind energy production in 2006 did not show growth due to poor wind resource compared with 2005. The production of 154 GWh corresponds to 0.2% of the annual gross electricity consumption of Finland.

There were 96 wind turbines in operation in Finland at the end of 2006 (Figure 2). Average wind turbine size is 900 kW. About 60% of the capacity originates from Denmark, 23% from Finland, and

Table 1 Key Statistics 2006: Finland

Total installed wind generation	86 MW
New wind generation installed	4 MW
Total electrical output from wind	0.154 TWh
Wind generation as % of national electric demand	0.2%
Target:	31% share of RES electricity in 2010 (earlier target 500 MW for wind power has been removed)

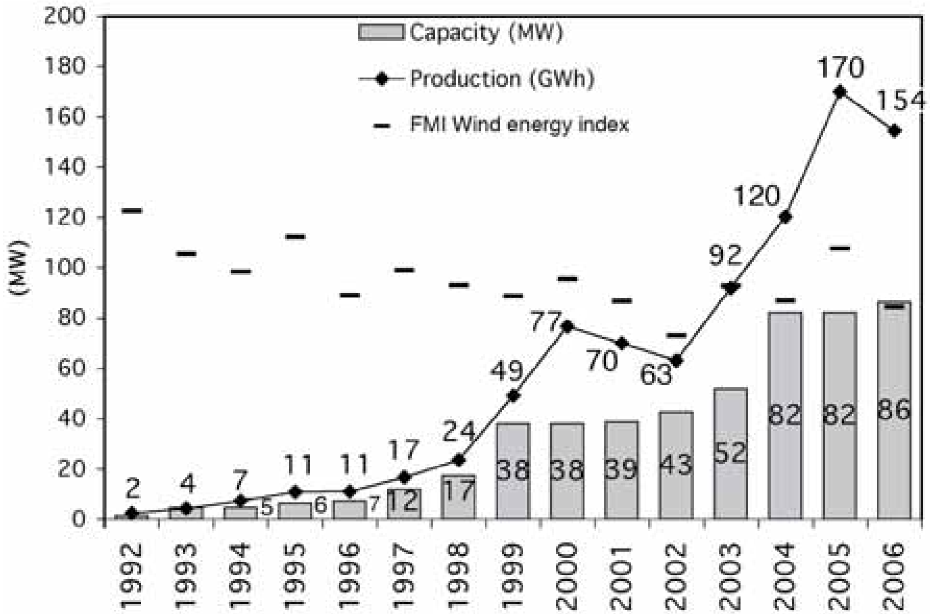

Figure 1 Development of installed wind power capacity (MW) at end of year, yearly wind power production (GWh), and wind production index (calculated from Finnish Meteorological Institute wind-speed measurements converted to wind power production, 100% is average production for 1987–2001).

17% from Germany. The size of the installed capacity ranged from 75 kW to 3 MW.

Several projects are in the building phase, so 40 MW are expected in 2007. In addition, more than 100 MW of projects are planned. The largest projects are in Pori (offshore demonstration; 45 MW in planning phase), Kemi (partly offshore; 30 MW in 2007 and 2008), and Tornio (28 MW in 2008).

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. Wind energy is expected to cover 10% of electricity consumption in the region by 2006. This figure stood at 7% in 2006, but when the 12-MW semi-offshore project in Båtskär currently under construction comes online, the share will be about 20%.

The environmental benefit of wind power production in Finland exceeded 100 million tons of CO_2 savings per year in 2005.

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. 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–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 that offshore projects are starting to interest the power companies. The two first semi-offshore projects are to be built in 2007 (six 2-MW turbines in Åland Båtskär (Figure 3) and five 3-MW turbines in Kemi (Figure 4), and the first demonstration project in Pori is in the planning phase (45 MW).

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 2004 in Oulu. The turbines operate at variable speed and have a slow-speed planetary gearbox and a permanent-magnet generator. WinWinD has manufactured 23% of all turbines in Finland (20 MW) (Figure 5). WinWinD

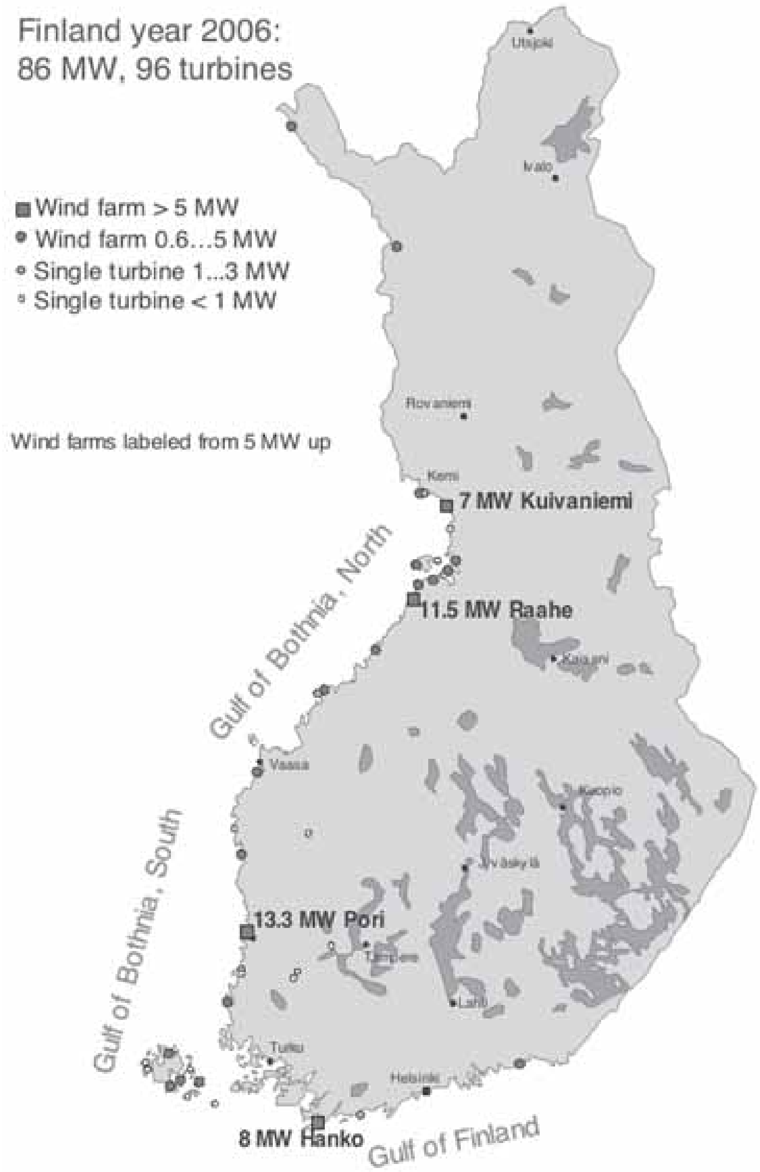

Figure 2 Locations of wind turbines in Finland at the end of 2006.

started its export activities in 2004, selling turbines to Portugal and Sweden. In 2005, a joint venture in China was founded, and the first demonstration turbine was erected. In 2006, their production capacity was raised to 40 MW/yr, a 24-MW project in Estonia was in the building phase, and projects in the Czech Republic and France were announced. In 2006, a capital investment firm from India, Sterling Infotech Group, became the largest single shareholder of WinWinD with an ownership share of 40%. In early 2007, the Indian company took over the majority of the company.

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 biggest 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. A new assembly plant for wind turbines and compo-

Figure 3 Building the foundations on the cliffs and small islands in Åland archipelago, Båtskär (Photo: Henrik Lindqvist).

Figure 4 Photo montage of the semi-offshore wind farm in Kemi, where ten 3-MW turbines are to be built in 2007 and 2008. The existing 3-MW power plant can be seen as the left-most turbine (Photo: H. Wallas).

nents was launched in 2005 by Hollming in Loviisa. The 3-MW turbines of WinWinD, as well as direct-drive generators for Rotatek, 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 270 million € in 2005; for 2006, the estimate exceeds 300 million € (Figure 6).

The manufacturing industry has formed a branch group under the Association of Metal Industries, now called Technology Industries in Finland, to promote technology development and to export wind technology.

The benefit to the national economy was estimated by the wind technology manufacturing industry under Technology Industries in Finland 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 € per year in 2020 and creating 18,000 new jobs. According to this scenario, total investment for wind power in Finland would be 100 million € per year 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 (Figure 7). The average capacity factor was higher between 2000 and 2006 than it had been in the 1990s, even though the FMI wind energy index has been lower in recent years. This improved production is mainly because more megawatt-scale machines are reaching a higher wind resource.

Average availability of the wind turbines operating in Finland was 94% in 2006 (95% in 2005). Two turbines were available for very limited amounts of time (37% and 60%) due to blade problems. Other causes for longer failures were repairs of gearbox, network connection, and control unit. In 2006, there were more gearbox failures than usual—a total of 9 out of the 96 turbines in Finland.

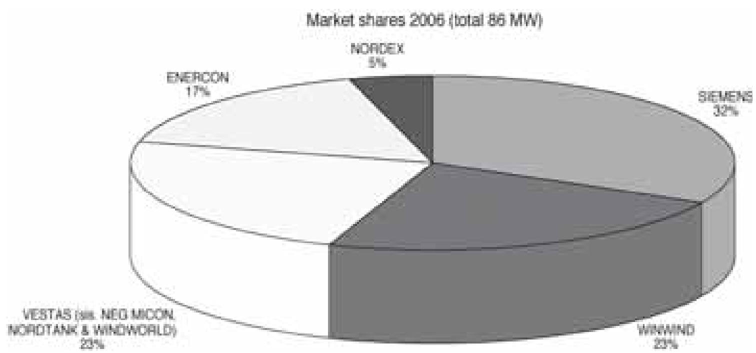

Figure 5 Market shares of turbine manufacturers in Finland as a percentage of the total capacity at the end of 2006 (86 MW).

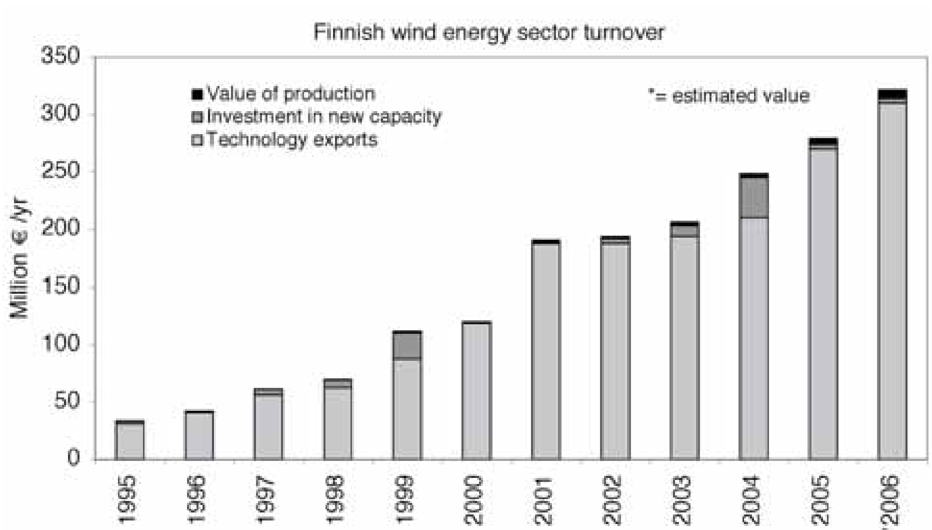

Figure 6 Finnish wind-sector turnover: wind power technology exports, investments, and production turnover. Turnover from electricity production sales has been estimated from the average spot price.

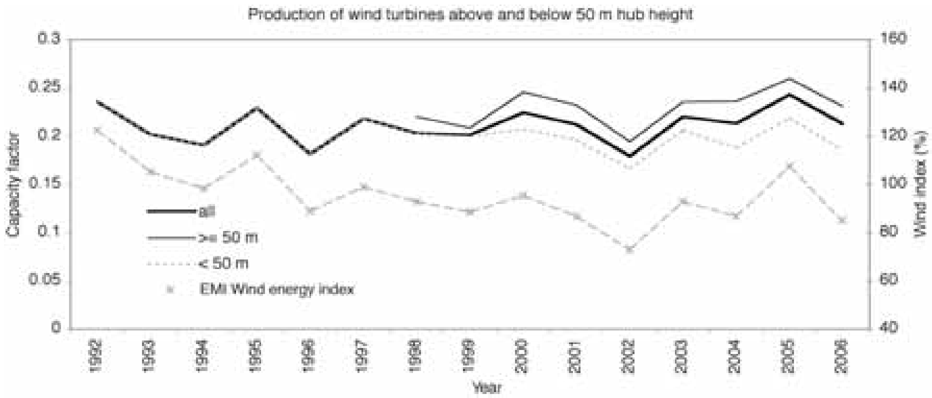

Figure 7 Average capacity factor of wind turbines in Finland for all turbines and for higher- and lower-hub-height turbines. The production index calculated from FMI wind-speed measurements is also shown (100% corresponds to average production in 1987–2001).

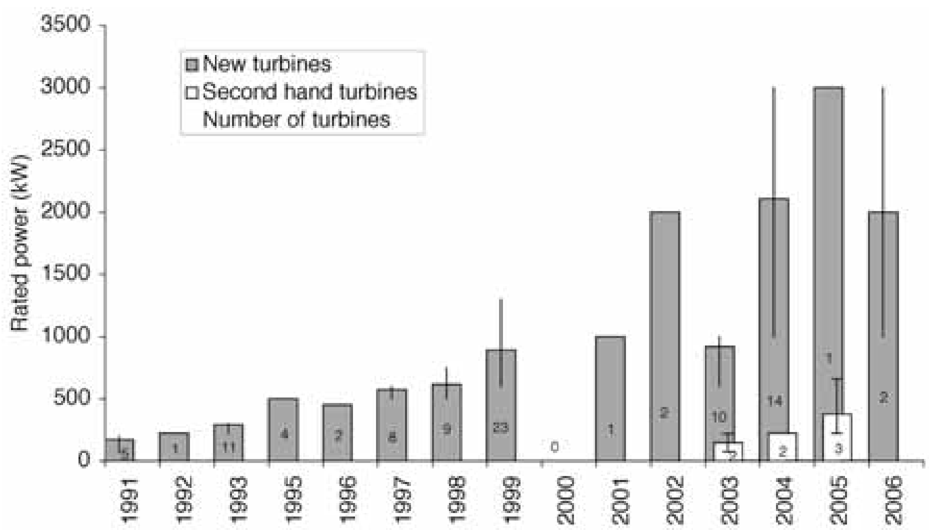

Figure 8 The average size of installed capacity (rated power in kilowatts) is indicated by the bar (for new and second-hand turbines). The number of installed turbines is marked in the bars. The vertical line represents minimum and maximum capacity of turbines installed.

This exceeded the average failure rate during the five previous years.

3.3 Economic details

At a good site on coastal Finland, the cost of wind energy production could be about 45 €/MWh to 65 €/MWh without investment subsidy (15 years, 7% internal rate of return) (Figure 9). The average spot price in the electricity market Nordpool was 27 €/MWh to 31 €/MWh in 2004–2005 and rose to 49 €/MWh in 2006 (Figure 10). Emission trade effects on the operating costs of thermal power have resulted in an increase of spot market prices; however, wind power can still only compete with the best available sites. In January 2007, the average spot price dropped to below 30 €/MWh for the first time since September 2005. This was due to improved hydro resources as well as to a drop in emission permit prices.

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. The average price for green or wind electricity is about 5 €/MWh higher than the average price of standard electricity for households, but it is possible to switch from a standard electricity supplier to a cheaper wind electricity supplier. The market success for these initiatives has, however, been modest. Only a few percent of household consumers have changed electricity suppliers at all since the electricity market liberalization.

If the impacts of emission trading continue to raise electricity market prices, this will improve the cost competitiveness of wind power and will also make it realistic to develop sites with a less-favorable wind resource. Also, a possible feed-in tariff for wind energy would 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 (Figure 11). Projects that applied for a subsidy between 2001 and 2006 received an investment subsidy of 35% on average. In addi-

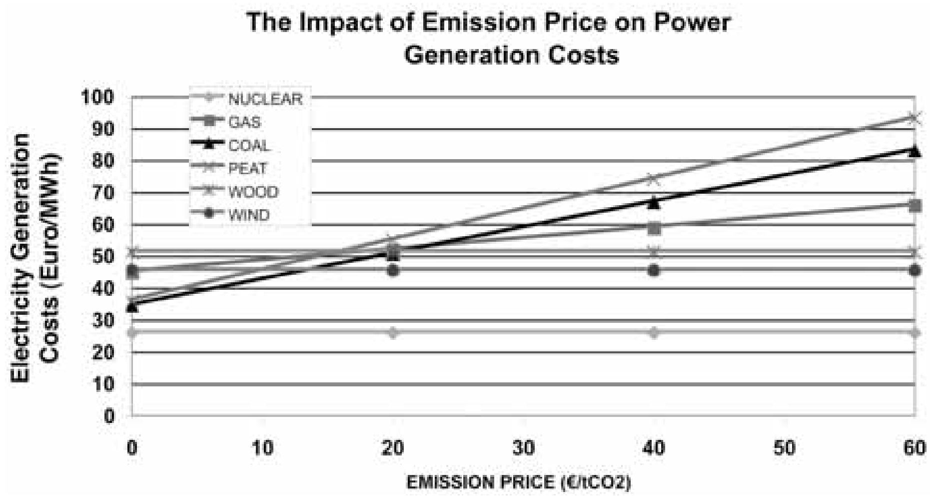

Figure 9 Comparison of costs from wind and other sources in Finland. Assumptions for wind generation: production 2,200 MWh/MW/yr; O&M costs 0.01 €/kWh; annuity 25 years and 5%. Source: Risto Tarjanne, Lappeenranta Technical University, 2006.

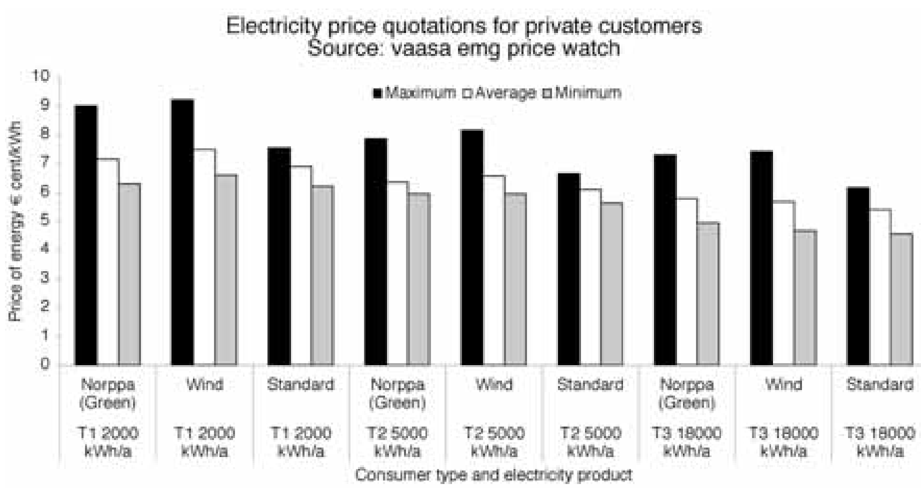

Figure 10 Electricity prices for private customers. Norppa denotes green electricity from a variety of renewable sources such as biomass, small hydro, and wind. Customer classes are T1 and T2, single-family house; T3, single-family house with electrical space heating.

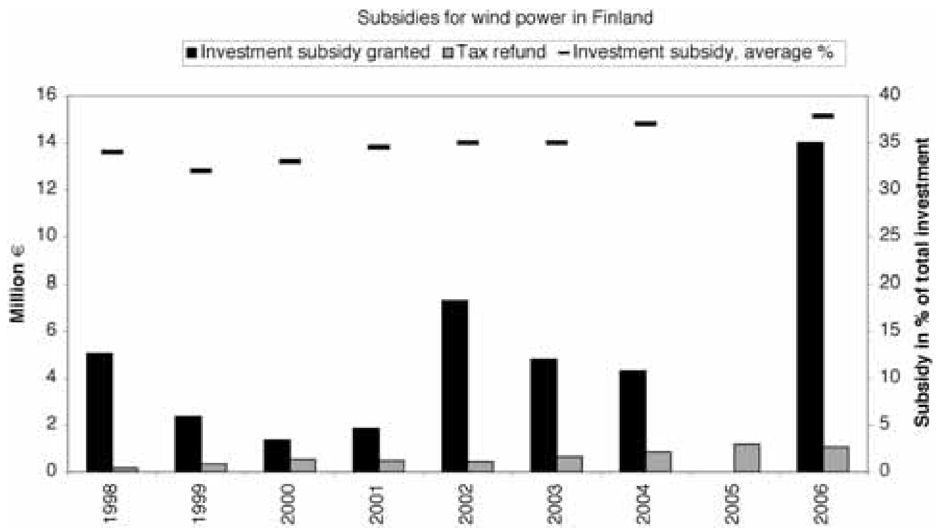

Figure 11 Investment subsidies granted for wind power and the total amount of tax refunds for wind electricity in Finland. The average investment subsidy as a percent of total investment costs is also shown. Most of the capacity granted with investment subsidies in 2006 (total 25 MW) will be built in 2007.

tion to the investment subsidy, a tax refund of 6.9 €/MWh is awarded. This corresponds to the tax on electricity paid by household consumers.

The national energy and climate strategy was updated in 2006. The target for electricity production from RES in Finland is 31.5% of gross demand; this is the same as in the European Union RES-E-Directive on national objectives concerning electricity produced from renewable energy sources. This target requires electricity production with renewable energies to increase by 8.3 TWh from the 1995 level. The major part, 75%, would be generated from biofuels. No major changes in measures were suggested. The wind-specific target was dropped; however, the parliament resolution requested that this has to be done in 2007.

Wind energy deployment is slow, 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 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 Gulf of Bothnia, north (about 4,000 MW), and the Gulf of Finland, west (about 200 MW). The planning process is ongoing for the Gulf of Bothnia, south, and the Gulf of Finland, east.

An addition to the electricity market act proposes a ceiling to the distribution network charges for distributed generation, including wind. Also the act proposes that grid reinforcement payments be borne by the consumers, not by the producer. The charges vary across the country and in some areas hinder local generation. Parliament approved the new act in February 2007.

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 12). 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) (2003–2007) contains wind-related research projects on the grid connection of distributed energy systems (protection, voltage regulation) and on storage of energy from distributed energy systems. National projects for collaboration with IEA Wind Tasks 19, 21, 24, and 25 are under the DEN-

SY program. The technology program CLIMBUS (Business Opportunities in Mitigating Climate Change) (2004–2008) aims to develop technology and business concepts related to reduction of greenhouse gas emissions.

The first short-term forecasting project by Foreca, VTT Technical Research Centre and Cybersoft showed the benefits of grouping wind farms along the coastline; dispersing the sites reduces forecasting errors. Forecast errors from day-ahead forecasts result in deviations in the bid amounts of production to the electricity markets. For the deviations, imbalance costs have to be paid. A case study of imbalance cost that was paid for by a Finnish wind producer with four sites showed a price of 1.5 €/MWh (2004 prices) when predicting production without meteorological forecasts and 0.8 €/MWh when predicting production on the basis of meteorological forecasts. The imbalance price is quite low compared with international experience and is due to the well working Nordic imbalance market resulting in low prices. Also the low amount of wind power in Finland means that wind-power production does not affect the overall power system imbalance and the amount up or down regulation used in the balancing market.

A project titled Demand for Finnish Energy Technology and Business Opportunities in Global Markets used the GlobalTimes model to analyze cost-optimal scenarios for future energy systems that are trying to achieve the CO_2 reductions needed to limit global temperature increase to 2°C. The role of wind power in electricity generation grows rapidly in these scenarios, and production could reach an annual rate of 3,000 TWh/yr by 2030 (Figure 13).

There are also several enterprise projects for technology development. WinWinD has developed 1-MW and 3-MW turbines for different weather conditions. ABB has developed a direct-drive multipole permanent-magnet wind turbine generator. Rotatek Finland and Verteco (The Switch) are developing multi-megawatt generators and modular series-connected frequency converter. Pem-Energy Oy is producing small wind turbines for rural and off-grid areas as well as for single-family houses, farms, and summer cottages. Pem-Energy's wind turbine has a rotor diameter of 3.2 m and produces 1.6 kW in 7 m/s wind. Production starts at low winds less than 2 m/s. A new turbine with a 1.5-m rotor is under development. Oivallin has developed an embedded condition-monitoring system to be used in wind turbines. The product is designed to be installed as an operations and maintenance product by a wind turbine or gear manufacturer. The system includes intelligent sensors, a master unit with Internet connection, and server technology.

As part of its strategic research program on Smart machines (2002–2006), VTT has developed technologies, components, and solutions for large wind turbines. As an example, technologies to control the shape of composite structures have been developed at laboratory scale.

5.2 Collaborative research

The VTT Technical Research Centre of Finland has been active in several international collab-

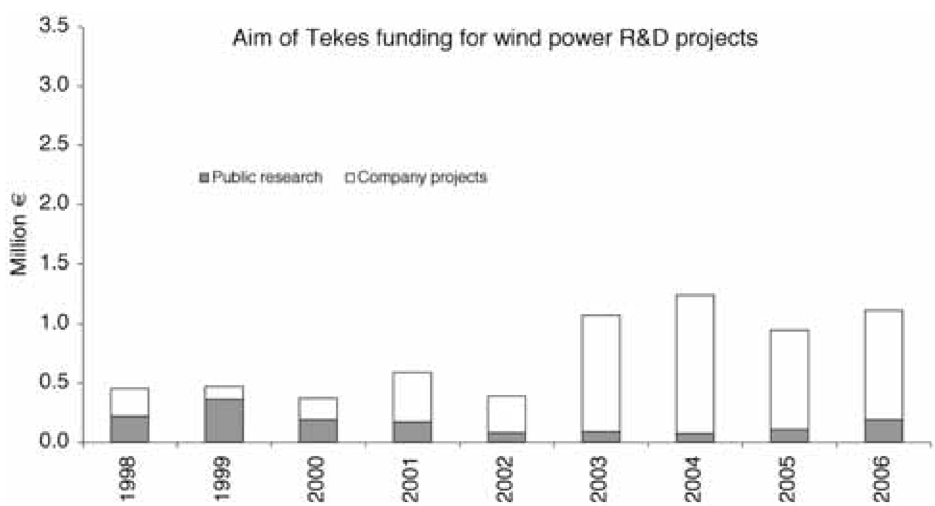

Figure 12 Development of R&D funding for wind power in Finland: Tekes funding and total funding.

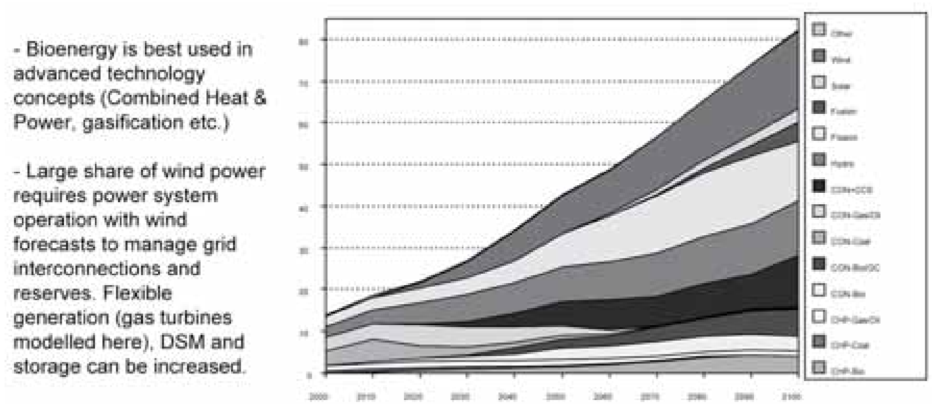

Figure 13 Results from simulating a cost-effective optimized global electricity production when restricting CO_2 emissions

orative 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 UPWIND and TRADEWIND, which started in 2006.

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

The work of Tasks 21, 24, and 25 is 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. There are about 20 MW currently in the building phase, and in 2007 up to 40 MW of new capacity will be added. In addition, projects totaling more than 100 MW are in various planning phases in Finland. About 200 MW of the huge offshore potential could be realized before 2010. 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.

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

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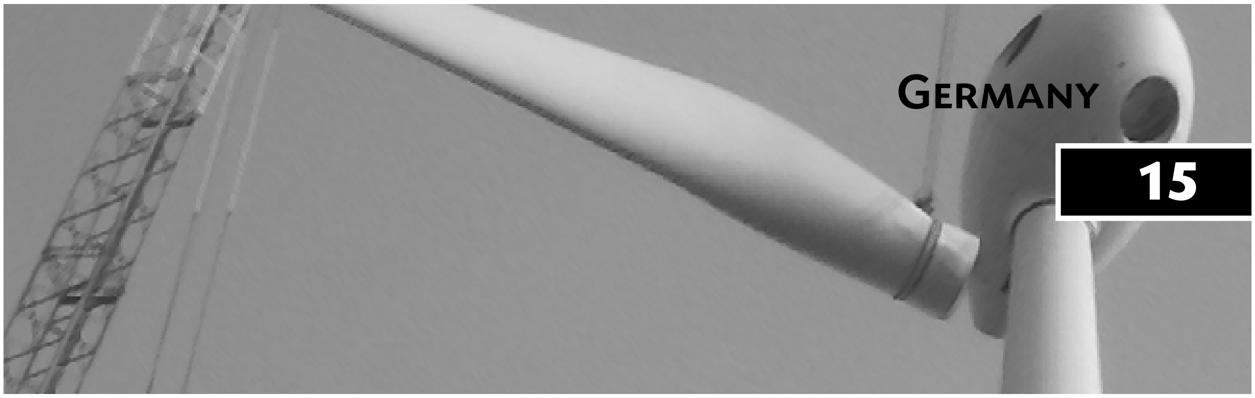

Germany 15

1.0 Introduction

Against the predicted trend in market development, new installed onshore wind power in Germany grew again in 2006 to a level higher than it had been two years earlier. Installed power increased by 23.5% in comparison to 2005. At this stage, wind energy is potentially able to produce 7.0% of German annual net electrical energy consumption. Irrespective of a relatively weak wind supply over the year, energy production in 2006 amounted to 30.5 TWh. This is an increase of 12.5% over 2005. Installed capacity exceeded the 20,000-MW mark (Figure 1).

Wind energy is the leading renewable energy in Germany with a share of 5% of national final electrical energy consumption. It is followed by hydropower (3.5%) and electrical energy conversion from biomass (3%). The wind industry is further 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. At least 70,000 employees are working in the wind energy industry to date.

Although offshore development in Germany is currently behind the strategic goal set by the government in 2002, medium- and 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 were taken in 2006 toward meeting these targets. Federal authorities have identified suitable areas for offshore wind farms in the North Sea and Baltic Sea, making planning easier for investors. The Infrastructure Acceleration Act came into force at the end of 2006. The law improves conditions for investors in offshore wind because it obligates transmission system operators to pay for and install the grid connection from the onshore grid access point to the offshore wind farm. In addition, relevant research projects flank the legislative improvements. The main activity is to establish an offshore test site in the North Sea. Also of importance is the erection of two more offshore research platforms and further developments to adapt multi-megawatt turbine technology to offshore conditions.

The leading federal state in Germany in wind energy deployment is Lower Saxony, with 5,282 MW installed and potentially 10.0 TWh produced in 2006. In three German states–Saxony-Anhalt, Schleswig-Holstein, and Mecklenburg–Western Pomerania in the northern lowlands–more than 33% of the energy consumed is provided by wind. In the two southernmost states, located nearly in the center of Europe, wind provides about 0.5% of the energy consumed (1).

Repowering is still behind its technical possibilities but became for the first time a visible factor with 135 MW in 2006.

Table 1 Key Statistics 2006: Germany (1,2,3)	
Total installed wind generation	20,622 MW
New wind generation installed	2,233 MW
Total electrical output from wind	30.5 TWh
Wind generation as % of national electric demand	5%
Target:	12.5% from renewable energy (RE) in 2010 (status in 2006: 12% from RE)

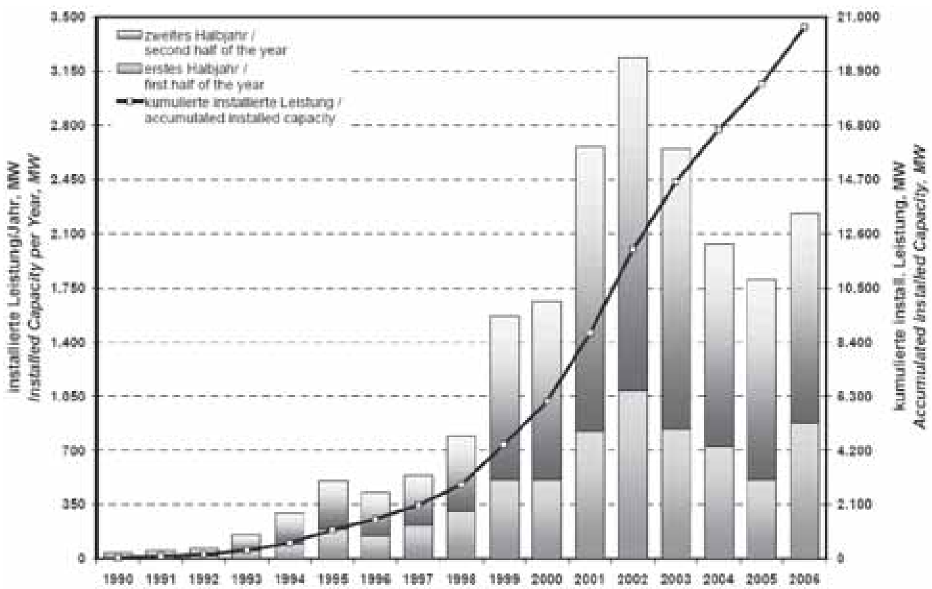

Figure 1 Development of the yearly and total installed capacity, DEWI.

2.0 Progress toward national objectives

The German government acknowledges the importance of renewable energies, and in this regard national policy was generally continued. The legislative framework was improved in 2006 with respect to offshore wind energy (see Section 1.0). The use of renewable energies continued to rise in 2006. Their share in primary energy consumption increased from 4.7% in 2005 to approximately 5.8% in 2006. The contribution by wind to total final energy supply (electricity, heating, fuels) increased to 7.4%.

Renewable energies accounted for 12% of the electrical energy consumption in 2006, compared with 10.4% in 2005—an increase of 15%. According to EU targets, 12.5% of consumption is to be met by renewable energy sources in Germany by 2010 (4). It is realistic to expect that this target will be surpassed in 2007 (Tables 1 and 2).

3.0 Benefits to national economy

German turbine manufacturers participated in the growing world wind market. Some manufacturers doubled their production capacity in 2006. Further new production capacity for 5-MW-class turbines is under construction. Generally, turbines with a capacity of less than 2 MW are increasingly difficult to place in the market. The number of employees in the wind industry has grown continu-

Table 2 Additional data about wind energy deployment in Germany at the end of 2006 (1, 2)

Number of turbines	18,685
Number of new turbines in 2006	1,208
Potential energy production	38.8 TWh
Potential part of German net electrical energy consumption	7.0% *
Total German net electrical energy consumption	540 TWh**
CO_2 reduction in 2006	26.1 Million t.
* Estimation	
** According VDEW	

ously during past years (Figure 2) and was at 70,000 in 2006.

The total contribution of the wind sector to the German economy (wind sector turnover) in 2005 amounted to about 7.3 billion €. The value of domestic manufacturing, taking into account turbine and component suppliers, was 4.8 billion €. Detailed economic data for 2006 will be published in July 2007.

The four leading manufacturers on the German market for turbines installed in 2006 were Enercon, Vestas, REpower Systems, and GE Energy (Table 3) (1).

4.0 National incentive programs

The Renewable Energy Sources Act (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 0.0836 €/kWh to the turbine owner for turbines installed in 2006 at least for five years (0.0853 €/kWh for turbines installed 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 2006 ranges from 0.0836 €/kWh to 0.0605 €/kWh. The EEG requires the starting tariff to be reduced by 2% yearly. A turbine installed in 2007 will therefore receive a starting tariff of 0.0819 €/kWh. Special tariffs exist for onshore repowering and for offshore wind farms. The EEG will be audited in 2007 to adapt prices for renewables to new market conditions and technological developments.

5.0 New R, D&D activities

Applied research in the field of renewable energies (except for biomass) is overseen by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Project Management Jülich (PtJ) is in charge of managing and controlling the wind energy research program on behalf of BMU. In 2006, BMU started 24 wind energy–related projects with a total of 16 million € for the years 2006 through 2009. The funds for ongoing projects for 2006 amounted to 9.6 million € (Figure 4).

A new announcement for proposed research in the field of wind energy published in September 2006 focused on cost reduction; improved reliability; optimization of maintenance; grid integration; and specific technologies for offshore such as foundations, logistics, and reduction of environmental impacts (5). Of special interest in the field of offshore wind energy are demonstration and test activities.

Among other research topics, the subject of grid integration of wind energy became increasingly important. A new research network is dealing with the storage of wind energy in underground air-pressure storage areas in combination with the energetic deployment of low concentrated North Sea gas resources. Existing underground holes resulting from former salt mines and ore mines are being evaluated concerning their availability as air-pressure storage areas for the intermediate storage of wind energy.

A relevant cost factor especially for offshore wind energy utilization in deep waters is the foundation. A new research network of steel and pipe companies, the offshore construction industry, a turbine

Figure 2 Employees in Germany's wind industry.

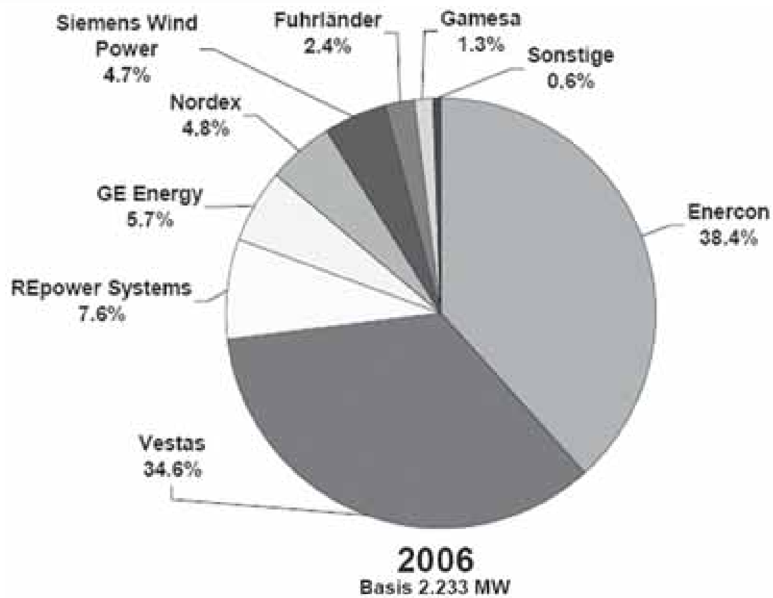

Figure 3 Market share of turbine manufacturers in Germany, DEWI

Table 3 Leading manufacturers for turbines installed in 2006

Company	Market share 2006 (%)	Market share 2005 (%)
Enercon	38.4	41.7
Vestas	34.6	26.8
REpower Systems	7.6	5.5
GE Energy	5.7	8.1

manufacturer, and research institutes was launched in 2006 to work toward the optimization of tripod and jacket foundations. The aim is to optimize the use of materails, the onshore and offshore construction process, and to improve the technical reliability of foundations.

Offshore installation and transport are becoming a bottleneck for Europe's offshore construction activities. Specifications for new offshore transport and construction equipment have been evaluated in a project of the offshore construction industry. The assumptions are for the markets of the Irish Sea, the North Sea, and the Baltic Sea by the middle of the next decade to be 2,500 MW/yr and 550 foundations/yr. Effective equipment should be available at least 75% of each month regardless of weather. Specifications for new equipment have been formulated on the basis of these assumptions.

So far, no German test facility has existed for rotor blade manufacturers to conduct static and dynamic tests of multi-megawatt turbine rotor blades. In 2006, such a test center was launched at the Fraunhofer Center for Wind Energy and Marine Technologies in Bremerhaven, and it will start its work in 2008.

Germany continued bilateral cooperation with Denmark on ecological research in 2006. Common projects investigated harbor porpoises and birds at the two Danish offshore wind farms Horns Rev and Nysted. A new project of the German Marine Museum Stralsund and the Danish National Environmental Institute is to develop standardized methods for the calibration and signal analysis of porpoise hydrophones (PODs). In related work, temperature measurements at the sea bottom above the 110-kV cables of the Nysted wind farm showed no dominant influence by the cable on the tempera-

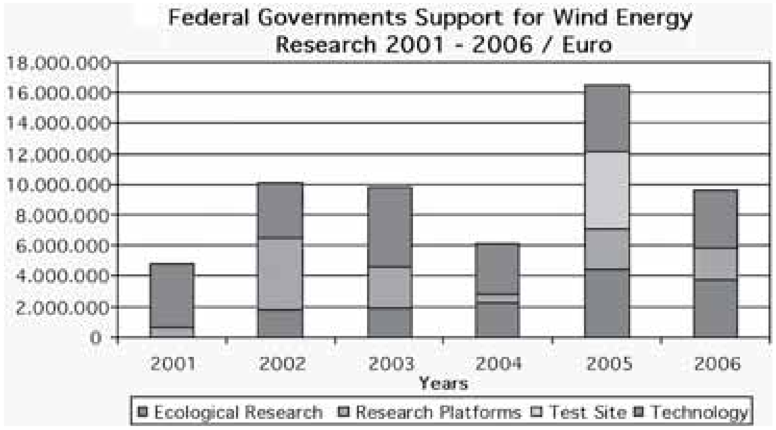

Figure 4 Government funds for wind energy research.

ture of the sediment surface layer above the cable. Compared with a reference site far from the cable, the temperature did not exceed the 2-K threshold at a sediment depth of 20 cm.

5.1 Offshore test site

According to the approval documents of the demonstration offshore wind farm Borkum West (which is near the research platform FINO 1 (www.fino-offshore.de) in the North Sea), a test site will consist of 12 turbines of the 5-MW class. The demonstration project will be operated by the German Offshore Test Site and Infrastructure Ltd. (DOTI), which was launched by the power companies Vattenfall Europe, E.on, and Energiewerke Weser Ems (EWE).

Much effort has been made to establish a comprehensive research program at the German

Figure 5 REpower 5M installed on a jacket foundation in the Scottish North Sea in August 2006. Source: REpower Systems Inc.

offshore test site. Project proposals concerning offshore-specific aspects of generators, gears, and rotor blades as well as investigations of external conditions, grid aspects, and condition monitoring have been evaluated and are in the planning phase. The main research topics have been agreed to by the future operator, and progress has been made in preparing for potential research activities. Test site research will be conducted as a collaborative program of research institutes and industry ranging from basic aspects to demonstration of new technologies as well as accompanying ecological research.

5.2 Multi-megawatt turbine prototypes

Two new multi-megawatt prototype turbines were tested in Germany in 2006. The DeWind Ltd. 2-MW type D8.2 was erected in the near-shore test site of DEWI-OCC in Cuxhaven. The low rotor speed is converted to a constant rotation speed, and the resultant current of the synchronous gen-

Figure 6 M5000 construction on shore in Bremerhaven at an offshore tripod foundation. Source: Multibrid Entwicklungsgesellschaft Ltd.

erator can be directly fed into the electrical grid (6). Another new 2.5-MW prototype is the Fuhrländer FL 2500-100. The first turbine was erected on a 160-m tower manufactured by Seeba. Another eight turbines will be installed in 2007 on 100-m steel towers (6).

Work continued with other large turbines. The Enercon company installed two E 112/6-MW turbines, an enhancement of the E 112/4.5-MW turbine. Special features are the gearless generator and a wide range of usable wind velocities. A REpower 5M was erected in 2006 in the Scottish Sea (Talisman Beatrice Gas Field project) (Figure 5). And two REpower 5MW were erected in November 2006 at the DEWI-OCC near the coast test site in Cuxhaven. A third type of wind turbine in the 5-MW class is the Multibrid Entwicklungsgesellschaft Ltd M5000 (Figure 6). The second M5000 was erected in 2006 near the coast in Bremerhaven on a tripod foundation. This will allow researchers to study how loads affect the overall construction of turbine, tower, and foundation. Results of such onshore experiments will contribute to the optimization of the future serial production of tripod foundations (7). A special feature of this turbine type is the relatively low weight (440 tonnes) of the gearbox and rotor. Finally, a newcomer on the multi-megawatt market is BARD Engineering Ltd. The BARD company is pushing the development of a new 5-MW turbine to be erected in mid-2007 at the company's own near-coast test site. BARD has also developed a new foundation type called "multipile" designed for water depths from 25 m to 50 m.

5.3 Scientific measuring programs

Final results from the Scientific Measuring and Evaluation Programme (WMEP) were presented in 2006. WMEP developed 63,000 reports detailing energy output data; operation experiences; and data about damage caused by lightning, storms, ice, and grid failures. The data were collected from 1,500 wind turbines together with wind data at 60 locations. This unique database will be extended to future offshore wind farms starting with the above-mentioned test site.

The research platform FINO 1 (www.fino-offshore.de) in the North Sea has been in operation for more than three years. Wind, wave, and load data are now available online (http://fino.bsh.de). FINO 1 will become still more important for offshore wind energy research after the offshore turbine test site is established there.

FINO 2 (www.fino2.de) is located in the Baltic Sea at the borders of the German, Swedish, and Danish EEZ. The monopile foundation was rammed in October 2006. Offshore installation of the deck and the measuring mast will occur in June 2007.

FINO 3 (www.fino3.de) will be commissioned in summer 2008 in the northern part of the German EEZ of the North Sea about 70 km west of Sylt Island. A special focus of FINO 3 will be geophysical investigations concerning interactions between sediment and monopile and lightning on the open sea and its possible impact on turbine components.

FINO 2 and FINO 3 will be constructed as monopiles. The wind measuring systems of all three platforms are based on the same principles to make the data comparable. All data will be available online at http://fino.bsh.de.

6.0 Next-term activities

The Second Scientific BMU Conference on Offshore Wind Energy Deployment took place in February 2007 in Berlin prior to the European Policy Seminar on Offshore Wind Energy Deployment. It focused on ecological aspects. In conjunction with the BMU-Conference, an IEA topical expert meeting on offshore wind and waves measurements was organized by the IEA Wind Energy Agreement and the FINO 1 team (Germanischer Lloyd Industrial Services Ltd., commissioned with operation and maintenance by BMU).

A kickoff presentation of the offshore test site research network is planned for spring 2008.

The European Policy Seminar on Offshore Wind Energy Deployment proposed the extension of the Danish-German Agreement to a other interested states. Germany, Denmark, and Sweden are in discussion to formulate such an agreement.

7.0 References

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

Greece

16

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 are to exploit the country's abundant wind potential to minimize CO_2 emissions and to replace expensive imported fuel currently used to produce electricity in much of the Greek territory.

In June 2006, the Greek government's Ministry for Development introduced new legislation, Law 3468 for the Generation of Electricity Using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat (Official Gazette A' 129/27.06.2006). The most important provisions of the law are the increase of the feed-in tariffs, the extension of the duration of the power purchase agreement to 20 years, and the reduction of bureaucratic obstacles.

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 renewable energy equal to 20.1%, with the contribution of large-scale hydroelectric plants included. This target is also compatible with the international commitments of the country resulting from the Kyoto Protocol. Based on expected electricity consumption in 2010, production of electric power from renewable energy sources on the order of 13.7 TWh (including large-scale hydroelectric plants) is set as the goal for 2010. To meet these goals, the installed capacity of wind farms should reach the level of 3,370 MW, and the corresponding energy generated should be on the order of 7 TWh. According to the most recent estimates (Third National Report Regarding the Penetration Level of Renewable Energy Sources Up to Year 2010, October 2005), the gross consumption of electric power in Greece in 2010 will reach the level of 68 TWh.

In 2006, the installed capacity of the wind turbines reached 749 MW, showing an increase over the previous year of 24%. In eight separate projects, 124 wind energy conversion systems with an installed capacity of approximately 142 MW were connected to the electricity supply network. According to the Third National Report cited in the previous paragraph, the current estimate of wind energy capacity in 2010 ranges between 2,100 MW (conservative scenario) and 3,270 MW (optimistic scenario). Development of wind energy during the past 10 years is shown in Figure 1, which depicts the total installed capacity per year.

The energy produced from wind turbines during 2006 was approximately 1,580 GWh. The energy produced in 2005, 2004, 2003, 2002, 2001, and 2000 was 1,270 GWh, 1,120 GWh, 850 GWh, 650 GWh, 756 GWh, and 460 GWh, respectively. Figure 2 shows the electricity produced from wind turbines during the past ten years.

Table 1 Key Statistics 2006: Greece	
Total installed wind generation	749 MW
New wind generation installed	142 MW
Total electrical output from wind	1.58 TWh
Wind generation as % of national electric demand	3%
Target:	3,370 MW

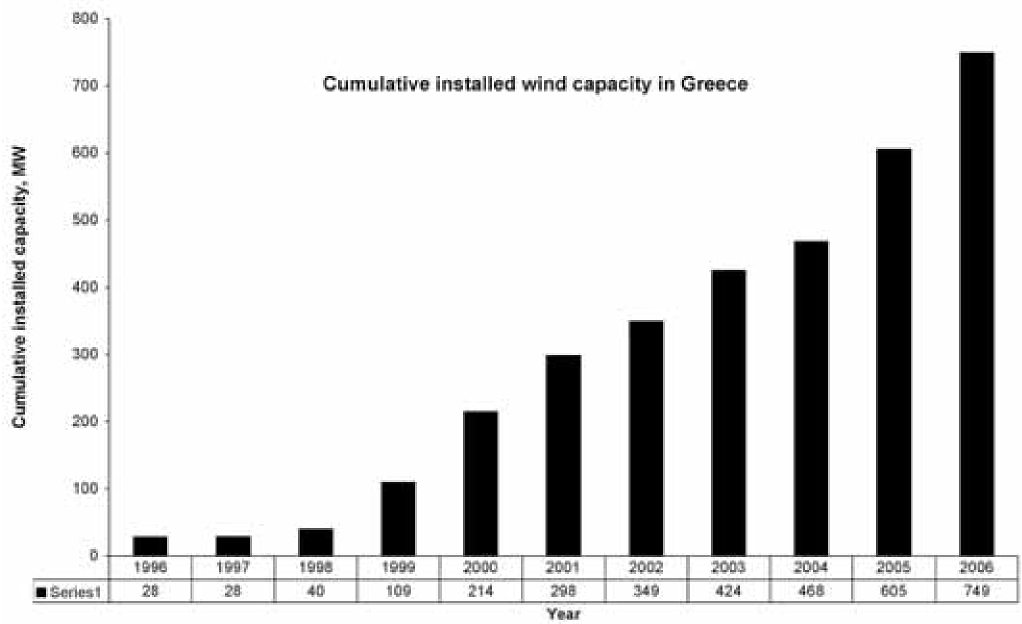

Figure 1 Cumulative installed wind capacity in Greece

3.0 Benefits to national economy

3.1 Market characteristics

There is increasing interest, 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 having poor infrastructure, where some of the most promising sites for wind energy development can be

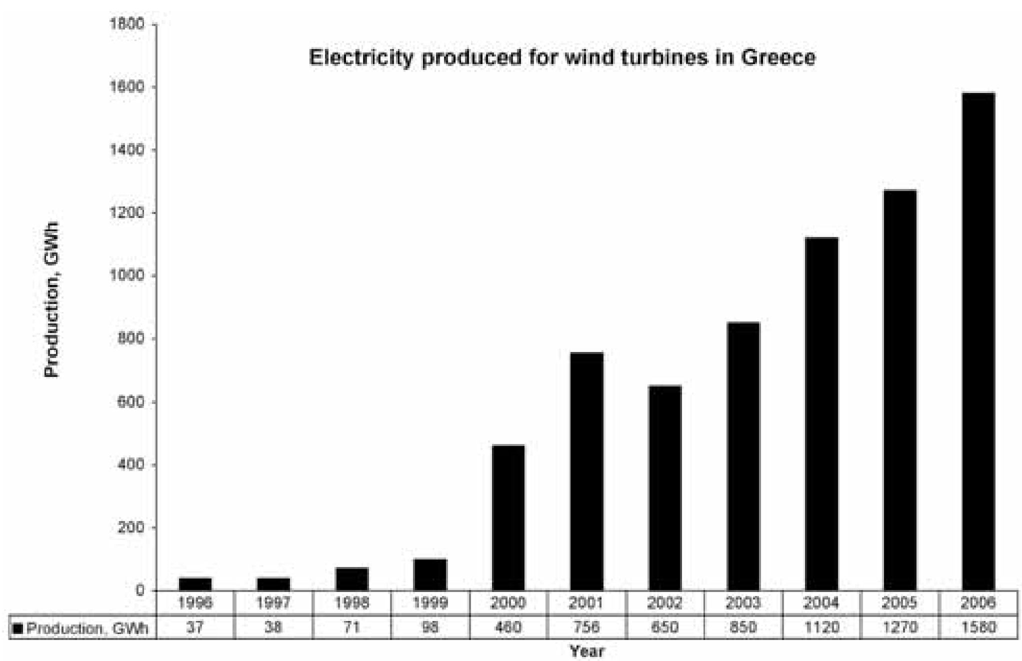

Figure 2 Electricity produced from wind turbines in Greece

found. Although manufacturing of wind turbines has not been established in Greece, there would be 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 would be 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, and these firms are 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 throughout Greece is depicted in Figure 3.

3.2 Industrial development and operational experience

No significant manufacturing developments occurred in 2006 apart from the continuing involvement of the Greek steel industry in wind turbine tower manufacturing.

The average capacity of the wind turbines installed in 2006 was 1,146 kW, while the average capacity of all the wind turbines operating in the country was 712 kW (Figure 4). Market share per manufacturer is depicted in Figures 5 and 6.

Due to the relatively short operation periods of most wind energy projects, limited malfunctions have been reported since their commissioning; these have been mainly related to gearbox failure and lightning strikes. No major events 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. This cost varies between 900 €/kW and 1,100 €/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 €/kWh and 0.047 €/kWh, depending on the site and project cost. The typical interest rate for financing wind energy projects ranges between 6% and 8%.

The power generation system in Greece is divided into two categories: the so-called intercon-

Figure 3 Distribution of installed wind farms in Greece

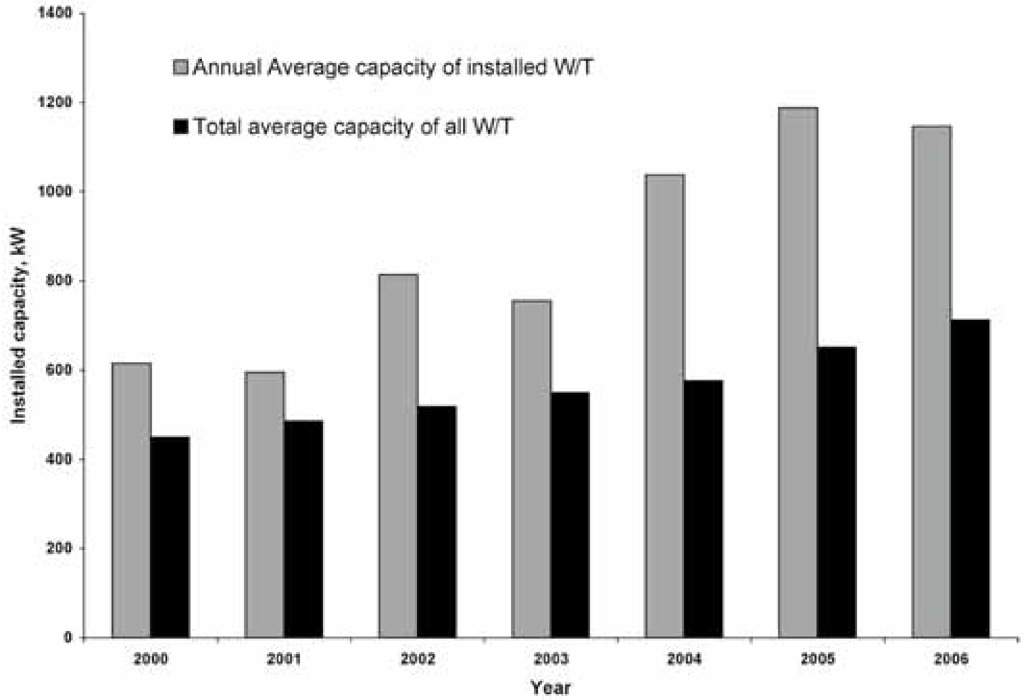

Figure 4 Average capacity of the wind turbines installed in 2006 and operating in the country

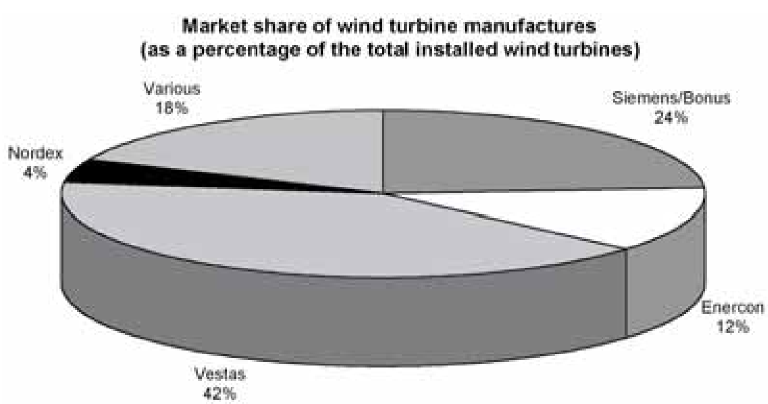

Figure 5 Market share of wind turbine manufacturers (as a percentage of total installed wind turbines)

Table 2 Energy tariff

Type of electric energy production	Mainland interconnected system (€/MWh)	Non-interconnected autonomous power plants, islands (€/MWh)
Wind onshore	73.0	84.6
Wind offshore	90.0	90.0

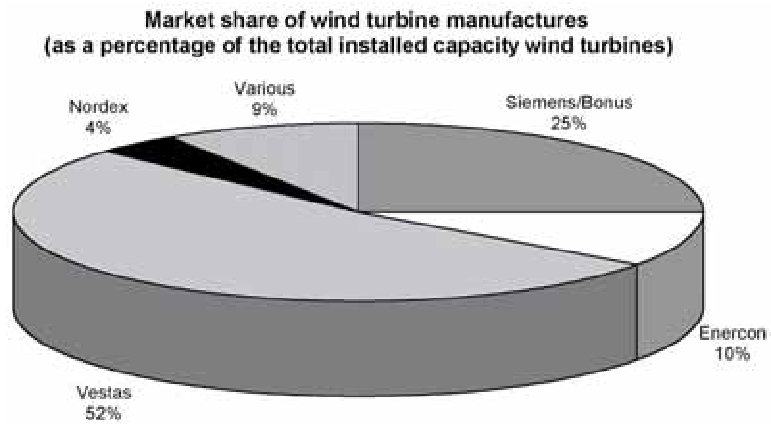

Figure 6 Market share of wind turbine manufacturers (as a percentage of total installed capacity of wind turbines)

nected system of the mainland and the autonomous power plants of the islands. The energy tariffs for the various kinds of installation are shown in Table 2.

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 and energy saving, substitution, and other energy-related actions. The public aid accounts for 30% of the eligible cost of the projects; it goes up to 50% in the case of transmission lines that will be constructed to connect renewable energy plants to the grids. During 2006, Measure 2.1, Action 2.1.3, and Measure 6.5 of the OPC were open for proposal submission.

In this framework, the Center for Renewable Energy Sources (CRES) acts as an intermediate agent in charge of administering and managing projects included in Measure 2.1, Action 2.1.4, and Measure 6.5 of the OPC. More specifically, CRES is the thematic intermediate agent responsible for administering and managing all wind energy projects on the mainland and those with nominal capacity greater than 5 MW in the Greek islands. Measure 6.5 finances the transmission cost for wind parks whose development has already been financed within Measure 2.1, Action 2.1.3. During 2006 and within Measure 6.5, Action 6.5.1.A, 38 projects were approved, of these, 36 were financed with 50% and 2 were financed with 45% due to their location. Additionally, within the second call of Measure 6.5 (August 2005), 7 projects were approved in October 2006. In this call, the financing includes both the eligible construction costs and the transmission costs of the wind parks. An installation permit is necessary to finance a project.

Eventually, financial support for wind energy investments is foreseen through the Law for Development 3299/2004, which provides grants for up to 50% of the total investment.

5.0 R, D&D activities

The Ministry for Development, through its General Secretariat for Research and Development (GSRT), 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 Greece are wind assessment and characterization, standards and certification, wind turbine development, aerodynamics, structural loads, blade development, noise, power quality, wind desalination, and autonomous power system 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 17025:2005.

Several research projects were running at CRES during 2006, 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 micrositing techniques for complex terrain topographies.

More specifically, CRES participates in UPWIND, one of the largest research projects in the area of wind energy. UPWIND is co-funded by the EC under the Sixth Framework Program, which was launched during 2006. UPWIND looks toward the wind power of tomorrow: very large turbines (8 MW to 10 MW) in wind farms of several hundred MW, both onshore and offshore. The project aims at the development and verification of substantially improved models of the principal wind turbine components, which the industry needs for the design and manufacture of these very large wind turbines in very large wind farms.

Within the UPWIND framework, CRES is the leader for work package 1.A.3, Training and Education. This package is aimed at disseminating the newest R&D knowledge through the development of modules for international courses in the field of wind power and the necessary supporting educational and training materials. CRES also participates in the following work packages:

- 1.A.1: Integral design approach and standards—performing aeroelastic studies.
- 1.A.2: Metrology—aiming to identify measurement problems related to wind energy applications and to develop methodologies for eliminating them.
- 1.B.1: Innovative rotor blade—performing aeroelastic studies and contributing to the joint development for the rotor blade.
- 1.B.4: Major barriers imposed by upscaling to 20 MW—deriving similarity rules for application to wind turbine upscaling.
- WP 2: Aerodynamics and aeroelastics—identifying important nonlinear effects in large wind turbines and improving the available aeroelastic tools.
- WP 3: Rotor structure and materials—developing tools for performing probabilistic strength analysis and executing experiments for improving knowledge of materials.
- WP 6: Remote sensing—developing experimental techniques for measuring wind at very high heights using both LIDAR and SODAR.
- WP 8: Flow—developing tools for wake modeling in complex-terrain environment.

Furthermore, OPTIMAT BLADES, a research project, was completed in 2006. This project focused on providing design recommendations for the optimized use of materials for rotor blades; it was co-funded by the EC under the Sixth Framework program. A wealth of experimental data gathered within this project, including results of CRES research, is available to the public at http://www.kc-wmc.nl/optimat_blades.

During 2006, CRES was granted a contract by the Regulatory Authority for Energy for the update of the Wind Atlas of Greece. The project aims at the refinement of the existing Wind Atlas and involves the installation of 40 new 30-m and 50-m masts in selected areas around the country. The project will be completed by the end of 2008.

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. In this framework, the laboratory was equipped with a state-of-the-art LIDAR system for wind-speed measurements up to 150 m high.

CRES also participates in the project entitled Floating, Autonomous, Ecological and Effective Desalination Unit, 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 (RO) unit for seawater desalination. The system mainly consists of a 30-kW wind generator, an RO unit of 80 m3/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. Since 1980, the National Technical University of Athens (NTUA) has been actively involved in both rotor aerodynamics and integration of wind energy into the electrical grid.

In 2006, the Electric Power Division of NTUA continued its research activities on renewable and distributed energy resources, focusing on several aspects of their technologies and on 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.
- Advanced short-term wind-power forecasting functions for operational planning using numerical weather predictions and advanced artificial intelligence techniques.
- Integration of wind power into the electrical grids, including isolated grids of small and medium-sized islands. Application studies for power systems in Greece and Cyprus.
- Technical issues and feasibility studies for the interconnection of isolated island grids to the mainland power system.
- Investigation of the PV penetration potential in isolated island grids with significant wind turbine installed capacities.
- 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 standalone systems fed by renewables; design of the electrical system and control for completely autonomous, wind-driven desalination systems.
- Development of laboratory infrastructure for renewable and distributed energy systems; participation in relevant laboratory and prestandardization 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.

5.3 Participation in IEA Wind tasks

Greece participates in Tasks 11 and 20. Task 11, Base Technology Information Exchange, promotes the understanding of wind turbine technology through cooperative activities and information exchange with other countries on R&D topics of common interest. 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 Task 20, HAWT Aerodynamics and Models from Wind Tunnel Measurements.

6.0 The next term

The new Law 3468 is expected to promote renewable energy sources, especially wind energy. This law and the national land planning study now being prepared are 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, southeastern Peloponnese, and Euboea). Significant institutional measures have been implemented in the new legal framework, whereas 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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Ireland

17

1.0 Introduction

Wind energy makes a very real and significant contribution to electricity supply in Ireland. In 2005 wind power has overtook hydroelectricity as being the primary source of renewable electricity in Ireland. At the end of 2006, 62 wind farms were operating in Ireland with a total generating capacity 744 MW. In 2006, an estimated 1.62 TWh were produced from wind power which equated to 5.59% of current national electricity supply. Wind farms displaced 1,000,000 tonnes of CO_2 emissions from conventional power plant.

Ireland needs to increase the share of renewable energy in its electricity generating mix in order to: 1) contribute to reducing national CO_2 emissions to meet Kyoto commitments; 2) reduce dependency on imported fossil fuels thus improving energy security; 3) mitigate the impact upon the economy of rising fossil fuel prices.

2.0 Progress toward National Objectives

Ireland has made a commitment to a target of meeting 13.2% of its electricity demand, or 4.78 TWh/yr from renewable energy sources by 2010. This is equivalent to the annual electricity demand of approximately 860,000 households and would displace more than 3 million tonnes of CO_2 emissions. Further analysis by government-convened groups has concluded that to meet this 2010 target, wind power must output 3.42 TWh annually. This would provide 9.4% of total electricity demand or the annual electricity demand of almost 620,000 households. It would displace 2.34 million tonnes of CO_2 emissions. An installed wind power capacity of approximately 1,100 MW would be required to provide this energy output.

On 19 June 2006 a new 2010 renewable electricity target of 15% of electricity demand requiring 5.43 TWh/yr from renewable sources was announced by Minister Noel Dempsey, the Minister for Communication, Marine and Natural Resources, whose ministerial portfolio includes renewable energy. If this increase is to be met by wind power, it would then contribute 11.4% or 4.13 TWh. This would be equivalent to the annual electricity requirements of 980,000 households and would require an installed wind generating capacity of 1,350 MW.

In March 2007, a 2020 renewable electricity target of 33% of electricity demand was announced in the government white paper "Delivering a Sustainable Energy Future for Ireland." Wind power will make the greatest contribution to achieving this target because no other renewable energy resource

Table 1 Key Statistics 2006: Ireland	
Total installed wind generation	744 MW
New wind generation installed	251 MW
Total electrical output from wind	1.62 TWh
Wind generation as % of national electric demand	5.59%
Target:	500 MW additional renewable energy 2001-2005. 15% of electricity demand from renewables by 2010 33% of electricity demand from renewables by 2020

available to Ireland can make such a contribution to national electricity demand on the required timescale at a reasonable cost.

By May 2007, 65 wind farms with a total generating capacity of 782 MW were connected to the electricity network in Ireland. A further 34 wind farms and wind farm extensions are planned totalling 449 MW in generating capacity with connection agreements to connect to the electricity network in coming years. This brings the total connected and committed capacity to over 1,230 MW which is close to meeting the revised national target for 2010 committed to by Minister Dempsey.

Additional applications for connection for planned wind farms total 3,314 MW in capacity. Were all of these wind farms connected to the electricity system, the total installed capacity would be in excess of 4,500 MW which could potentially provide 12 TWh/yr, equivalent to one third of Ireland's 2020 projected electricity demand.

Also in 2006, projects to be included in "Gate 2" of the group processing scheme for renewable generators grid connection applications were announced. This scheme was introduced in 2004 subsequent to a large backlog of wind farm connection applications having amassed after a temporary moratorium was imposed by the TSO on issuing grid connection offers. Tranches or rounds of renewable generator applications to be processed concurrently are announced at regular intervals and termed Gates. Gate 1 included a modest 350 MW of renewable generation capacity. After consultation with wind energy sector participants, a more ambitious Gate 2 was launched, which encompassed 1,350 MW of renewable generation. The offers issued under the group processing scheme are primarily on the basis of combined connections for clustered projects, with single isolated projects being treated individually.

For three years running, approximately 250 MW of new wind capacity has been commissioned annually in the Republic of Ireland. This confirms that the step-change that occurred in 2004, when the installation rate increased almost four-fold, can be sustained by the wind industry in Ireland into the future. Indeed this and the numbers of planning permissions and grid connection applications indicate that the wind sector can deliver the installed capacity required to meet the 2020 government renewable energy targets a number of years in advance of 2020. The actual rate of installation will be limited by the rate at which offers for grid connection are issued and the lead times for the associated grid infrastructure. The installation rate must decline before 2020 if the connection capacity created is limited to the capacity required to meet the government target for 2020.

3.0 Benefits to National Economy

3.1 Market characteristics

At the end of 2006, the total value of wind farm construction activity in Ireland could be estimated at 375 million €. As 80% of this cost is taken up by the wind turbine and electrical equipment costs, which are imported, the benefit to the local economy from wind farm construction is 20% of this or 75 million €.

The value of the annual maintenance activity in existing wind farms is reported to be approximately 3.5% of the capital value of the wind farms. This comes to approximately 26 million €. A large portion of maintenance costs would be for imported replacement parts, so the value to the local economy is much lower. The value of operating and maintenance activity will, however, occupy a proportionately higher fraction of the total economic value of wind energy as the installed capacity of wind farms increases.

3.2 Industrial development and operational experience

There is no significant wind turbine manufacturing industry in Ireland. There have been several initiatives to set up manufacture of specific wind turbine components and to manufacture micro-scale turbines. Sustainable Energy Ireland has funded several R&D projects in these areas and these are detailed below. Several companies in Ireland have been successful in supplying components in the wind turbine supply chain, in particular electrical and electronic components.

3.3 Economic details

Wind generating plant in Ireland currently produces electricity at lower cost than the most efficient combined cycle gas turbines (CCGT's), the current conventional generating technology of choice in Ireland. The Government Renewable Energy Feed-in Tariff (REFIT) price support scheme underwrites a maximum price of 57 €/MWh for wind farms larger than 5 MW whereas the official

2007 benchmark market Best New Entrant BNE price for electricity from new combined cycle gas turbines, is 86 €/ MWh.

The public service obligation mechanism is a manner of recovering the costs of certain electricity generation activities, which are judged to be for the public good, from a levy on all electricity consumers. Activities supported under this mechanism include electricity generation from renewable energy and from peat and emergency peaking power plant. Many of the historic AER contracts have current prices for electricity below the proxy benchmark market price for electricity "the Best New Entrant" or BNE. In such a case, rather than ESBCS being paid for the excess in renewable electricity price the government receives a credit which is offset against other PSO costs.

In 2007, renewable electricity generation supported under the PSO mechanism, and primarily wind energy, rather than requiring compensation payment to the relevant supplier, will bring about a surplus of 29.8 million € returned to the PSO fund. This will largely offset net costs of 9.5 million € for peat-fired generation and 24.2 million € for emergency generation (33.7 million € total). It has resulted in a decision by the Commission for Energy Regulation not to levy a PSO on consumers in 2007.

The steadily improving competitive position of wind power as compared with fossil fuelled generation has resulted in benefits for the electricity consumer. The average bi-monthly electricity bill for urban householders in Ireland is 106 or 638 € annually excluding the PSO. The improvement in the relative cost of wind energy has resulted in the annual PSO levy for domestic consumers excluding value added tax (VAT) reducing from 23.84 € in 2005 to 9.68 € in 2006 to zero in 2007. (Including VAT = 27 € in 2005 to 11 € in 2006 to zero in 2007). This is equivalent to a reduction in the bi-monthly domestic bill of 1.83 € (including VAT) or 1.7% in 2007 compared to 2006 and of 4.51 € (including VAT) or 4.25% in 2007 compared to 2005.

4.0 National Incentive Programs

A change of the price support mechanism for renewable electricity in Ireland was announced in April 2006. The previous competitive tendering system is to be replaced with a feed-in tariff providing prices of 54 to 57 €/MWh for wind projects greater than and less than 5 MW capacity respectively. Draft details of the scheme have been published but it has not yet been launched.

5.0 RD&D Activities

5.1 Wind energy R&D policy

The Department of Communications Marine and Natural Resources (DCMNR) has the overall wind energy policy brief in the Irish government. There is no specific R&D budget or program dedicated solely to wind energy research. Two programs exist under which wind energy R&D may be funded: 1) the Parsons Energy R&D Awards and 2) the Sustainable Energy Ireland Renewable Energy R,D&D Programme.

Sustainable Energy Ireland (SEI) has been charged with operating the sole current government-funded wind energy R&D program. The SEI RERDD Programme has an indicative budget of 16 million € for the period from 2001 to 2006. Of this, over 4 million € has been allocated to wind R&D projects to date. Significant wind R&D Projects funded under this program were detailed in the 2005 IEA Wind Annual Report. There is ongoing progress on many of these projects, including IEA Task 21 Dynamic Models of Wind Farms for Power System Studies. No significant new wind energy R&D projects were approved for funding in 2005. In 2006, the DCMNR announced an energy research program and a governing council was formed to oversee that program.

5.2 Wind R D&D achievements

5.2.1 All Island (Ireland) Grid Study on Renewable Energy

This is the most significant current R&D initiative. It was begun in June 2006 by the Republic of Ireland and Northern Ireland Ministers to investigate grid issues for renewable energy to 2020. Wind energy will contribute the greatest percentage of renewable energy among the renewables in Ireland. The Steering Group includes: DCMNR/DETI/ESBNG/SONI/SEI/Action Renewables. Its objectives are to examine penetrations of renewable energy sources of 15%, 20%, and 30%; determine the cost of various renewable energy mix options; determine technical issues for high renewable energy penetration; and inform the government in detail of the implications of renewable energy policy choices.

Four workstreams are operating:

- Workstream 1: All-Island Renewable Energy Resource Study for 2020
- Workstream 2: Examines the Issues for System Operation with 2002 RE Penetration
- Workstream 3: Study on the Network Issues for Incorporating 2020 RE Penetration
- Workstream 4: An Economic Study Drawing the Results of Previous Worksteams Together to Inform Governments of Costs of Policy Options

5.2.2 SEI-Funded Electricity Storage Demonstration

SEI has provided 50% funding to Tapbury Management for a study into a new electricity storage system which could guarantee an uninterrupted supply of wind generation to the national grid. Tapbury Management is to begin testing a Vanadium Redox Battery Storage System (VRBESS™) at Sorne Hill Windfarm in Donegal. The system is from the Canadian Company VRB Power Systems Inc. If successful, the technology would allow wind energy generated at off-peak times to be stored and supplied to the grid at a scheduled time. The energy storage system has the potential to increase the reliability of wind energy supply and thereby reduce the cost of providing the power reserve requirements from electricity generation plants as more wind power connects to the system.

An integrated wind power forecasting system will be developed which will determine the storage requirements to ensure a smooth reliable delivery of power from the wind farm over a 24 hour period. The system will also determine the optimum schedule of release of the energy from storage to ensure that value and revenues can be maximized. The study is expected to be completed by the end of this year and will be used to determine the economic potential for battery storage operating in the forthcoming Single Electricity Market in Ireland. Electricity storage technology will enable the development of all intermittent renewable energy sources including future wave energy systems.

The results of the feasibility study for the implementation of this wind energy storage facility will be published by SEI in April 2007. The analysis into the feasibility of using an innovative energy storage system showed how such a system could support an uninterrupted supply of wind-generated electricity to the national grid and significantly improve the efficiency of the energy produced. The study was jointly funded by SEI and Tapbury Management Limited, which oversees the management of Sorne Hill Windfarm. It examined the costs and benefits of integrating a battery-based power storage system with a 6-MW wind farm. The purpose of the report was to determine the optimum size for such a system in order to deliver an optimum return on investment, and to review the main benefits that this system would offer. The report concluded that the optimum battery is a 2-MW capacity battery delivering six hours of electricity storage.

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18 Italy

1.0 Introduction

The program of the new Italian government, which has been in charge since May 2006 and includes the Green Party, provides for several measures aimed at improving and encouraging the deployment of renewable energy sources (RES). For the time being, however, the wind sector is awaiting new concrete actions, particularly those devoted to overcoming non-technical barriers ensuing from bureaucracy, authorization procedures, and so on—not to mention the opposition to generating plants (particularly new wind farms) often shown by regions.

The promising trend that started in 2004 was partially confirmed in 2006, thanks to the completion of many wind farms at the end of the year. In fact, until mid-November 2006, less than 170 MW of new wind-power capacity had been installed, and the largest contribution, more than 240 MW, was added only in the last forty days of 2006. This result cannot be considered a full success, in that the 2006 growth was slightly lower than the previous year. Nevertheless, considering that many additional turbines have already been erected and are only waiting to be connected to the grid—and taking into account the other work in progress and the new major orders placed for turbine supply—one could say that the very optimistic forecasts for 2007 and 2008 have a good chance of becoming a reality (Table 1).

In addition to the average lengthy time required to connect wind turbines to the grid, the shortage of turbine components is a serious constraint. Now and in the near future, this shortage is likely to noticeably affect the growth of the sector. However, the main problem still remains the negative approach of many regions toward wind energy. At the moment, only the Apulia and Campania regions (where the commercial phase of the wind sector started in 1996) and Sicily have shown confidence that wind power could be an actual opportunity for their territory.

Nevertheless, at the end of December 2006 a more restrictive regulation about new-plant permitting, partly involving wind projects already approved but for which construction had not yet started, also came up in Sicily. This worried many investors on the island. It is worth noting that in Sardinia, the energy and environment plan issued in late 2005 set a ceiling of 550 MW of wind capacity.

The news is better from the Apulia region, where a new energy and environmental plan has been approved. This regional plan now considers wind energy as a strategic option and thus ends a moratorium on authorizing wind plants. Consequently, many wind projects have been presented, and more than 800 MW of new capacity has already been authorized. It is estimated that about 60% of that capacity will be completed by the end of 2007.

Table 1 Key Statistics 2006: Italy	
Total installed wind generation	2,123 MW
New wind generation installed	417 MW*
Total electrical output from wind	3.215 TWh
Wind generation as % of national electric demand	1%
Formal wind target:	2,500 MW by 2008-2012
Decree 387/2003:	22% of electricity from RES by 2010
Government's Current Target:	25% of electricity from RES by 2011
* 417-12MW = Net increase 405	

Even in the mountain areas, the three-year trend toward the use of larger machines was also confirmed during 2006, notwithstanding the greater complexity of such installations . In fact, just a little less than 50% of new wind-power capacity was set up with turbines in the range of 1.5 MW to 2 MW. The remainder consisted of 850-kW machines.

According to Italy's 2006 provisional electricity statistics set out by the grid operator TERNA, domestic net electricity production in 2006 was 302 TWh, an increase of 3.8% over the previous year's production. At 46 TWh, the share of imported electricity was 7.8% lower than in the previous year. Electrical demand on the domestic grid (including customer loads and grid losses) was 338 TWh, 2.2% more than in 2005. On the whole, Italy's 2006 gross electricity consumption (gross domestic production plus the balance between import and export) can be put at about 360 TWh.

Thermal production of electricity, with 263 TWh net production, increased by 4% in 2006, keeping its place as the most important energy source. Fuel for thermal generation was almost completely imported. Gas from Russia, the Netherlands, and Algeria replaced several oil plants and continuously increased the contribution of gas to electricity generation.

As usual, hydropower, with 43 TWh produced in 2006 (just 0.2% more than in 2005), was the most important RES (although this figure also includes the production of pumped-storage plants), followed by geothermal plants with 5.5 TWh, 3.8% more than the previous year. Electricity generated from wind rose by 37% in 2006, with a total production of 3.22 TWh. Wind is the renewable resource that most increased its electricity production over 2005 levels, but its share of total electricity generation is still limited to a low 1%.

2.0 Progress toward national objectives

Legislative Decree 387 of 29 December 2003 was aimed at implementing EU Directive 2001/77/EC, and it actually confirmed the previous target of 76 TWh/yr to be achieved in 2008–2012 from RES. This target was first established in 1999 in the National White Paper for Exploitation of Renewable Energy to comply with the Kyoto Protocol. The target was subsequently included in the EU directive as well, which stated that Italy would increase the contribution of RES to gross electricity consumption from 16% in 1997 to 22% in 2010.

Against this background and despite the growing demand for electricity, the absolute target fixed for wind energy for the period 2008–2012 has remained the same as in the 1999 White Paper—that is, 5 TWh/year, corresponding to about 2,500 MW capacity. Such a capacity target is now likely to be achieved in mid-2007. According to ENEA, on the basis of work currently in progress, newly placed orders for wind turbines, and the current energy and environment plan (PEAR) of the Apulia region, another 2,500 MW could be added by 2010. This would bring the overall capacity up to about 5,000 MW, with an energy contribution from wind of around 10 TWh/yr.

2.1 Commercial development

As 2006 ended, wind-power capacity in Italy had reached 2,123 MW, with 417 MW of new capacity added in the year. This amount was just a little less than in 2005. Despite delays that occurred in connecting several wind farms to the grid, which reduced the 2006 annual growth rate to less than 25% from rates of 39% and 35% the previous two years, the installation trend is expected to rise again in 2007 and 2008. This rising trend is thanks to the renewed attention likely to be paid to the wind sector at the political, industrial, financial, and commercial levels. In particular, it is estimated that 2007 will become a record year, and cumulative wind capacity very close to 3,000 MW is likely to be achieved by year's end. Uncertainty remains about what will happen in the medium and long term. It will depend on the willingness of the national and regional governments to take additional measures.

In 2006—following a trend that started in 2002 with the construction of Italy's first wind farm composed of large wind turbines in Sardinia—some 200 MW, corresponding to nearly 50% of the year's new wind capacity, was installed with turbines in the range 1.5 MW to 2 MW. The remaining capacity was mostly achieved through 850-kW machines, which are also very common in Italy.

In all, new wind capacity added in 2006 was 417 MW, with the installation of 363 units. This brought the cumulative wind capacity to 2,123 MW, up from 1,718 MW in 2005. It must be taken into account that 46 machines totaling 12 MW were dismantled in 2006 (Figure 1 and Figure 2).

The southern regions—Sicily with 137 MW and Apulia with 125 MW, followed by Basilicata with 67 MW—had an active role in the growth of the sector. Other regions such as Tuscany and Calabria, which had only one small wind farm each until the beginning of 2006, finally gained more significant installations. This trend will largely continue in

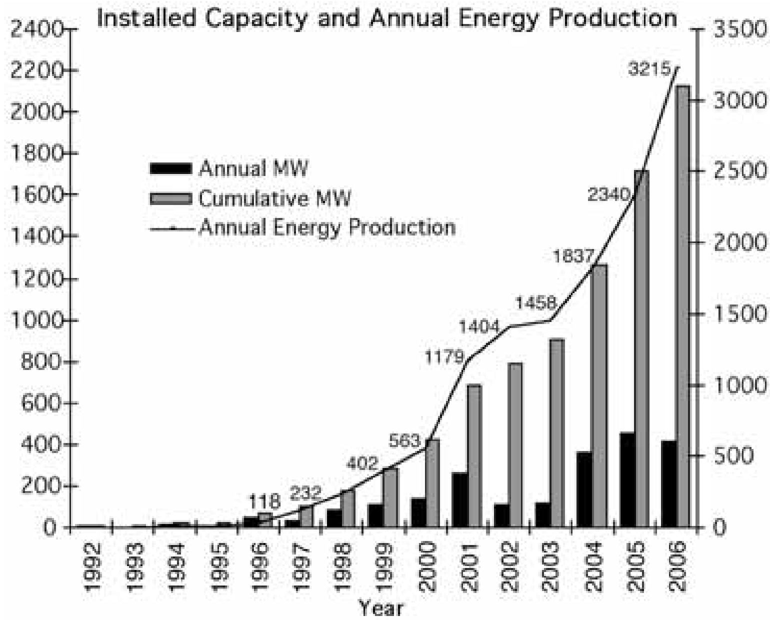


Figure 1 Trend of annual and cumulative wind turbine capacity and electricity production from wind in Italy.

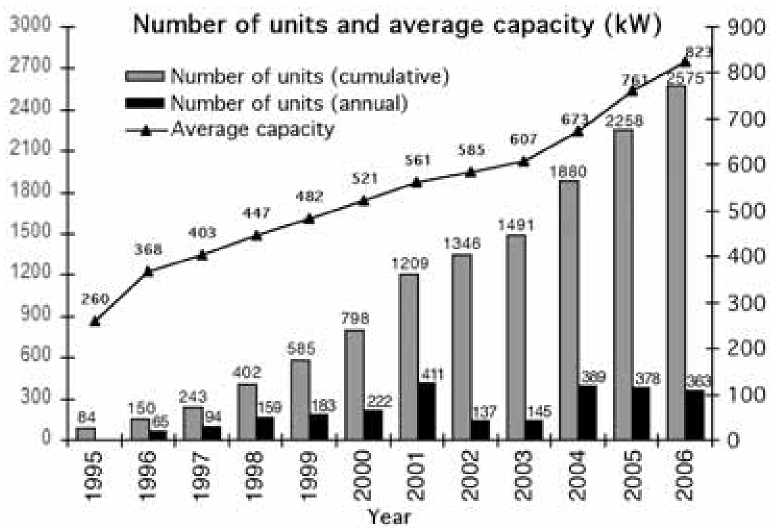


Figure 2 Trend of cumulative and yearly added numbers of wind turbines in Italy and average on-line unit capacity.

2007–2008, especially in Calabria, where some 100 MW are anticipated.

Some repowering of old wind farms also took place. Thirty-six old single-bladed turbines at Enel's demonstration wind farm Collarmele were replaced by four GE 1.5-MW units, with another to be added shortly. In this case, total plant capacity was reduced from 9.1 MW to 6 MW for the time being, and it will later be raised to 7.5 MW. However, this does not lessen energy output, and uses less of the land for the turbines and equipment. On the whole, in 2006 a total of forty-six wind turbines ranging from 200 kW to 450 kW were replaced by fifteen larger machines in the range of 800 kW to 1.5 MW.

This increased total in-field capacity by 4 MW but had a larger benefit in terms of energy production. Apart from these few cases, widespread repowering of smaller and older machines has not yet started in Italy. Soon, however, Italy's largest developer, IVPC (to which the country's oldest commercial turbines belong) is planning to replace several old turbines in Apulia and Campania.

Gamesa, which installed more than 200 MW in 2006, has taken the second largest share of the Italian market, with 20% of total capacity. Only Vestas Italia has a higher share, having maintained the highest portion of the Italian market since 1996 (Vestas's 2006 cumulative capacity share was 57%). Both manufacturers will be widely involved in wind energy development in Italy in the coming years, as shown by important commitments already obtained from Enel and IVPC totaling some 330 MW.

Among Italian wind plant developers, in 2006 FRI-EL and Moncada installed just a little less than 100 MW each, increasing their respective shares of total on-line capacity to 9% and 5%. Larger developers include IVPC with 31% of total on-line capacity and the two main utilities Enel and Edens that have on-line capacities of 14% and 13%, respectively.

IVPC is completing its first wind farm with large turbines (a 30-MW plant in the Apulia region) and has planned to build another 138 MW in 2007–2008. Vestas will supply turbines for these two projects. In particular, two wind power plants, Fortore and Irpinia, are to be set up in the Campania region of southern Italy. The Fortore project is located near the city of Benevento and consists of eighteen V90 units (3 MW each), fifteen V90 units (1.8 MW), and two V90 units (2 MW) to be installed at the sites of Baselice, Foiano, Molinara, and San Marco dei Cavoti. The Irpinia project is located near the city of Avellino and consists of nineteen V90 units (2 MW), two V90 units (1.8 MW), and thirteen V52 units (850 kW) at the sites of Bisaccia, Lacedonia, and Greci.

New, relatively large companies such as Alerion Industries and Sorgenia are entering the Italian market. Alerion has acquired several projects in southern Italy totaling 192 MW already authorized and an additional 200 MW in the pipeline. Sorgenia is developing and building wind farms of its own. Sorgenia (the former Energia S.p.A. and one of the first Italian energy operators) is acquiring growing importance in the Italian wind sector. The company's industrial plan is based on investments in combined cycle gas turbine (CCGT) power plants and on electricity generation from RES—namely hydroelectric, photovoltaic, and wind plants. Sorgenia acquired the wind company Anemon and a wind farm placed in Fossato di Vico, in the Umbria region, for 1,500 kW installed capacity. The company then obtained authorizations to build three new wind farms—in Castelnuovo di Conza, San Gregorio Magno (Campania), and Minervino Murge (Puglia)—for 70 MW installed capacity overall. The 2007–2010 business plan of the Sorgenia Group sets the target of 450 MW of wind capacity.

Figure 3 and Figure 4 depict the overall situation at the end of 2006 regarding market shares of wind turbine manufacturers and wind energy producers expressed as percentages of overall on-line capacity. Figure 5 shows the annual growth rate and Italy's cumulative wind capacity since 1997.

The electrical energy produced from wind in 2006 equaled 3,215 GWh, an increase of less than 40% over wind electrical energy produced in 2005. This yield was lower than expected for two main reasons: First, as we have already said, most of

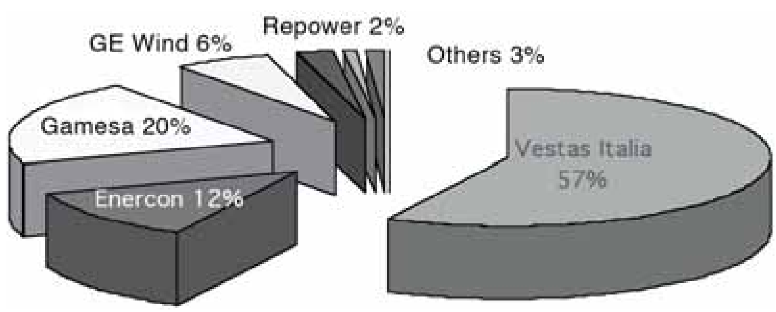


Figure 3 Market shares of wind turbine manufacturers at the end of 2006 (percentages of total on-line capacity).

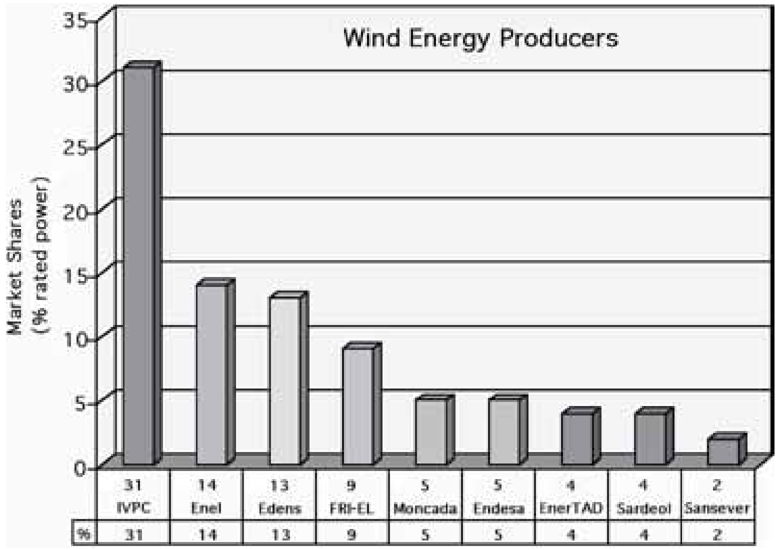


Figure 4 Market shares of wind plant developers at the end of 2006 (percentages of total on-line capacity).

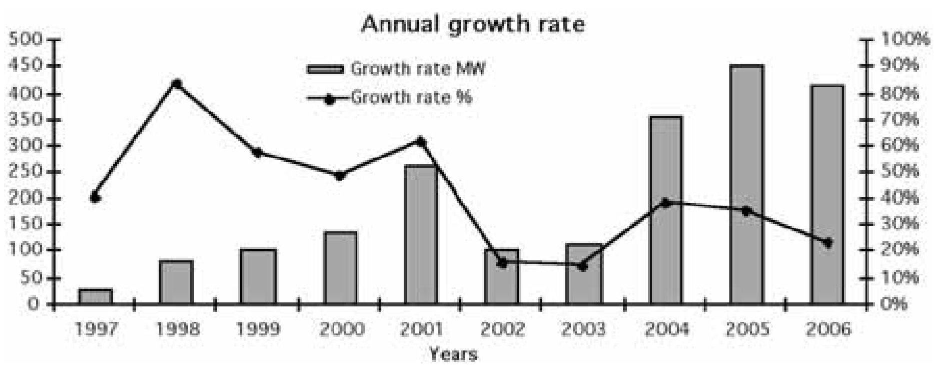


Figure 5 Trend of annual growth rate (absolute and as a percentage) of Italy's cumulative wind capacity.

the 2006 added capacity came on line only in the last few months of the year; secondly, the generally windiest months, November and December, were affected by a heavy drop in available wind energy owing to persistent high pressure over the country. Until November 2006, the forecast had been for a 60% energy increase.

2.2 Constraints

The lack of nationwide plant permitting guidelines, which were called for by Article 12 of Decree 387/2003 on RES, continues. As a result, the various regions are proceeding autonomously, issuing guidelines or establishing rules to manage wind plant authorization procedures that differ remarkably among regions. This situation clearly poses undue hindrances to wind plant deployment. Some help, however, came from the Italian state in 2006. For instance, the Constitutional Court repealed the wind energy moratorium established by the Apulia region. This prevented other regions (for example, Basilicata and Molise) from establishing their own moratoriums, which would have stopped wind deployment, at least temporarily.

Difficulty connecting wind plants to the electrical grid quickly enough, has been a frequent complaint in years past. It seems to have bothered some developers in 2006 as well, despite new rules issued by the Regulatory Authority for Electricity and Gas at the end of 2005 (Provision 281, 19 December 2005). Actually, the completion of several wind farms originally planned by the end of 2006 has not yet happened due to major unexpected delays in the grid-connection process. Of course, the implementation of new grid-connection procedures takes some time, and some aspects of the authority's new provision still require clarification and fine-tuning. With this in mind, one could expect that in coming years, outstanding grid-connection issues may be settled and time lags become more acceptable to investors.

Another obstacle is the prejudice that some regional and local decision makers seem to bear against wind technology. This prejudice generally ensues from a lack of knowledge and could easily be overcome through better information currently available from various sources and by visits to existing wind farms, particularly in the southern regions.

3.0 Benefits to national economy

3.1 Market characteristics

In 2006, according to the national wind energy association ANEV the number of employees involved in wind energy in some way, was about 4,500. Of this number, some 1,000 were engaged in project development, consultant work, and plant operation and maintenance. The total economic turnover of the year attributable to wind energy activities was about 500 million €, more or less the same as in 2005. ENEA and ANEV anticipate that this figure should increase substantially in 2007.

The wind capacity distribution pattern over the country shows (Figure 6) that the wind business mostly benefits Italy's southern regions, thus helping to solve the problem of local unemployment. Manufacturing of wind turbines and components is concentrated mainly in the Apulia, Campania, and Sicily regions, where wind capacity is highest.

The share of wind-power capacity held by the main developers IVPC, Enel, and Edens at the end of 2006 totaled less than 60%, about 11% less than their share a year earlier. This means that new investors such as Moncada have appeared, and older ones such as FRI-EL (Figure 7) have grown in size. Another utility, Endesa Italia (Figure 8), considerably increased its share in 2006 through the acquisition of three wind farms, bringing its total capacity up to some 100 MW.

The strong presence of utilities on the market (one-third of total wind capacity) is mainly due to their obligation to comply with the RES quota established by the law (3.05% for 2007) and to their wish to demonstrate willingness to diversify energy production using a clean source. In Italy, unlike in

Figure 6 Wind capacity at regional level in Italy at the end of 2006 in MW. Wind capacity added in 2006 is indicated in bracket.

some other countries, private citizens, farmers, and co-operatives have not entered the wind market so far. This more diverse ownership pattern has been detained by medium-sized wind energy companies and a few utilities. However, there are prospects that larger energy and insurance groups, too, may join in shortly.

The most important utility, Enel, has further confirmed its interest in RES, energy efficiency, distributed generation, hydrogen, and zero emissions through new investments. Its investments for 2007 to 2011 total 4 billion €, both in research and commercial deployment (double its previous investment). Some 3.3 billion € will be devoted to renewable plants; 1.6 billion € of this amount will be used to build plants in Italy. This would mean adding 1,700 MW of new generating capacity, of which 1,500 MW would be wind, 100 hydro, and 100 geothermal plants.

3.2 Industrial development and operational experience

In 2006, Vestas Italia, located in Taranto (where 50% of the turbines installed in Italy as of the end of 2006 were produced), increased the number of its employees by about 20%; there are now 600 employees. Its sales of 850-kW machines equaled a total capacity of about 440 MW. More than 60% of these machines were exported to China. Vestas in Italy comprises two production units, Vestas Nacelles Italia S.r.l. and Vestas Blades Italia S.r.l., and a sales unit, Vestas Italia S.r.l., which is responsible for the Italy and Eastern Mediterranean markets. All three units are located in Taranto. Vestas produces some 550 wind turbines per year.

It is worth mentioning that Vestas Italia had strong growth between 2003 and 2006, increasing both wind capacity and employment by 200%. In the spring of 2007, Vestas will complete the first two wind farms comprising 3-MW turbines ever installed in Italy; their total capacity will be 108 MW.

Manufacturers of smaller wind turbines received a boost to the sector in 2006. The Regulatory Authority for Electricity and Gas issued Provision 28 of 10 February 2006 regulating the energy exchange (net metering) between the network and RES plants up to a capacity of 20 kW. Thanks to this measure and the reduction to 50 MWh of the threshold energy amount for obtaining green certificates, the industry comprising manufacturers of smaller wind turbines is expected to grow more significantly in 2007 than in previous years.

Several developments in the small wind sector took place in 2006. Jonica Impianti has concentrated its production on the unit JMP 20. It has a total capacity of sixty units per year. Since January 2007, it has also improved this 20-kW model through the adoption of a new 10-m rotor, increasing the energy

Figure 7 Vestas V90 3-MW turbines at Ricigliano in the Campania region, a 36-MW wind farm developed by FRI-EL

Figure 8 Gamesa G90 2-MW turbines at Scansano in the Tuscany region, a 20-MW wind farm developed by Endesa.

generated. A new company, BluMiniPower, has recently entered the market with the 20-kW BMP 20 model and has established its factory at Olbia in Sardinia. The turbine has a rotor diameter of 8 m, a rated wind speed of 12 m/s, and a synchronous permanent magnet generator (Figure 9). Other companies that have recently entered the small-turbine sector include the Tozzi Group and Cepa. Their entrance is a response to the adoption of the net-metering system and to the simplified authorization procedure enforced in the Tuscany and Apulia regions.

3.3 Economic details

Total plant costs of wind installations were significantly higher in 2006—20% to 30% more than in the two previous years—so that the average investment cost can now be put at around 1.2 million €/MW installed. Maintenance and operational costs remained, on the contrary, about the same as in 2005, averaging roughly 10 €/MWh. The increase in the cost of wind turbines was caused by factors that were unpredictable a few years ago—for example, insufficient wind turbine production. This in turn was caused mainly by a shortage of components due to fast-growing demand, rising costs of raw materials, technology innovation (particularly concerning blades), and use of larger blades for less windy sites.

In addition to turbine cost, the cost of electrical and civil works is estimated to be around 30% of total investment cost for plants with smaller turbines (capacity <1 MW) and 20% of total investment cost for plants with larger turbines (capacity >1 MW). A sort of compensation for increasing plant costs is now given by higher market prices of green certificates issued for the 2006 RES electricity production, around 125 €/MWh. Income from selling green certificates adds, as is known, to the wholesale market price of wind-generated electricity, which averages around 60 €/MWh. Since 2006, the availability term of green certificates has been extended from eight to twelve years from the beginning of plant operation.

4.0 National incentive program

4.1 Major RES support instruments

In 2006, too, a good number of RES plants were still benefiting from the feed-in tariffs granted by CIP Provision 6 of 29 April 1992. These tariffs are different for the various technologies and are updated every year. They are paid to entitled plants for all the energy they can feed into the grid and consist of two items:

- The avoided cost, granted over the full lifetime of the plant as a reward for avoiding production from conventional sources, and
- The incentive, granted over the first eight years of plant operation only.

Figure 9 BMP 20, the 20-kW prototype developed by BluMiniPower srl.

In 2006, several wind plants were still within the eight-year term and therefore got the full feed-in tariff. In the most favorable case of plants yielding all their energy to the grid, the tariff was 149.4 €/MWh.

Unlike these older plants, all new wind plants now come under the current support scheme, which is based on a compulsory quota for electricity from RES and on tradable green certificates (TGCs). This scheme was set up and regulated by Decree 79 of 16 March 1999 (restructuring the electricity market) and the subsequent Decree 387 of 29 December 2003 (implementing EU Directive 2001/77/EC on RES promotion). Further implementation measures were then taken in 2005 and 2006.

Since 2001, the RES electricity quota obligation has been laid on operators who, in the reference year, have produced or imported electricity from non-renewable sources exceeding 100 GWh/yr (electricity from CHP plants, auxiliary service consumption, and exports of energy are excluded from this computation). These operators must feed into the Italian grid, before the end of the subsequent year, an amount of RES electricity equaling a minimum quota of this non-renewable electricity. The RES electricity quota was originally 2% but was subsequently raised by 0.35% a year to 2.35% in 2005, 2.70% in 2006, and 3.05% in 2007. No quota has yet been set for subsequent years.

To show compliance with the quota, operators can either hand in TGCs from their own RES plants or can buy TGCs from other RES producers. To reduce their obligation, they are also allowed to feed imported RES-generated electricity into the Italian grid, but this energy must be certified by a Guarantee of Origin. The market price of TGCs should thus be determined on the basis of demand by obligated operators versus supply by qualified producers. Qualified RES electricity producers get one TGC for each 50 MWh of their production over a term that was formerly eight years but has, since 2006, been extended to twelve years of plant operation. The sale of TGCs brings them income in addition to the proceeds from the sale of energy on the wholesale electricity market.

It must be pointed out, though, that, to avoid double benefit, TGCs that would be due to plants already getting CIP 6/92 feed-in tariffs are retained by GSE (the body managing all RES support schemes). GSE must sell them at a price fixed every year on the basis of current CIP 6/92 feed-in tariffs, among other things. Since the number of these TGCs is still fairly large, qualified RES producers actually have to sell their own TGCs at a price close to, but obviously not greater than, the price fixed for the GSE certificates. As compared with TGC schemes in other countries, the Italian TGC price is therefore not left to the mere interplay of supply and demand but is controlled in a way that gives RES investors more guarantees of enough income.

Actually, the price of TGCs sold by GSE has been growing steadily in the past few years. Specifically, the price of GSE's TGCs relating to 2006 RES production was fixed at 125.28 €/MWh. The GSE price has kept up the TGC market price as well, thus bringing a reasonably rewarding income to investors in addition to the sale of electricity on the wholesale market. This of course holds especially for more mature RES technologies, including wind, while other technologies such as photovoltaics have had to be granted special feed-in tariffs to help fund their development.

In spite of these financial conditions, which look very favorable in principle, investors in RES have still been complaining about the way some aspects of Italy's support policies have been implemented. Particularly, they have long been complaining of delays in issuing measures regarding, for example, the fixing of electricity quotas for RES to be produced from 2008 onward, the setting of regional targets, establishing a single national procedure for plant permitting, and other actions required by Decree 387 of 29 December 2003. Settling these pending issues would bring more clarity and certainty to the framework within which investors have to work. Some investors have even stated they would be content with lower energy and TGC prices in exchange for better-defined boundary conditions for their businesses in the long term.

5.0 R, D&D activities

5.1 National R, D&D efforts

Several companies tested prototype turbines in 2006. The Leitner Group continued its demonstration tests in the Alps on its recently developed 1.2-MW and 1.35-MW prototypes, and it is now ready to enter the international market. Also, Moncada Costruzioni, which completed four wind farms in 2006, has been conducting experimental tests on its 750-kW prototype in Sicily and has also been developing a smaller (20-kW) turbine.

Among Italian universities involved in wind research activities, Bologna University has been particularly concerned with lightning protection and offshore foundations, Trento University with cold-climate applications and the development of small wind turbines, and Milan Technical University (Polytechnic) with integrated aeroelasticity simulation software. Genoa University is still involved in the study of wind potential onshore and offshore, as well as the simulation of wind flow.

In the field of small turbines, new interest was shown by a few entrepreneurs engaged in the development of innovative models, one of which is intended for use in the urban environment. In particular, the Tozzi Group has been developing, with scientific support by Trento University and Milan Polytechnic, a project devoted to the design and construction of two classes of turbines: vertical-axis turbines with a power <3 kW to be located in urban areas, and horizontal-axis turbines up to 80 kW for suburban, rural, and industrial applications. The solutions adopted for these two models will be assessed and then industrialized through extensive testing of prototypes, both in a test field operated in Trento by Tozzi Nord and in public research structures such as wind tunnels and laboratories for materials tests.

Italy's first offshore wind applications are being planned. A large project (around 300 MW) planned by Gamesa off the northern Apulia coast and other initiatives are under consideration in the Calabria and Sicily regions. Enel is also considering offshore as a possible option in its research plan. In particular, it has been drafting a new design for a wind platform off the Tuscany coast, the most ambitious research project disclosed in this sector to date.

Research activities performed in the interest of Italy's electricity system were taken over from CESI in 2006 by the new company CESI RICERCA. The staff of CESI RICERCA has resumed work on the Wind Atlas of Italy developed with CESI between 2000 and 2002. As described in the IEA Wind Energy Annual Reports of 2002 and 2003, this atlas was intended to provide a general picture of Italy's wind resources and to be used as a tool for singling out windy areas mainly for the purposes of regional energy planning and wind farm siting. The work was initially based on the simulation of wind flow through models in co-operation with Genoa University. The resulting maps were then adjusted by comparison with data recorded by wind-measuring masts scattered all over Italy. The new version of the Wind Atlas features several improvements, the most noteworthy of which are the following:

- Four series of wind-speed maps and four series of specific energy production maps at the heights of 25 m, 50 m, 75 m, and 100 m above ground;
- Extension of all maps from on-land areas to a sea strip of 40 km width from the coastline;
- Further validation of maps by additional measuring data collected especially at coastal and offshore locations;
- Easier access by users, who can now avail themselves of interactive consultation facilities including a computation module to evaluate the technical and economic performance of a wind farm of given characteristics at any chosen spot on the maps;
- Text providing a brief but thorough overview of the main topics of wind energy exploitation for the convenience of readers who may not be fully familiar with all aspects that bear on the feasibility of a wind project.

The new version of the Wind Atlas of Italy will be posted on a dedicated Web site now being prepared.

In 2006, CESI RICERCA also conducted research aimed at going deeper into the technical and economic aspects of offshore wind farms along the Italian coasts, especially with an eye to foundations and supporting structures. The application of innovative models to the analysis of wind conditions at "mixed" locations (namely areas comprising both sea and land stretches) was also the subject of investigation.

5.2 Collaborative research

Italy, through Trento University, is participating in the IEA Wind Task 19, Wind Energy in Cold Climates.

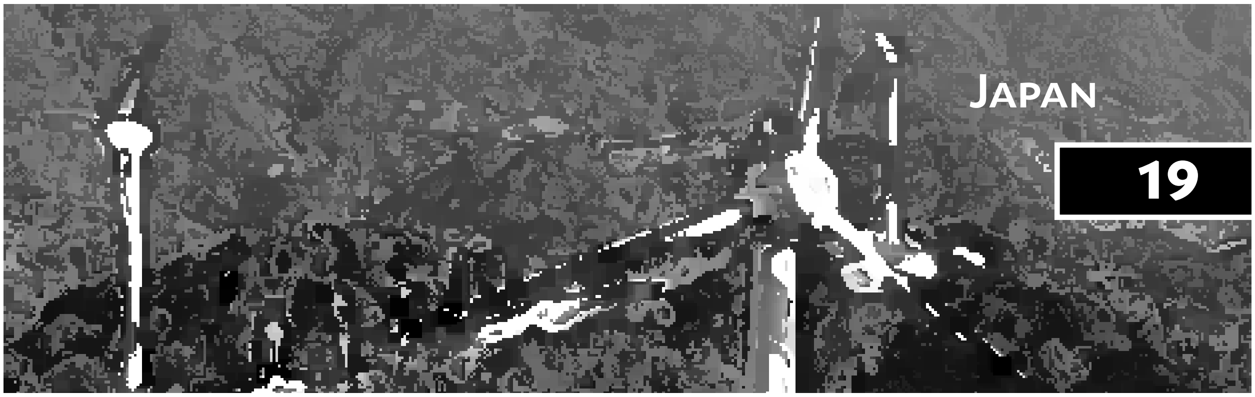
6.0 The next term

The positive trend of wind plant deployment started in 2004 will, in all likelihood, continue at least for the next two years through the completion of large projects already authorized and partly underway at their sites. Some 1,000 MW to 1,500 MW in new wind-power capacity could be added by the end of 2008.

It is more difficult to anticipate what will happen in 2009 and later, as it will largely depend on the national and regional targets to be set and the policy measures that will be adopted to achieve them. However, a total wind-power capacity of 5,000 MW on line by the end of 2010, with a production of about 10 TWh/year, could be considered a feasible goal. That would double the official target of 2,500 MW and 5 TWh/yr established for 2008–2012 by the 1999 White Book.

These figures are, on the other hand, in good agreement with the likely exploitable wind potential that can be estimated from the Wind Atlas of Italy developed by CESI RICERCA.

Authors: Luciano Pirazzi (ENEA); Claudio Casale (CESI RICERCA), Italy.



19 Japan

1.0 Introduction

At the end of fiscal year 2006 (March 2007), the total wind-power capacity in Japan is estimated to be 1,574 MW with 1,358 turbine units, which corresponds to approximately half of the national target for wind-power capacity by 2010. One of the most important technical issues is extreme meteorological conditions such as high turbulence or attacks by typhoons or lightning; not a few turbines have been damaged, sometimes severely, by these events. Therefore, most national wind activities are aiming to investigate or develop a J-Class Wind Turbine Guideline so that we may achieve sounder wind turbine technology for the Japanese environment.

Another significant issue is grid connection. Compared with EU countries, Japan is very much isolated, and so the influence of wind generation on grid stability is considered very large, regardless of how small the penetration ratio is. Therefore, some electric power companies must limit new wind farm projects and choose them by drawing lots. Moving to offshore installations has not yet begun due to deep-water conditions, but some investigations have been initiated.

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 set the target for wind power for 2010 at 3,000 MW in its latest Primary Energy Supply Plan.

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. The contribution of renewables to total primary energy resources is expected to be 3% in 2010, up from 1.2% in 1999. Under the RPS, Japan's utilities are obligated to source 1.35% of total electricity supply from renewables by 2010. To counteract natural and social obstacles to wind power development, the government has been taking some new measures to add to the conventional subsidies as mentioned previously.

2.2 Installed capacity

Japan's cumulative wind-power capacity was 1,078 MW with 1,055 units at the end of fiscal

Table 1 Key Statistics 2006: Japan	
Total installed wind generation	1,574.2 MW*
New wind generation installed	493.5 MW*
Total electrical output from wind	1.910 TWh/yr** (1)
Wind generation as % of national electric demand	0.216%** (2)
Target:	3,000 MW by 2010

* Predicted by the end of March 2007
** From April 2005 to March 2006
Data from Web sites for the Japanese Renewables Portfolio Standard and the Federation of Electric Power Companies of Japan

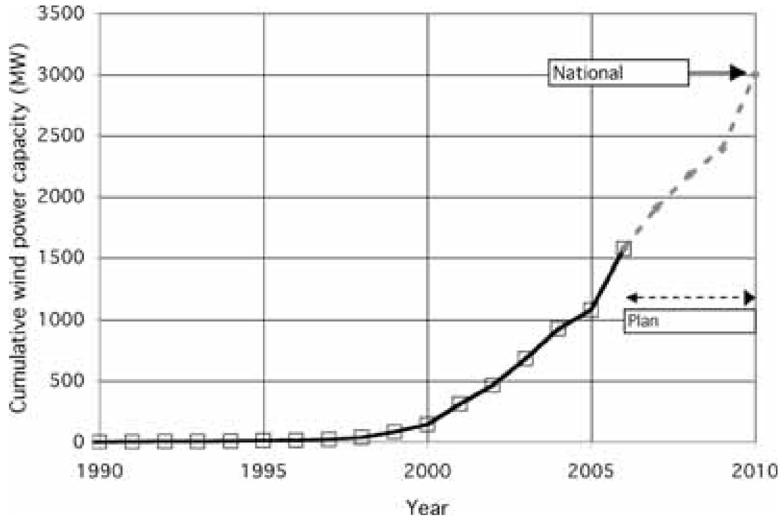


Figure 1 History of wind-power development in Japan.

year 2005 (March 2006), and capacity will be 1,574 MW with 1,358 units at the end of fiscal year 2006 (March 2007). Figure 1 shows the history of wind-power development in Japan. Capacity values are recorded for the end of each fiscal year. To project the 2006 value based on previous years, we performed a linear interpolation and arrived at 1,451 MW.

2.3 Contribution to national energy demand

Wind power generation from April 2005 to March 2006 was 1,909.7 GWh. National energy demand during the same period was 882.6 TWh, and the contribution of wind power accounted for 0.216%.

2.4 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 with a fitting curve. The annual rate of increase ranges from 40% to 70% on average, and the values are very high. However, the fitting curve suggests some deceleration in recent years.

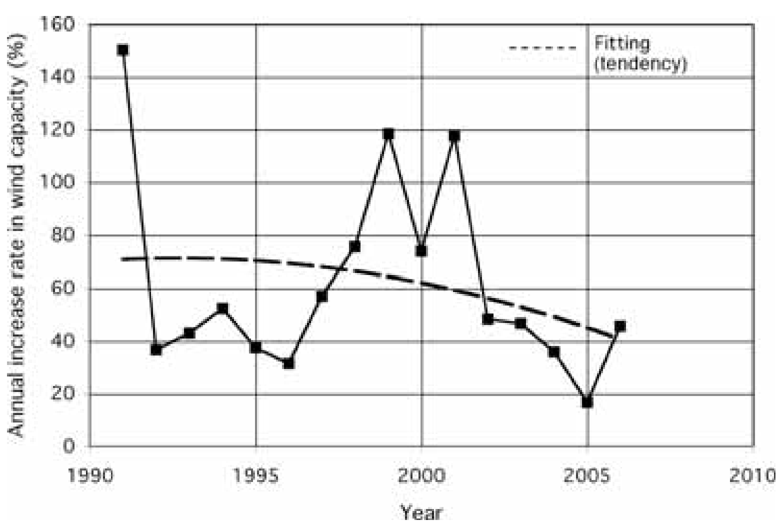


Figure 2 History of annual increase rate of wind power capacity (percent) with a fitting curve.

3.0 Benefits to national economy

3.1 Market characteristics

Wind power development in Japan has brought certain benefits to the wind industry. Until 2005, only one wind turbine manufacturer produced commercial turbines above 1 MW. Now there are two: Mitsubishi Heavy Industries Ltd. (MHI) and Fuji Heavy Industries Ltd. (FHI). In addition, membership in the Japan Wind Power Association (JWPA) has increased to 121 member companies. Many entities are developing wind power: citizen groups, NPOs, third sectors, local governments, and big private companies. However, the Japanese market is deeply influenced by external conditions, both natural and grid-related.

Grid connection is one of the biggest issues. Huge cities such as Tokyo, Osaka, and Nagoya, where electricity demands are very high, are located in the middle of Japan. Windy areas are mostly rural areas at the northern and southern ends of the country. In these areas, electric power companies must set a regional limit of allowable wind capacity for grid connection.

3.2 Industrial development and operational experience

Mitsubishi Heavy Industries (MHI) has long been the only national manufacturer that supplies medium-sized to large wind turbines. At the beginning of 2006, MHI erected a new 2.4-MW wind turbine, the MWT92, in Yokohama (Figure 3).

Fuji Heavy Industries Ltd. (FHI) became the second large-scale wind turbine manufacturer when it developed a prototype 2-MW SUBARU 80/2.0 wind turbine with a downwind rotor configuration (Figure 4). This turbine was constructed in December 2005 at Hasaki in Ibaraki Prefecture 100 km east of Tokyo. FHI has been conducting demonstration tests including performance and reliability tests, especially tests of the downwind effect on stresses, noise, and power generation.

Figure 3 MHI's MWT92 turbine in Yokohama.

Figure 4 FHI's new 2-MW, downwind-type wind turbine, the SUBARU 80/2.0, installed at Hazaki.

A few new wind farms marked new records. The largest wind farm ever established in Japan, Koriyama Nunobiki Kogen Wind Farm, was developed in December 2006 (Figure 5). Total power output is 65,980 kW with thirty-two units of 2-MW turbines and 1,980-kW turbine. This wind farm is owned by J-POWER, which has developed 210.5 MW in Japan.

Ichimokusan Wind Farm, whose total output is 8,500 kW with five units of Vestas 1,700-kW tur-

Figure 5 Koriyama Nunobiki Kogen Wind Farm.

bine, is now under construction at Oguni, Kumamoto, in Aso Kujuu National Park, one of Japan's most important national parks (Figure 6). This is the first wind farm permitted as a private commercial power station by the Ministry of Environment. This project serves an educational purpose for the nearby Oguni Nature School, and it supplies electricity to Oguni City.

Another major achievement is the Matoyama-oshima Wind Farm (32,000 kW with sixteen units of Vestas 2,000 kW) on Matoyama-oshima Island near Hirato, Nagasaki (Figure 7). Commercial operation is scheduled to begin in March 2007. This is the first wind farm to be connected with the longest submarine cable (15 km) in Japan.

Zephyr Corporation has developed the Z-1000 Airdolphin, a small 1-kW wind turbine. The prototype machine is being demonstrated at many sites around the world, such as Tarifa (Spain), Soria (Spain), Rimini (Italy), the UK, and many sites in Japan. Zephyr started a round-robin campaign moving a turbine around to sites with different operating conditions cooperating with CIEMAT (Spain), Tokyo University, and Kyushu University.

Erimo Misaki Cape is one of the best high-wind-speed areas in the world. It is located at the southern part of Hokkaido Prefecture, the northern island of Japan. The wind speed at Erimo is so high that people have not risked to installing large wind turbines there. For more than 290 days in a year, wind speed averages more than 10 m/s. However, since December 2005, an Airdolphin has been operating with the cooperation of Erimo City. Figure 8 shows a photo and figure 9 shows one month's worth of operation data.

Strong Japanese winds have taken their toll on wind turbines this year. On 8 January 2007, one 1.3-MW wind turbine at the 32.5-MW Iwaya Wind Farm in northern Japan, consisting of twenty-five units of Bonus turbines, was fell over from the base of the tower. The night before the barometric pressure was low, and extreme wind speeds above 40 m/s were measured.

As we reported last year, Miyako Island was hit by an enormous typhoon, and all seven wind turbines were toppled or lost blades. These accidents during extreme winds are intermittent, but still serious. Lightning strikes are also a severe problem in Japan. For these reasons, the government has set up several committees to investigate external conditions in order to find reliable design solutions.

Figure 10 shows wind turbine accidents and failures for the last three years. They were investigated by the New Energy and Industrial Technology Development Organization (NEDO) Wind Turbine Availability Improvement Committee. The J-Class Wind Turbine Guideline Committee is producing a guideline to prevent severe accidents due to external conditions.

Figure 6 Ichimokusan Wind Farm.

Figure 7 Matoyama-oshimaWind Farm.

3.3 Economic details

Since most wind turbines are imported from Europe and the United States, unit cost itself is considered to be the same as in Europe or the United States. However, factors including transportation cost and the additional cost of grid connection require additional plant costs.

According to a wind farm model, a 25-MW wind farm discussed at a national committee, is estimated to have a cost of energy (COE) of 10.20 JPY/kWh with subsidy. Today, 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).

Figure 8 Zephyr's Airdolphin at Erimo Misaki cape southern Hokkaido Prefecture, the northern island of Japan.

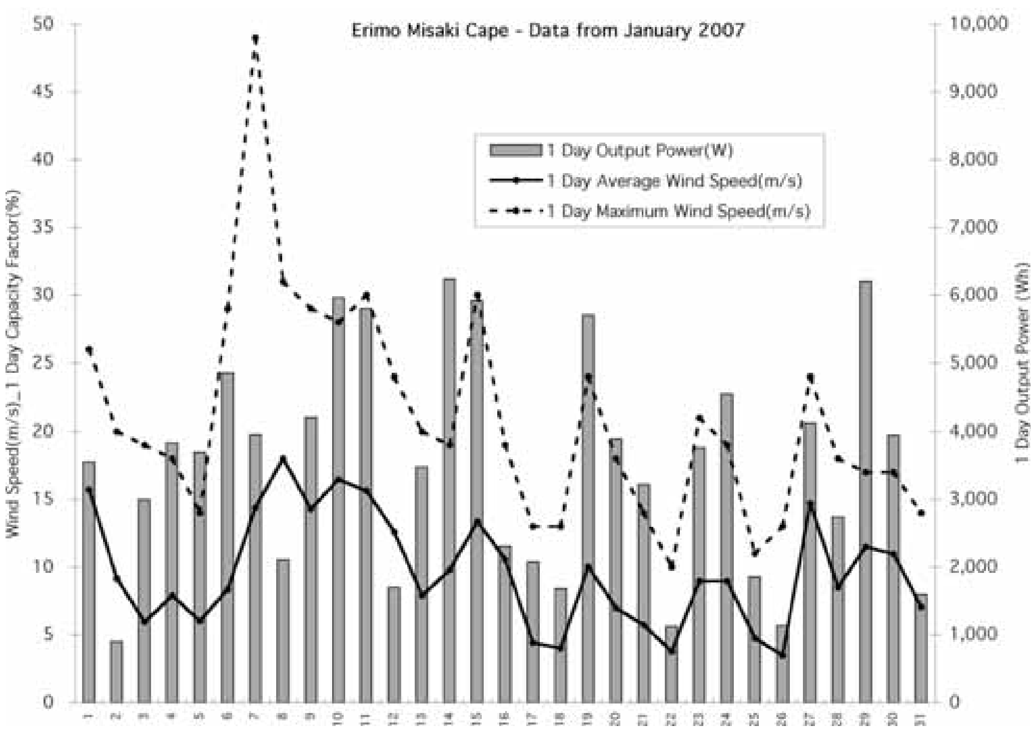


Figure 9 Daily operational data from Airdophin at Erimo during January 2007.

Table 2 Japanese national incentive programs[*]

Type	Program	Purpose	Category	Budget (million JPY)
R, D&D (METI)	Field test program	Measure wind to develop wind plant candidates (Subsidy rate: 100%)	Wind	60.0
	J-Class Wind Turbine Guideline	Investigate current standards by means of field measurements; develop J-Class Wind Turbine Guideline that takes into account external conditions such as typhoons, gusts, turbulence, and lightning strikes	Wind	291.4
	Demonstration of grid stabilization with battery backup system	Demonstrate grid stabilization technology with battery backup system at wind farm sites	Wind	720.0
Subsidy (METI)	New Energy Business Support Program	Subsidize business development of generation plant for initial cost (subsidy rate maximum 30%)	Wind (new energy)	23,700.0 (35,271.5)
	Regional New Energy Development Stimulation Program	Subsidize local new energy development of generation plant for initial cost (subsidy rate maximum 30%, local authorities; 50%, nonprofit organizations)	Wind (new energy)	1,350.0 (5,181.3)
	Measures for grid connection	Subsidize technical measures for grid connection for wind power	Wind	1,868.7
NEDO (own)	Investigations	Investigate offshore wind, wind measurements, effects of field test program, and advanced wind energy technology	Wind	94.0
Committee	Wind turbine availability improvement 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

For large-scale wind farms comprising wind turbines with capacities of more than 1,000 kW, COE is 7.00 to 9.00 JPY/kWh.

Current cost for a wind turbine is approximately 100,000 JPY/kW. Cost to install turbines is decreasing as the number of large-scale wind-power plants increases. The cost varies depending on wind conditions, grid conditions, and plant size. For 2003, the average initial cost was estimated at 190,000 JPY/kW.

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 the closing of active national wind energy R, D&D programs in fiscal year 2002, most government efforts have focused on incentive programs consisting of subsidies and investigations. However,

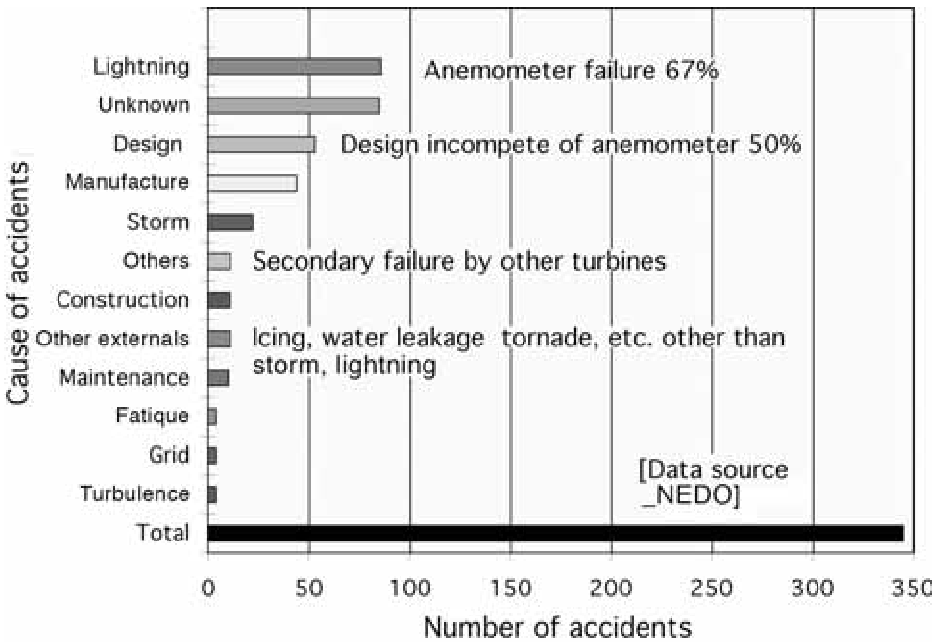


Figure 10 Wind turbine failures and causes, 2004–2006.

certain activities have been shifted from demonstration or investigation to real-world research and development.

The governmental incentive programs under the Ministry of Economic Trade and Industry (METI) in FY2006 is summarized in Table 2. 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. Main support and market stimulation incentives were mostly subsidized 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

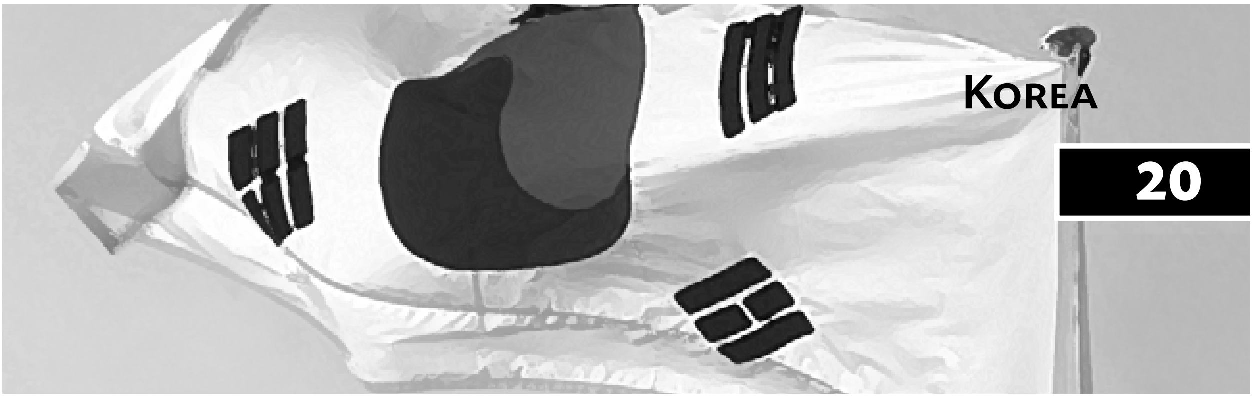
The J-Class Wind Turbine Guideline is a very important research program. By using actual measurements of wind characteristics and mechanical loads at several wind plant sites over Japan, it aims to develop guidelines to build turbines that stand up to external conditions such as typhoons, gusts, turbulence, and lightning strikes. The final report including these guidelines will be published in 2008. We intend to propose these guidelines to be incorporated into the IEC 61400-1 standards for the S-wind turbine class. As a result this work will be available to regions worldwide where meteorological and topographical conditions are similar to those in Japan.

Technical developments are proceeding in connection with the study of a grid stabilization system with battery backup. Current efforts are focused on demonstrating the system on a wind farm.

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, Kyushu University, Japan.



Korea

20

1.0 Introduction

The progress of wind generation development in the Republic of Korea's wind market was rather moderate in 2006. The cumulative installed capacity is 175 MW, of which 77 MW was newly installed in 2006—a bit below the national target projection. With an attractive feed-in tariff and R&D support, Korea is trying to achieve the national target of 2,250 MW by 2012. Obstacles to achieving this ambitious goal include public resistance and the difficult mountainous site characteristics of the available onshore territory. Under these circumstances, the government also supports R, D&D into offshore sites, which are expected to provide continuous growth in the future. The official data used in the following tables and elsewhere in this report were provided by the New and Renewable Energy Center of the Korea Energy Management Corporation (KEMCO).

2.0 Progress toward national objectives

As a non-annex party of the United Nations Framework Convention on Climate Change (UNFCCC), Korea can host clean development mechanism (CDM) projects. By participating in such projects, Korea is playing its part in mitigating greenhouse gases. Large-scale projects in Gangwon and Yongdeok (see Figures 1 and 2)—representing 98 MW and 39.6 MW, respectively, out of Korea's total installation capacity of 173 MW—have been successfully supported by CDMs. The Gangwon Wind Farm is the first renewable CDM-supported project in Korea, and its success indicates that installation of a project that uses a renewable source can be subsidized by the sale of emission reduction certificates associated with the project.

At the end of 2006, 118 wind turbines were operating in Korea. Of that number, 40 newly installed systems were generating 77 MW of capacity (Tables 1 and 2), including 35 Vestas V80 systems in the Gangwon project. According to the 2003 installation target set by the government in its document "The Second Basic Plan for New and Renewable Energy Technology Development and Dissemination,"new wind energy capacity of 2,040 MW, or 340 MW/yr, is needed to reach the target for 2006 through 2012. In the plan, the offshore portion is 675 MW (30% of the total of 2,250 MW) by 2012.

3.0 Benefits to national economy

3.1 Market characteristics

Korea wind market is structured the way the European market was structured in its initial phase. The government is a key driver in the local wind market, providing an attractive wind price backed by a fifteen-year long-term guaranteed feed-in tariff, tax incentives, and a subsidy policy. Encouraged by this environment, several big companies have joined the government in supporting the localization of wind turbine manufacturing to sustain long-term development. Previously, local utility companies and private site developers imported wind turbines

Table 1 Key Statistics 2006: Korea	
Total installed wind generation	175 MW
New wind generation installed	77 MW
Total electrical output from wind	.247 TWh
Wind generation as % of national electric demand	0.065%
Target:	2,250 MW by 2012

Table 2 Total installed wind generating capacity in Korea							
Year	Up to 2001	2002	2003	2004	2005	2006	Total
Capacity (MW)	7.9	4.7	5.4	50	30	75	173
Electrical output (GWh)	25	15	23	38	125	247	473

from abroad (including for the government-led demonstration project during the initial phase), leaving O&M in the hands of foreign manufacturers. Now, however, local manufacturers and developers are putting their best efforts toward building up the kind of in-house technical expertise in Korea that is characteristic of other markets.

The Korean wind farm business is still in its infancy and has been developed so far by virtually a single private developer, Unison. This company accounts for 138.6 MW of the total 175 MW of installed capacity accumulated by the end of 2006. The manufacturer Vestas has up to 98% of the market share for turbines in Korea, having received orders for the two large projects, Gangwon and Yongdeok, as well as a few small demonstration projects.

Recently, the issue of public acceptance has become an increasingly serious barrier preventing the onshore wind market from expanding further. Public concerns about visual impact and environmental issues make it more difficult to obtain construction permits and carry out the construction process. Military radar issues also act as a barrier to acceptance.

3.2 Industrial development and operational experience

Until recently, Korean industry had little opportunity to gain experience with renewable energy including wind energy. Similarly, the government has only recently set up policies to manage the market for renewables. The private developer Unison, having established itself as the leading development company in Korea with its two big projects, has established its own engineering project consultancy and O&M services. This company is developing wind turbines with government-funded projects: A 750-kW prototype is in field testing, and a 2-MW model is under development until through August 2007. The other local manufacturers, Hyosung and Hanjin, are also engaged in development–750-kW and 2-MW geared, doubly-fed, induction-generator wind turbines for Hyosung, and a 1.5-MW model for Hanjin. Doosan Heavy Industries recently began development of a 3-MW offshore model.

Poscoenc (a construction company experienced in power and infrastructure development projects) and electric power companies entered the

Figure 1 Yongdeok Wind Farm faces the East Sea of Korea; twenty-four units of 1.65-MW NM82 (V82).

Figure 2 Gangwon Wind Farm, the biggest in Korea; ninety-eight units of 2-MW V80.

wind farm market with their foreign partners (Eurus, GE, and Lahmeyer International GmbH) in the Gangwon and Gyongbuk Province wind farm projects. The local generation companies that have been split from the Korea Electric Power Corporation (KEPCO) agreed with the government to diversify their generating sources by including renewables.

4.0 National incentive programs

The Second Basic Plan sets a target of 5% of national energy consumption to come from renewables by 2012. Except for energy from wastes, wind energy accounts for the biggest portion (about 9.8%) of the final target in the plan. To achieve this goal, The Korean government is prepared to support the wind industry with a policy of incentives including subsidies, feed-in tariffs, tax incentives, and soft loans. Wind generation is eligible for a fifteen-year feed-in tariff of 107.29 Won/kWh that is scheduled to be reduced 2% every year after October 2009.

Government subsidies to developers covered up to 70% of installation costs for demonstration projects between 2000 and 2005. However, beginning in 2006, these subsidies were only available to small wind projects (<10 kW). The government also compensates commercial banks for the difference between commercial rates and lower than commercial rates up to a certain portion as long-term project financing to renewable energy construction projects. A single renewable construction facility can make a proposal to KEMCO for a maximum of 20 million USD payable over ten years following an initial five-year grace period.

5.0 R, D&D activities

The government's long-term budget projection is for more than 240 million USD to support wind R&D between 2004 and 2012. Many of the government-sponsored projects that emphasize local manufacturing of wind turbine systems and their components are still under way. 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.

Significant government funding has enabled Korea wind turbine manufacturing industry to gradually become competitive with foreign players. The local manufacturers, Unison and Hyosung, developed a 750-kW wind turbine. Hanjin took it a step further by acquiring a type certification of its 1.5-MW system from Deutschen Windenergie-Institutes Offshore Certification Centre (DEWI-OCC) for commercial production. The turbine will be installed in 2007 as a demonstration project (see Figure 3). Unison has developed gearless 750-kW and geared 2-MW turbines employing permanent magnet generators, while Hyosung has devoted itself to 750-kW and 2-MW geared, doubly-fed, induction-generator wind turbines. Both 750-kW prototypes are currently in field testing, and the

Figure 3 Hanjin's 1.5-MW wind turbine.

2-MW models will be fabricated by the middle of 2007. Doosan Heavy Industries will develop a 3-MW offshore model by the middle of 2009.

6.0 The next term

The wind market is in the spotlight, and significant government support is proposed not only for development, but also for achieving outstanding results in local manufacturing. In 2007, 750-kW and 1.5-MW wind turbines, the first domestic models, will be demonstrated at several locations. In addition, 2-MW prototypes are scheduled for installation in the field for testing.

For wind farm site development, local generation companies that are interested in diversifying to renewable sources and that receive financing from KEPCO are ready to be important players. However, increasing community opposition to site permitting is slowing new onshore development. This slow down is forcing Korea government to search for potential offshore sites, and at the beginning of 2007 it started a project to map offshore sites.

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Mexico 21

1.0 Introduction

At present, there is a constructive environment for launching the implementation of wind power in Mexico. More than a few official documents recognize that Mexico's most important wind resource would be sufficient for the installation of at least 5,000 MW of wind power. In a May 2005 topical workshop, the most important promoters of wind power 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, 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. The Federal Electricity Commission has issued an official program for the construction of four wind power plants during the next nine years; the first of these (83.3 MW) was constructed and commissioned in 2006. More than six private wind project developers affirm that they are close to the financial closure phase. Nowadays, the income tax law allows accelerated depreciation for investments in renewable energy technologies. Early in 2006, the federal Energy Regulatory Commission issued a regulatory instrument that improves the economic feasibility of self-supply wind power projects. In December 2005, the federal congress approved the initiative Law for the Use of Renewable Energy; however, at the end of 2006 the initiative was still pending in the Senate.

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 5.2% for the period 2005 to 2014. This growth results in a projected requirement of 305 TWh of electricity generation for 2014, representing an increase of 122 TWh and equivalent to 22.1 GW of additional new generating capacity. Of this, 6.2 GW is already under construction or planned, the majority using combined-cycle gas-turbine technology, in addition to several new hydro and geothermal plants. The remaining 15.9 GW will come from new projects. An opportunity niche therefore exists for supplying a reasonable portion of the uncommitted 15.9 GW of new capacity using Mexico's wind energy resource.

Table 1 Key Statistics 2006: Mexico	
Total installed wind generation	85.5 MW
New wind generation installed	83.3 MW
Total electrical output from wind	Not available
Wind generation as % of national electric demand	Not available
Target:	6% of electric generation by 2030*
*Shared vision from 2005 workshop	

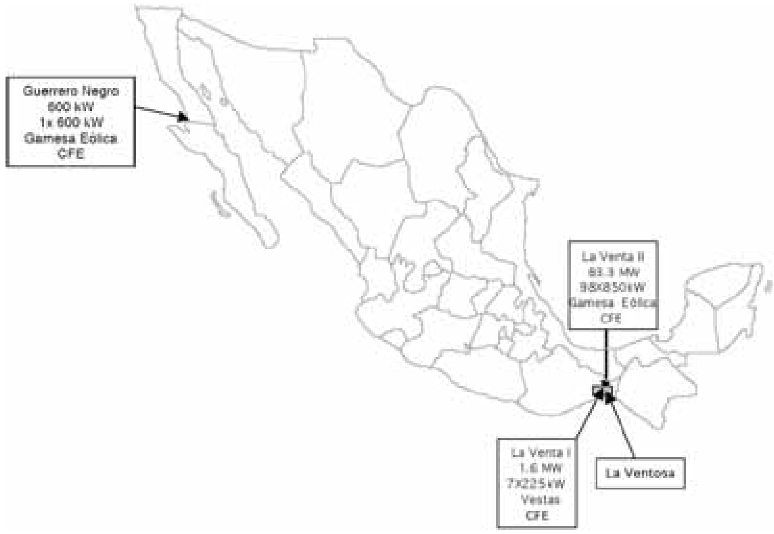

Figure 1 Location of wind turbines installed in Mexico by December 2006.

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. The new government is preparing the National Development Plan for 2007 through 2012. In accordance with recent statements from the president of Mexico, a National Programme for Climate Change will be issued. It is expected that this program will increase the opportunities for the implementation of renewable energy.

2.1 Strategy

One of the main official instruments aimed at including renewable energy in Mexico's electricity generation mix is the initiative called 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) based on 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.

Numerous stakeholders from both the public and private sectors are promoting the use of renewable energy in Mexico. However, during 2006, some constraints against this goal arose within the political arena. The major stakeholders of wind power are removing the various barriers by means of a systematic approach with the following major components.

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 the IIE.

By the end of 2006, GEF approved for Mexico a sponsorship for a 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, the Federal Electricity Commission (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, which means that a private contractor is responsible for financing and construction of the wind power plant, and CFE pays the contractor the total amount of the contract when the plant is commissioned. Next, 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 indicator for the 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 the CFE and several private wind project developers for the future construction of a transmission line aimed at transmitting electricity from several wind-power plants planned for the Isthmus of Tehuantepec. These 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 for 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 will give the green light to the construction of the first privately owned wind-power plants.

Several organizations have been issuing reports about wind energy. The Secretariat of Environment and Natural Resources (Semarnat) prepared a National Standard for the Construction, Operation, and Decommissioning of Wind Power Plants. This standard is already completed and is under consideration by the Commission for Regulatory Improvements.

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 2006					
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		

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 the Federal Electricity Commission, 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 already have 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 2006, electricity production from the La Venta I wind power station was 3.74 GWh. The facility operated at an annual capacity factor of 24.5%, according to Carlos García Aguilar, the station's general manager. The capacity factor of this plant was lower than in previous years because one of the seven Vestas 225-kW wind turbines was out of service all year long due to failure of the yaw system. In addition, by late 2006 one of the wind turbines collapsed, during a 53 m/s wind gust. The base of the tower totally bent around 4 meters above the foundation; thus the nacelle and the rotor moved downward to the ground. It is assumed that all of these failures are the effect of premature fatigue attributable to the strong winds in the region. In the early years of its operation, the whole plant reached more than 40% capacity factor, which has steadily and progressively declined. The seven wind turbines are exposed to the same wind regimen (plain terrain, unidirectional wind, three diameters of separation between wind turbines). Therefore, a possible reason for such operational constraints at a time when they have been in use for only around 60% of their expected commercial life is that the wind turbines are not technically appropriate for the strong and persistent winds in La Venta.

Commercial implementation of wind-power plants in La Venta and contiguous areas requires a careful selection of wind turbines. The suitable installation of wind turbines over 40 m in height could require special-class wind turbines, in accordance with IEC standards. Otherwise, a 20-year useful life would be unlikely to result. However, within the Isthmus of Tehuantepec there is plenty of land where Class I as well as Class II wind turbines could be installed.

Data from previous years show that the 600-kW wind turbine installed at Guerrero Negro operated at a capacity factor of 25%. According to CFE, annual average wind speed at this site is around 8 m/s at 50 meters aboveground. However, CFE has not released performance data for the years 2003 to 2006. And because the La Venta II wind power station was commissioned in late 2006, no information about this plant is available (Figure 3).

A 5-kW wind turbine of Mexican design is currently manufactured in Mexico, primarily for export markets. A Mexican company has manufactured several 750-kW electric generators for an international wind turbine manufacturer. 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. 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.

A niche of economic opportunity for wind energy already exists in the commercial and public service scenarios. The challenge is to develop and implement an adequate strategy for creating a convenient wind-power market. At present, a special buyback price for wind energy has not been set in Mexico.

The main constraints on wind-power market development in Mexico are as follows:

- Electricity for the industrial sector is subsidized.
- 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.

Figure 3 La Venta II wind park, commissioned in 2006.

Table 3 Electricity prices in Mexico, September 2006	
Sector	Average price (Mexican Pesos/ kWh)
Industrial	0.90
Agricultural	0.38
Residential	0.95
Commercial	1.96
Public services	1.49

- A comprehensive national program for wind-power deployment does not exist.
- 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 windlandowners (especially to peasants) in the negotiation of wind power projects.
- There is substantial lack of electricity transmission capacity for potential wind power development in the Isthmus of Tehuantepec.

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 the Federal Electricity Commission, 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.

In December 2004, a new incentive was issued. Today, 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.

The construction of the Regional Wind Technology Centre is scheduled to begin in February 2007. It is the first project to receive a permit to operate as a small power producer in Mexico.

The wind energy resource in several promising areas has not been evaluated in detail. Therefore, the 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 2006, one full year of data had been collected for fifteen 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. Finally, there is increasing interest by CFE in the short-term prediction of wind power output at La Venta II. CFE has contracted with the IIE to carry out a project in this regard.

6.0 The next term

The official Program of Investment for the Electric Sector (2004–2013), prepared by CFE, is considering the construction of another three wind power plants rated at around 100 MW each. A call for bids to construct one of these wind power plants is anticipated in 2007. In addition, it is expected that at least two privately owned wind power projects will be able to start construction during 2007.

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1.0 Introduction

The Netherlands saw an all time record of 350 MW of new installed wind capacity in 2006.

The share of renewable energy in the Netherlands energy supply increased to 2.6% in 2006 of the total primary energy consumption of 3,313 PJ. The domestic production of renewable electricity in 2006 increased to 7.6 TWh or 6.5% of the total electricity consumption of 116 TWh, of which 2.7 TWh or 2.4% of total consumption was from wind. The first offshore wind farm of 108 MW was built and brought online in December 2006. It is unique in the world, standing in water depths of 17 to 23 m at a distance of 8 to 12 km from the coast.

2.0 Progress toward National Objectives

In 2005, the net increase in installed wind capacity in the Netherlands was 335 MW, bringing the total installed capacity to 1,559 MW. The production of wind electricity in 2006 increased to 2.7 TWh or 2.4% of the total electricity consumption (Table 1 and Table 2) (1).

In 2006, 154 turbines were installed with a total capacity of 350 MW, and 40 turbines with a total capacity of 15 MW were decommissioned. The net installed capacity in 2006 was 335 MW, and the total installed capacity at the end of 2006 was 1,559 MW. Of the decommissioned turbines in 2006, 21 with a total capacity of 4.3 MW were replaced with 13 turbines with a total capacity of 26.5 MW. The net repowering effect was an increase of 22 MW (Figure 1).

The national targets in 2006 were to have 5% of total energy consumption from renewable energy in 2010 and 10% in 2020. The intermediate target for electricity is 9% of total electricity consumption from renewable electricity 2010. The target for wind energy on land is 1,500 MW in 2010. With 1,451 MW land-based wind capacity installed at the end of 2006, this target will be met in 2007. It is up to a new government to specify its ambitions for 2020 for offshore wind energy (expected mid 2007).

3.0 Benefits to National Economy

3.1 Market characteristics

Total investment in wind energy in the Netherlands for 2006 can be estimated at 480 million €, assuming an average investment cost for land-based wind of 1,100 €/kW for the 242 MW installed and an average investment cost for offshore wind of 2,000 €/kW for the 108 MW installed. Like the all time record for installed wind capacity, 2006 was a record year for investment costs made higher by the large investment in offshore wind capacity.

The majority of the wind farms are owned and operated by private owners. Energy companies rarely own wind farms by themselves. Among the types of private ownership, quite a few involve joint

Table 1 Key Statistics 2006: The Netherlands	
Total installed wind generation	1,559 MW
New wind generation installed	350 MW
Total electrical output from wind	2.7 TWh
Wind generation as % of national electric demand	2.4%
Target:	9% Renewable Electricity in 2010

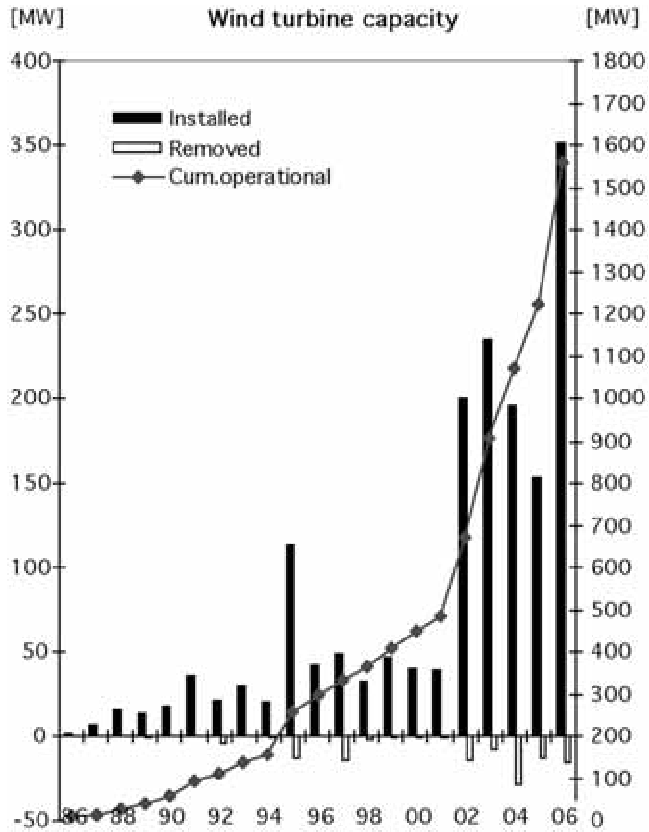

Figure 1 Installed, removed, and cumulative wind turbine capacity in the Netherlands.

ventures between 'pure' private owners and energy companies. An example of this is the Offshore Wind Farm Egmond aan Zee (OWEZ) (formerly the Near Shore Wind farm (NSW)) that is jointly owned by Shell Renewables and Nuon, one of the major energy companies in the Netherlands (Figure 2).

3.1.1 Offshore development

Offshore development is the new trend for wind farm projects. Project development companies that have started the process of obtaining building permits by drawing up environmental impact statements include WEOM a Dutch development company in the energy sector (on behalf of Nuon and ShellRenewables), E-Connection, Evelop, Airtricity, Raedthuijs, Arcadis, Bard Engineering Gmbh, Eolic Power Gmbh, and Global Wind Support Gmbh. WEOM has been a developer of wind farms since the mid-nineties and is now a subsidiary of Nuon. On behalf of Nuon and Shell WindEnergy, they were strongly involved in the development of OWEZ. E-Connection is one of the oldest independent developers of wind farms since the mid-eighties in the Netherlands. E-Connection developed the offshore wind farm Q7. Evelop is a subsidiary of Econcern. In 2005, Evelop bought the wind farm Q7 from E-Connection, which is now under construction. Airtricity is a well known Irish developer and owner of wind farms. It owns the first Irish offshore wind farm Arklow Banks. Raedthuys has been developing wind projects since 1995. It uses a fiscally-driven participation model for wind farm development. Arcadis is a global consulting and engineering company active in the fields of infrastructure, environment, and facilities. Bard Engineering Gmbh, Eolic Power Gmbh, and Global Wind Support Gmbh are closely related German offshore wind farm developers. Their applications in the Dutch North Sea are located close to the German developments north of the Watten Isles.

Table 2 Wind generated electricity, avoided fossil fuel, and national electricity consumption

	Wind generated electricity	Primary energy savings	National electricity consumption
	[GWh]	[PJ]	[GWh]
1985	6	0.05	
1986	7	0.06	
1987	14	0.12	
1988	32	0.26	
1989	40	0.33	
1990	56	0.50	78,582
1991	88	0.78	80,803
1992	147	1.30	83,173
1993	174	1.56	84,318
1994	238	2.12	87.067
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	17.11	114,700
2006	2,747	22.73	116,237
CBS	Numbers CBS final		

The status of applications for offshore building permits is given in the Table 3.

Nine developers have 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 (2). These developers selected locations with a total surface area of 2,552 km² on which, dependent on the layout, the installed capacity can be between 20 GW and 25 GW. However, the overlap in locations is about 1,240 km². That is why the installed capacity can at the most be from 10 GW to 13 GW. If realised, this wind capacity could yearly generate approximately from 30 TWh to 37 TWh of electricity. This is 27% to 32% of the present electricity consumption in the Netherlands.

Not all applications have been approved. On July 28, the application for a building permit for the offshore wind farm Den Haag I of WEOM (on behalf of Nuon en Shell WindEnergy) was declined. The reason was a relocation of shipping lanes foreseen by the Ministry (3). On November 26, the applications for a building permit for the offshore wind farms Q4-WP and P12-P of E-Connection Project B.V were declined. The environmental impact statements and building permits applications were supplied in 2005. Additional data supplied by E-Connection were, even after repeated requests, insufficient for the evaluation of the application or the preparation of the permit (4). For another nine wind farms the environmental impact statements and building permits applications were supplied in 2006.

On November 29 the completed environmental impact statements and building permit applications for two wind farms were laid down for public inspection. This implies that the Ministry will not deal with other existing or future claims of other developers for the same site, unless the building permit is declined. The first one is from WEOM for the wind farm IJmuiden with a surface area of 17 km² and a potential capacity between 140 MW and 246 MW. The second one is from Airtrcity for the wind farm West Rijn with a surface area of 45 km² and a potential capacity between 250 MW and 350 MW (2).

The reasons for developing wind power offshore in the Netherlands stem from the fact that the country is densely populated and heavily built up. This has led to the common understanding that it would be almost impossible to find enough sites for wind capacity to contribute sufficiently to reach the national renewable energy target. The Dutch North Sea with water depths of 20 to 40 m and yearly average wind speeds of 9 m/s at 80 m height offers good opportunities to develop up to 10 GW of offshore wind capacity, which could supply around 30% of the electricity consumption of the country.

3.1.2 Repowering

Although the government does not have a separate repowering program, it was possible under the MEP subsidy rules to redevelop an existing site

Figure 2 Offshore Wind Farm Egmond aan Zee (OWEZ) construction yard, IJmuiden harbor. Towers, blades, nacelles are shown. Photo J.L. 't Hooft, SenterNovem.

Table 3 Status and progress for applications for offshore building permits

Developer	Inception memorandum	MER and permits applications	Declined	In inspection procedure since
WEOM	9	4	1	1
E-Connection	11	2	2	
Evelop	12	2		
Airtricity	9	2		1
Raedthuys	18			
Arcadis	3	1		
Bard Engineering, Eolic Power, Global Wind Support	3			
Total	65	11	3	2

and be eligible for the full MEP-subsidy until 1 June 2006. In past years, this has led to the refurbishing of numerous wind sites installed in the mid-eighties to mid-nineties that had older wind turbine technology with modern multi-MW turbines. Another drive for repowering has come from local planning authorities. In areas where many smaller turbines are spread out e.g. with individual turbines, the authorities try to encourage regrouping new turbines into large wind farms in which the original owners of the smaller units can participate. This is usually a tedious process, because it has to be done on a voluntary basis.

3.2 Industrial development and operational experience

The average installed capacity per turbine increased very sharply from 1,358 kW in 2005 to

2,248 kW in 2006. This is because the new wind farms are using turbines with a capacity of between 2 MW and 3 MW, with a majority using 3-MW machines. The average hub-height rises with this class of machines to around 70 m. On the other hand, the installed swept area per unit of power decreased to around 2.1 m^2/kW (see Figure 3).

Of the wind turbines installed in 2006, Vestas' share was 62% (see Table 4 and Table 5). Enercon's share of 24% in 2005 went up sharply to 36% in 2006. The other manufacturers' shares the remained at 2%. Unlike the previous year, General Electric Wind did not install any turbines in the Netherlands in 2006. Seven wind farms with an installed capacity of 10 MW or higher were installed in 2006. The largest is OWEZ with 108 MW. The two second largest at around 50 MW each are equipped with Enercon turbines.

Emergya Wind Technologies (EWT) installed its first DirectWind turbine of 900 kW, 54-m diameter. EWT markets, sells, and assembles direct-drive wind turbines based on technology of the former Lagerwey company. Besides the original 750-kW turbine they have developed a 900-kW turbine.

3.2.1 Business developments

The participation of large companies, as described below, in wind energy developments is important.

Econcern is the holding company of Ecofys, Evelop, Ecostream, and Ecoventures. The mission of these European companies is to ensure "a sustainable energy supply for everyone." Econcern delivers projects, innovative products, and services for a sustainable energy supply. Econcern received a total injection of capital of 80 million € from SHV and Entrepreneurs Fund in the Netherlands. The company employs around 550 people. Ecofys was established in 1984 and specialises in energy saving and renewable energy solutions. It offers research and consultancy services as well as product development. It employs almost 300 people in eleven countries.

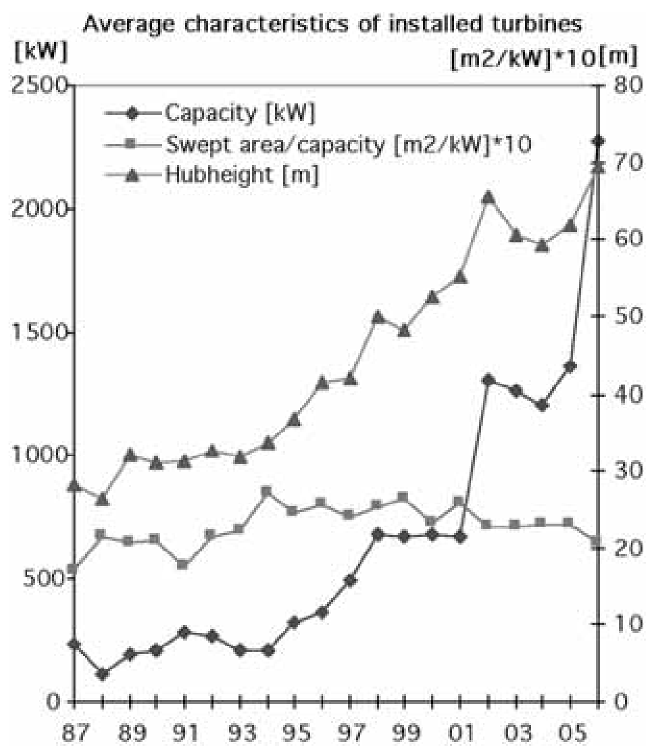

Figure 3 Annual average characteristics of installed turbines in the Netherlands.

Table 4 Distribution of new wind turbines by manufacturer				
Manufacturer	Turbines	Installed		Rotor area
	[number]	[MW]	[%]	[m^2]
Vestas	93	216.2	62	483,970
Enercon	58	127.1	36	225,334
Nordex	2	5.0	1	12,723
Siemens	1	0.6	0	1,521
Emergya WT	1	0.9	0	2,290
Micon	1	0.9	0	2,290
Total	156	350.7	100	728,128

Table 5 Size of wind plants installed in 2006						
Wind farms > 5MW	Manufacturer	Turbines	Height	Diameter	Capacity	Swept area
		[number]	[m]	[m]	[MW]	[m^2]
Offshore Wind Farm Egmond aan Zee	Vestas	36	70	90	108.0	229,022
Delfzijl Zuid	Enercon	26	85	71	57.4	102,939
Lelystad Mammoettocht-Neushoorntocht	Enercon	20	68	71	46.0	79,184
Biddinghuizen	Vestas	17	70	80	34.0	85,451
Dronten-Zeebiestocht	Enercon	7	70	71	16.1	27,714
Middelharnis #	Vestas	7	60	80	14.0	35,186
Rotterdam-Dintelhaven	Vestas	4	105	90	12.0	25,447
Oosterschelde-Neeltje Jans	Vestas	3	78	90	9.0	19,085
Nrd-Beveland-Jacobahaven	Vestas	3	80	90	9.0	19,085
Waddinxveen	Vestas	3	75	90	9.0	19,085
Anna Paulowna	Vestas	7	50	52.2	6.3	14,981
Oosterschelde-Noordland	Vestas	2	78	90	6.0	12,723
Kerkrade	Nordex	2	80	90	5.0	12,723
Various < 5MW	NL/DK/GE	-	-	-	19.2	45,476
Total					351.0	728,102

Areas of expertise include solar energy, wind energy, biomass, hydrogen technology, energy supply, and climate policies.

Ecostream supplies turnkey solar power plants and PV systems in seven European countries and the United States. Ecoventures commercializes innovative products, systems, and services developed within the Econcern group. It does this by establishing dedicated companies, often together with strategic partners, or by selling licenses. Companies cover the areas of: bio-methanol; CHP; zero-energy buildings; closed greenhouses; wireless and solar powered multi-service shops; carbon credits; seawater air-conditioning systems; a solar-grade polysilicon plant for the photovoltaic industry, innovative solar water heaters and solar modules.

In April 2006 Econcern took over the wind project developer WinWind, with a portfolio of 300 MW of wind projects, and 50 MW under construction. In November 2006 Econcern took over the French developer of wind farms Terra Nova. Terra Nova has a portfolio of 66 projects with around 1,000 MW, mainly in the North of France and has 7 employees. Ecoventures, a daughter of Econcern, took a 51% share in DarwinD. During 2006, the company DarwindD was restructured. Darwind is an initiative of foundation ATO that was formed to promote industrial development in the Province of North-Holland. DarwinD is a developer and manufacturer of offshore wind turbines. Econcern wants to enable and participate in the development a "non-compromise" innovative offshore wind technology. It needs reliable offshore wind turbines for the development of 2,000 MW of offshore projects. In the following years DarwinD will produce a prototype of a direct-drive, permanent-magnet, single bearing wind turbine. It will be installed at the enlarged Energy Research Centre of the Netherlands (ECN) wind test site in Wieringermeer. The province of North Holland guarantees 8.5 million € for these prototype turbines, on top of 2 million € for testing and certification of the prototype (see also news (5) and (6).

3.2.2 New commercial applications such as offshore deployment

During 2006, the Egmond Building Combination (EBC) built the Near Shore Wind farm (NSW) on the order of NoordzeeWind a legal entity of Shell Renewables and Nuon. The EBC is a joint venture of Ballast Nedam and Vestas. The NSW was renamed by NoordzeeWind into Offshore Wind farm Egmond aan Zee (OWEZ). Investment costs are around 200 million € and financed on balance by Nuon and Shell. The wind farm will initially be operated by EBC under a 5-year warranty, operations, and maintenance contract. The electricity is sold to Nuon Energy Trading, an affiliate of Nuon. It will produce approximately 350 GWh per year. The EBC drove the first of the 36 monopiles with the crane ship Svanen on 17 April 2006 and the last one on June 28. A2SEA placed the first turbine on 6 June 2006 with the crane ship Ocean Energy, and it placed the last turbine on 26 August 2006. The transformer was put in the transformer station in the dunes at Velsen-Noord on 11 May. The first row of turbines was put into operation on 5 October 2006 and the last row in the third week of December (Figure 4).

In September, construction started on the second offshore wind farm Q7 in the Netherlands part of the North Sea. This offshore wind farm is just outside the 12-mile zone south-west of OWEZ. The 120-MW wind farm Q7 will consist of 60 Vestas 2-MW, 80-m diameter turbines. The project is owned and developed by a group of companies of ENECO Holding NV, Econcern BV, and Energy Investment Holdings. It is built by Vestas Wind Systems A/S, Van Oord Dredging, and Marine Contractors BV ("Van Oord") under separate construction contracts. The windfarm will initially be operated by Vestas Offshore, an affiliate of Vestas, under a 5-year warranty, operations, and maintenance contract. It is expected to be completed by 1 March 2008, for a total investment cost of 383 million € . It will sell electricity to ENECO Energy Trade B.V, an affiliate of ENECO. It will produce approximately 400 GWh per year. Van Oord's installation ship Jumping Jack started driving monopiles in the sea-bed for Q7 in September (Figure 5).

Q7's financing is probably the first non-recourse financing for an offshore wind farm. The tailor-made financing structure includes 219 million €, 11-year, non-recourse, long-term facilities financing and 160 million € for short-term construction facilities (7). Further details of this intricate piece of financial engineering were revealed during an offshore financing workshop of the consortium We@sea and can be found at their website (8).

3.3 Economic details

The Ministry of Economic Affairs contracted ECN and KEMA (a commercial enterprise specializing in high-grade technical consultancy, inspec-

Figure 4 Construction of Offshore Wind farm Egmond aan Zee (OWEZ). Photo G.Pascaud, A2SEA.

Figure 5 Picture of Jumping Jack placing a transition piece on Q7 monopile. In the background the OWEZ. Photo Mammoet van Oord.

tion, testing and certification) in 2006 to assess the financial viability of the different renewable electricity production technologies (9). The Ministry intended to use this assessment to decide on the level of the MEP-subsidies required to bridge the difference between cost and market prices for each renewable electricity source and technology for 2008. Due to the stop in production subsidies as of 18 August 2006, no final advice was given on subsidy levels. Also the results have not been presented to stakeholders for consultation. Nevertheless the ECN and KEMA report gives the technical-economic parameters.

3.3.1 Wind on land

Learning effects have had a downward influence on the cost of wind turbines but were not reflected in the market price during 2006. This is due to the strong international increased demand for large turbines of 2 MW to 3 MW capacities with tower heights of 80 to 90 m and the (temporarily) higher steel and copper prices. As a consequence, delivery times of wind turbines increased to more than a year and market prices did not decrease. The reference value for investment costs increased to 1,200 €/kW in 2008. The total for the reference costs for operation and maintenance remain the same. The values are summarized in Table 6.

3.3.2 Wind offshore

The international spread in investment costs for wind offshore is large at 1,650–2,250 €/kW. The costs are largely dependent on weather and wave conditions, water depth, and distance to the coast. New offshore wind farms in the Netherlands have to be built outside the 12-mile zone with distances of 20 to 60 km from shore and in 20 to 35-m deep water. Internationally, there is large uncertainty in the offshore wind sector, because projects have longer lead times than anticipated and the costs are unclear. For new projects in the Netherlands, there are claims that prices are up to 3,000 €/kW (e.g. the Q7 wind farm). The ECN/KEMA report recommends using a reference price of 2,200 €/kW for 2008 and to actualise the investment costs at a later date. Reference costs for O&M contracts remained the same, and full-load hours increased to 3,650, which seems representative for sites further out at sea (Table 7).

For both wind on land and offshore the ECN/KEMA report forecasts the grey electricity market price to rise from 37 €/MWh to 56 €/MWh. For long-term contracts the report expects a reduction of 5 €/MWh of the market price.

4.0 National Incentive Programs

For the basic description of support initiatives and market stimulation instruments in the Netherlands, please refer to pages 162 and 163, IEA Wind Energy 2004 Annual Report (10).

The government announced an immediate standstill for new offshore wind production subsidies on 10 May 2005 in light of the possibility of overachieving the 9% sustainable electricity target for 2010. The Minister of Economic Affairs announced that for another 480 MW of offshore wind the MEP production subsidy would be tendered for the lowest electricity price. During 2006, this has not resulted in rules or regulations. A change in the MEP production tariff for wind on land was announced by the government early in 2006. Starting July 1, the tariff would change from 77 €/MWh for the first 18,000 full-load hours to 65 €/MWh for the first 20,000 full-load hours. On August 18 the Minister of Economic Affairs announced an immediate reduction to 0 €/MWh of the subsidies for all new renewable electricity projects. Projects which applied for the MEP production subsidy before August 18 were still eligible. The reasoning behind these measures was as follows: The interim government (at that time) would step down on November 11, with the general elections. It had promised to be prudent with policy decisions that reached after its term. The already appropriated budgets for existing and applied projects would be sufficient to reach the Netherlands target of 9% electricity in 2010. The expected expenditure for these projects in 2007 is 550 million € and in the years after that 650 million €. The interim government left decisions about new targets for renewable energy and the necessary extra budgets to the new

Table 6 Technical and financial parameters of wind onshore

		2006-2007	2008
Investment costs	[€/kW]	1100	1200
Full load hours	[h/yr]	2000	2000
Fixed O&M costs	[€/kW]	39	39
Electricity price	[€/MWh]	37	56
Reduction long term contracts	[€/MWh]	5	5
Imbalance costs	[€/MWh]	6	4

Table 7 Technical and financial parameters wind offshore			
		2006-2007	2008
Investment costs	[€/kW]	2000	2200
Full load hours	[h/yr]	3350	3650
Fixed O&M costs	[€/kW]	80	80
Electricity price	[€/MWh]	37	56
Reduction long term contracts	[€/MWh]	5	5
Imbalance costs	[€/MWh]	6	4

government, which was expected in the beginning of 2007.

4.1 Impacts of incentive programs

The effect of MEP production subsidy in 2006 was that 350 MW of new wind capacity was installed. 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 July 1, and this resulted in wind projects with a total capacity of 600 MW to be installed up to 2008.

Also the market expected that the MEP-tariffs after 2007 would go down because of the rising grey electricity prices. After all, the MEP-tariff is based on the calculations each year of the financial viability of typical wind projects. Basically, the financially viable electricity price of a project minus the grey electricity price is the MEP-tariff (11). Finally, developers felt uncertain about the amount of subsidy available after 2007. The effect of reducing the subsidy to zero in August was that the markets put the investment decisions for new projects on hold.

4.2 Effect of Energy Transition initiatives

A new energy policy “Energy Transition” was introduced by the Ministry of Economic Affairs in 2001. At the basis of this policy are long-term energy scenarios for the transition to a sustainable energy society (CO_2-free electricity in 2050). A strong R&D agenda was set by formulating the energy research strategy called EOS. Energy Transition focuses on processes that lead to the desired sustainable energy society and removes obstacles on the way to this transition. In 2004, the government organised the so-called transition platforms. The platforms consist of stakeholders from environmental groups, industry, electricity companies, and government. The platforms set out the transition routes and recommend measures, demonstration projects, and areas for research. The government has a budget available of 400 million € for a 5-year timeframe.

One of these platforms was the Transition to Offshore Wind (TOW). The main target of TOW for the next 2 years is to set out routes for the period 2010-2020. This should result in the development of offshore wind farms by market parties on commercially and socially sustainable grounds. In the end, offshore wind should provide 10–20% of the Netherlands’ electricity consumption. The platform identified three domains in which significant progress is needed to reach these targets: achieving commercial value of energy delivered; improving the cost efficiency of energy production systems, support systems, installation and maintenance; and achieving acceptance by society. The platform represents organisations that cover all aspects of offshore wind such as development of knowledge, project development, construction, exploitation, grid integration, financing and public acceptance, the ministry of economic affairs, and the ministry of traffic and transport.

The Platform for a Sustainable Electricity Supply is developing four transition routes: increasing the share of renewable energy sources; improving the sustainability of traditional electricity production (e.g. through CO_2 storage and co-generation); modifying the electrical infrastructure, and achieving electricity savings. The platform represents organisations like the major electricity companies; universities; financing; research institutes, developers and environmental interest groups.

5.0 R&D Activities

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. It has a yearly budget of around 42 million €. One of the themes of the program is "Offshore wind generation and electricity grids." Table 8 gives the four focal points and objectives.

In 2005, the Ministry EZ decided to fund research in which ECN has a major strength directly from the EOS research program. In 2006, the 4-year program of ECN was approved by the Energy Advisory Committee of the program. The program concentrates on five major research areas: 1) aero elasticity; 2) condition monitoring and measurement techniques; 3) control technology; 4) wind farm aerodynamics; and 5) decision support models for maintenance and operation.

The Consortium We@sea develops knowledge and skills to build, exploit, and decommission large-scale offshore wind farms. It runs a 4-year program on offshore wind energy that is funded from the national natural gas fund. This program, running from 2004 to 2008, of 26 million € with a subsidy of 13 million € concentrates on medium-term research. The consortium consists of companies in offshore technology, wind energy technology, offshore wind farm development, logistics, investors, energy consultants, environment, and other stakeholders. The research lines are: offshore wind power generation; spatial planning and environmental aspects; energy transport and distribution; energy market and finance; installation, operation and maintenance, and dismantling; education, training, and knowledge dissemination; and the PhD@Sea project. The PhD@Sea research subjects are divided over the research lines of the overall program. Its topics are: large blades; wind turbine concepts; morphology of the North Sea bed; grid stability of large-scale integration of wind energy in electrical power systems; park-grid interaction; offshore access through the Ampelmann; reliability, availability, maintainability, and serviceability analyses and scenarios.

5.1 Interesting new research efforts

Rotorflow I is a project in which ECN and Twente Technical University (TTU) are researching new methods for the calculation of aerodynamic loads that combine the computational efficiency of blade element impulse methods (BEM) while aiming for the accuracy of computational fluid dynamics (CFD). To increase the computational efficiency ECN developed a hierarchic structure of meshed elements and tested it extensively. Belonging to the test procedure was the visualisation of the distribution of the computational elements for different geometries. An example is given in Figure 6.

For research areas in which ECN together with TU Delft and the Knowledge Centre WMC have a major strength, the consortium INNWIND was funded with 1 million € per year for a 4-year program. The program concentrates on five thrust areas: concepts and components; aerodynamics and construction dynamics; materials and constructions; model development and realisation of an integrated design environment and design guidelines.

Projects awarded under the EOS LT program area 'Offshore wind generation and electricity grids' in 2005 and 2006 are listed in Table 9.

5.2 Interesting completed research

WT-Bird The ECN research program concluded the development of a new method for detection and registration of bird collisions that is suitable for continuous remote operation in both onshore and offshore wind farms. It tested a prototype on a land-based multi-megawatt turbine at their wind turbine test site. The WT-Bird method is based on detection of a bird collision through vibration of the blade that triggers video registration. Functional tests with bird dummies of only 50 grams and 7 cm in diameter, representing the smallest abundant bird species along the Dutch coastal region, showed that the majority of impacts were detected. The flight

Table 8 EOS-LT focal points and objectives of theme Offshore wind generation and electricity grids

Focal points	Objective
Knowledge for design of wind conversion offshore	Wind conversion offshore competitive with fossil fuel based generation in 2020
Integration of 6,000 MW of offshore wind in the Netherlands electricity grid	Economic, reliable, and stable.
Technical transition of electricity networks	Technologies for a sustainable energy supply
Management and maintenance of electricity networks	Sustainable use of electricity grids in capacity and time

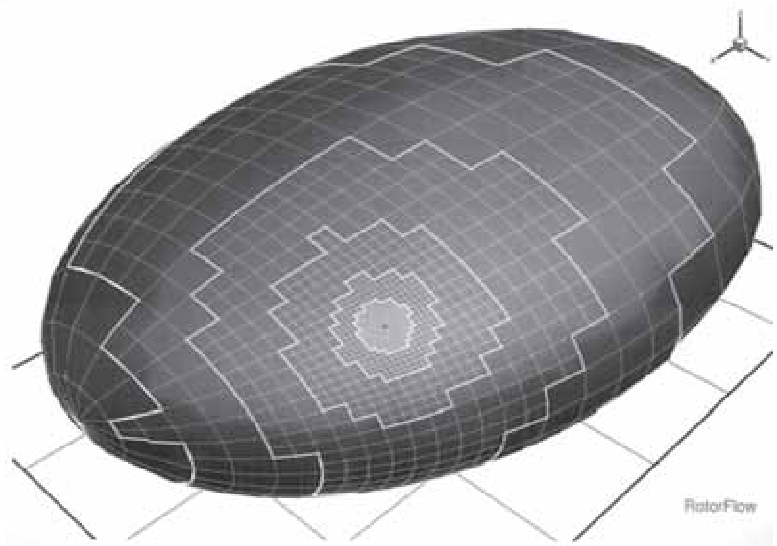

Figure 6 First visualisation of one of the results of the geometric core. Picture A. van Garrel, ECN.

Table 9 Projects funded under the EOS-LT research program

Title	Partners	Funding period (years)
I Projects offshore wind generation		
New methods for the calculation of aerodynamic loads (Rotorflow I)	ECN, TUT	4
Sustainable Control. A new approach to operate wind turbines. (SUSCON)	ECN, DTU, Nordex, Mitsubishi, Ecotecnia	4
Program consortium INNWIND	ECN, DTU, WMC	1 of 4
Wind multi year program ECN	ECN	1 of 4
II Projects electricity grids		
Flexible electricity grids for integration of RES (Flexibel)	ECN, KEMA, ETU	4
Stability and control of the future electricity grid in NL (STABE)	DTU	4
Electrical infrastructure of the future (EIT)	ETU, KEMA, ECN	4
Quality of the voltage in future infrastructure (KTI)	ETU, ECN, Laborelec	4
Synergy of intelligence and energy in future grids (SINERGIE)	DTU, NUON	4
Intelligent E-Transport Management (ITM)	KEMA, ECN, Essent, Continuon, IWO	4
Rules for a reliable and sustainable production of electricity (Rules)	ETU	4
Transition Roadmap Energy Infrastructure for the Netherlands (TREIN)	ETU	4
Grids multi year program ECN	ECN	1 of 4
Total funding during 2005 and 2006: 20 million €		

track of these dummies and the collision events were clearly visible on the video registrations. So far only one real bird collided with a blade and luckily survived the hit. As ECN's wind test site is in an area with few birds, the systems needs to be calibrated in an area where the probability of a bird collision is higher and refinements to the system can be made. ECN intends to offer a service to wind farm owners and operators in which it is responsible for the installation and operation of the system and reports bird collisions to the customer.

EWTW Validation Measurements ECN concluded a data collection project to validate models for performance and load calculations of wind turbines in wake conditions. ECN researchers installed a data-acquisition system and measured and collected data during two years at the ECN Wind Turbine Test Station Wieringermeer (EWTW). Part of this test site consists of a row of five Nordex 80 wind turbines with variable speed and pitch control. The turbines are placed at a distance of 3.8 rotor diameters. The farm is equipped with a meteorological mast. Meteorological data up to a height of 108 m, operational parameters of all turbines, and bending moments in blades and tower of one turbine were measured during two years and automatically stored in a database. The project included processing measurement data for direct validation of models for calculation of wind characteristics and farm performance in the wake and for determination of extreme and fatigue loads.

Heat & Flux Wind Turbine Controller Over the years 1999–2003, ECN invented and patented the control technique called Heat & Flux. The idea behind Heat & Flux is that tuning turbines at the windward side of a wind farm will making it more transparent than usual (i.e. realising an axial induction factor below the Lanchester-Betz optimum of 1/3) should raise net farm production and lower mechanical turbine loading without causing drawbacks. For scaled farms in a boundary layer wind tunnel, ECN proved this hypothesis in previous projects. To enable alternative turbine transparencies, the wind turbine controller must support the additional control aim "desired transparency." During this study, ECN has determined a general method to design a transparency control algorithm. This method has been implemented in ECN's Control Tool for designing wind turbine control algorithms. The aeroelastic wind turbine code Phatas was used to verify the resulting control algorithm. Heat & Flux does not fundamentally change the control of horizontal axis, variable speed wind turbines. The axial induction can be reduced by an offset on blade pitch or generator torque.

Monitoring and Evaluation of OWEZ Further results of the Monitoring and Evaluation program of the Offshore Wind farm Egmond aan Zee (OWEZ, formerly know as NSW) became available in 2006. Wind Climate NoordzeeWind supplied the "Manual data files meteo mast NoordzeeWind," which introduces the project and the site and briefly describes the instrumentation, the data files, and quality of data. It lists the instruments, channels, and data and gives the instrumentation drawing of the met mast. The wind climate in this undisturbed situation contains one year of 10 min average wind measurements of the site at three heights of the meteorological mast from July 2005 to June 2006. The data for the coordinates of the metrological mast and wind turbines are necessary to determine the wind directions for undisturbed wind measurements and PV-curve measurements, single, and multiple wake measurements (Figure 7). The data can be downloaded from the SenterNovem offshore wind energy web page on wind climate (12).

The research also produced a report on biological fouling: Biological Fouling Pre-survey of marine fouling on turbine support structures of the Offshore Windfarm Egmond aan Zee. The report describes the methodology, the results of the pre-survey into existing knowledge, and the approach of monitoring. The data can be downloaded from the SenterNovem offshore wind energy web page on biological fouling (13).

A report on the effects ship collisions, oil spills, and shipping radar is titled MEP-NSW: Maritime and Marine risk assessment of calamitous (oil) spills. It reports the results of a study by WL/Delft Hydraulics in collaboration with MARIN. It assesses the probabilities of collisions due to the presence of the OWEZ, the effects of calamitous oil (chemical) spills due to shipping collisions with the OWEZ, and of the effects of the OWEZ on shipping radar. The data can be downloaded from the SenterNovem offshore wind energy web page on shipping (14).

We@sea Program The consortium We@sea was active in 2006. It organised an offshore financing workshop in which various experts revealed the finer points of financial engineering. The presentations can be found at their Website (8). We@sea also sponsored the Sixth International Workshop on Large-Scale Integration of Wind Power and Transmission Networks for Offshore Wind Farms, October 2006 in Delft, The Netherlands. Two PhD students from PhD@Sea project were instrumental

Figure 7 Meteorogogical mast NoordzeeWind. Photo S. de Jong, Rijkswaterstaat Noordzee.

in the success of the workshop organised by Delft Technical University, Energynautics GmbH, and Royal Institute of Technology, Sweden.

As part of the PhD@Sea project System Integration of Large-Scale Wind Power in the Netherlands, B.C. Ummels et. al. presented the following results of a study of unit commitment and dispatch in the Netherlands in the presence of future large-scale wind energy production. The aim was to identify bottlenecks in system planning and operation due to wind integration, in particular base-load and ramp rate problems. These may constrain the amount of wind that can be accommodated given a projected production park of dispatchable units and yearly load profile by 2012. Wind data from 2004–2005, interpolated to existing locations for onshore and planned locations for offshore wind parks, were used to create a realistic yearly wind energy output profile. The unit commitment and economic dispatch formulation includes ramp rate constraints for generation schedules and reserve activation as well as minimum up- and down times. Of particular interest in this study are the combined heat and power (CHP) units, which impose additional constraints coupling their heat and energy production. Since no insight was available into the aggregated predictability of wind generation, both a 0-MW prediction, where conventional units are scheduled to meet the total load, and a perfect prediction have been investigated. No forms of electrical or heat storage were considered. The results show no ramp rate problems in the Dutch system by 2012; however base-load problems may arise at high wind penetration levels, only to be prevented by wasting available wind resources.

As part of the PhD@Sea project Comparison of Support Schemes and Market Designs for Wind Power, K. Verhaegen et. al. presented the results of an evaluation and impact on the system integration of wind power. A system model was developed for the simulation of system balancing including wind power integration under various regimes. The preliminary results demonstrate that the market design for integrating wind power has a major impact on the overall system balance, most notably the Area Control Error, being a key parameter for system operation. In case wind power has to be balanced by the TSO, some wind power fluctuations may be cancelled out between different wind farms due to geographical spread, but large imbalances are inevitable. In a market-based environment however, the market parties should be responsible for balancing their portfolio as such in order to keep the imbalance on system level as low as possible.

More info of We@sea work can be found on their website (15).

5.3 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 participation of Dutch researchers in expert meetings of Task 11 is valuable for the exchange and discussion of ideas and projects in progress and is highly appreciated by Dutch researchers because of the ample time for discussion and free flow format. Participation in Task 20 on aerodynamics gives direct access to data from the NASA/Ames wind tunnel experiments which would be too costly to repeat in the Netherlands. The number of aerodynamics researchers involved in the task creates the critical mass that makes fruitful research possible. Resulting knowledge about the fundamental mechanisms of aerodynamics and its modelling are subsequently incorporated in national research and design codes. Participation in Task 21 on dynamic models of wind farms for power system studies gives access to measurement data that are not available in the Netherlands. The participants are able to improve dynamic models of wind farms and validate them against measurements. The resulting models are used in the EOS long-term research program for detailed grid studies in voltage stability with large amounts of offshore wind power. Participation in Task 23 on offshore deployment gives access to the experience of offshore wind farms in the participating countries. Sharing the experiences gives all participants access to a larger installed base than each individual country. Bottlenecks identified can then be resolved together through collaborative research. The results can accelerate the implementation of offshore wind power in the Netherlands. Task 25 on design and operation of power systems with large amounts of wind power production make it possible to tap in to the collective research power of the ten participating countries to study the economic and technical conditions to realise a maximum amount of wind energy in North American and European power systems. The result will be of value for the Netherlands Transition Platform for a Sustainable Electricity Supply. Participation in the IEA Wind tasks is also a cost-effective way to do research. On average, each euro spent in our country on research gives access to five euros value of research spent in the other participating countries.

Netherlands research institutes also participate in the European projects Mexico, Optimat Blades, Accuwind, and Upwind which is closely interlinked with the Netherlands Innwind project.

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(2) For a complete updated list see http://www.senternovem.nl/Offshore_Wind_Energy/locations_and_licences/licence_system.asp.

Figure 8 108 MW Offshore Wind Farm Egmond aan Zee. Photo by S. de Jong, Rijkswaterstaat Noordzee.

(3) 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 press release . EUR 379 M Facilities for the construction and operation of an offshore wind farm at http://www.q7wind.nl/en/news.htm

(8) Download the file 'Key aspects of the financing of Offshore Windpark Q7' via http://www.we-at-sea.org/docs/Q7tailormadefinancingstructure.pdf at http://www.we-at-sea.org/index.php?keuze=n&nummer=26

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(13) Download data biological fouling from http://www.senternovem.nl/Offshore_Wind_Energy/technology/Monitoring_MEP-NSW/biofouling/index.asp

(14) Download data shipping from http://www.senternovem.nl/Offshore_Wind_Energy/environment/Monitoring_MEP_NSW/shipping/index.asp

(15) Info of We@sea work at http://www.we-at-sea.org/index.php

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Norway

23

1.0 Introduction

In 2006, installed wind-power capacity in Norway increased from 270 MW to 325 MW (Figure 1). In Norway, interest in wind power as a commercial source of electricity is high. By the end of 2006, 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 NOK (approximately 2.3 billion €) to a new fund. The first 10 billion NOK are proposed to be allocated to the state budget for 2007 presented to the Storting on 6 October 2006. 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, amounting to approximately 700 million NOK, which is financed by an earmarked levy on the distribution tariff. The state-owned agency Enova will administer the yield from the Basic Fund.

In 2006, renewable sources of electricity contributed 98.9% of national electrical demand. About 0.55% 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 2006 was a normal year with average hydropower production.

For 2010, the target set by the government for the renewable share of electricity consumption is 90%. According to a government statement, this target corresponds with approximately 6 to 7 TWh new production capacity of electricity from renewable energy sources being introduced from 1997 to 2010.

Table 1 Key Statistics 2006: Norway	
Total installed wind generation	325 MW
New wind generation installed	57 MW
Total electrical output from wind	0.671 TWh
Wind generation as % of national electric demand	0.55 %
Target in 2010	3 TWh

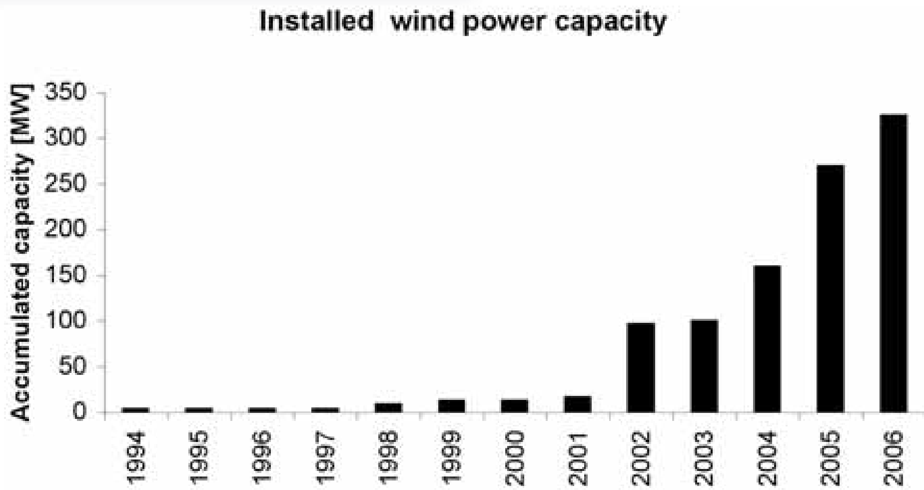

Figure 1 Installed wind power capacity in Norway.

2.2 Progress toward the wind target

Interest in wind power is high, and several projects have been submitted for approval. More than 1,200 MW has received approval. This indicates that the 3-TWh target can be reached by 2010, assuming that effective economic incentives can be put in place. In addition, projects totaling an annual production of 35 TWh have been proposed, including a 1,400-MW (4.5-TWh/year) offshore wind-power project, suggesting additional substantial development after 2010.

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 12 wind-power projects. The projects represent an estimated 1.56 TWh/year of energy production (approximately 500 MW). By the end of 2006, approximately 300 GWh was under construction. Enova did not give investment grants to new wind-power projects in 2006.

3.0 Benefits to the 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

ScanWind Group AS is a new Norway-based manufacturer of large wind turbines (3 MW and larger) for use in Class 1 wind areas. The company has developed a 3-MW direct-driven wind turbine design (ScanWind 3000 DL) and a geared version of the same size (ScanWind 3000 GL).

Some of the Norwegian industry takes part in component production for wind energy systems, e.g., wind turbine blades and nacelles. 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

The unit cost of the Norwegian wind turbines erected in 2006 was on average 10,000 NOK/kW (1,250 €/kW), including infrastructure and grid connection. 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 generation 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 370 NOK/MWh (46 €/MWh), including capital costs (discount rate 6.5%, 20-year period) and operations and maintenance. During the past few years, the spot market electricity price on the Nord Pool (Nordic electricity marketplace) has increased noticeably, leading the long-term expected price to be more than 320 NOK/MWh (40 €/MWh). Unfortunately, the cost of wind energy has increased during the same period of time, so it is still unable to compete on commercial terms.

Nor is wind energy competitive with the price of many new hydropower projects, which still is an option for new green power in Norway. Even though both wind and hydro resources are large, the development of hydropower is more controversial than the development of 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 kilowatt-hour in 15 years. The support level is proposed as is shown in Table 2.

5.0 R, D&D activities

The governmental research program for sustainable energy is called RENERGI. Its budget for wind energy R&D in 2006 was 12.5 million NOK (1.5 million €).

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)

The following wind energy R&D projects have been approved for funding:

- A study of the potential of offshore wind energy is planned.
- 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 2008.
- Several projects will deal with wind resource mapping and micrositing in complex terrain.
- In 2001, to assist the development of wind energy in Norway, SINTEF Energy Research, the Institute for Energy Technology (IFE), and the university in Trondheim (NTNU) undertook a joint initiative to develop a test station for wind turbines on the midwestern coast of Norway. The test site was opened during the summer of 2005 and is now operating. For more information, see 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 a 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.

In addition, a wind power and hydropower integration study has been initiated to establish a dataset to represent the wind regime during the past 30 years. The data will be compared with the hydrologic data we already have. Because the Norwegian energy supply system is largely dependent on hydropower, it is therefore critically vulnerable to annual variations in precipitation and to prolonged droughts. An increasing share of wind power gives topical interest to the integration of wind power and hydropower, since both resources are naturally intermittent. The question is whether the two can be complementary and can be combined to improve overall performance or whether, 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.

6.0 The Next Term

By the end of 2006, project plans for 120 MW of new wind capacity were under way, and more than 1,200 MW had received permission/approval. However, the availability of financing and public acceptance will determine how many turbines are installed in the coming term.

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Portugal

24

1.0 Introduction

Portugal has few indigenous energy resources, such as those that satisfy the majority of the energy needs of the economically developed countries, such as oil, gas, and coal. This situation leads to a large dependence on foreign economies for fossil primary resources. In this context, the contribution of renewable energies and the need to improve their penetration becomes of strategic relevance for the country's development.

In 2006, the total renewable sources installed capacity was 6,961 MW. The total electric energy production from renewables has shown an impressive 86% growth rate with respect to the end of 2005, its final value being reported as 16,120 GWh. This growth was strongly correlated with the variation in hydropower production, about 124%.

In what concerns to wind energy, as will be shown in the next paragraphs, there was a moderate growth in the installed capacity when compared to previous years. In 2006, the 2005 policy continuance was verified, with special relevance to the ending of the first phase of the 1,500 MW public call for wind park grid connection opened in July 2005.

Table 1 represents the key statistics for 2006 in Portugal.

2.0 Progress Toward National Objectives

During 2006, Portugal presented a moderate growth rate of wind capacity installation, although it was lower than in previous years. The new wind capacity installed in the whole Portuguese territory (including the Madeira and Azores archipelagos) was 634 MW. This capacity corresponds to a growth rate of about 59%, and the accumulated installed capacity corresponds to 45% of the 2010 goal. The slowing of the growth rate was already expected since the need to construct new transmission lines and the limited production capacity of the manufacturers of wind turbines is starting to play an important role in the wind capacity installation evolution.

Although the wind capacity installed by the end of 2006 apparently showed a moderate growth rate, and the corresponding generated electrical energy already represents about 6% of the total national electric demand according to Rede Eléctrica Nacional (REN) the Portuguese Transmission System Operator (TSO) (1).

In 2006, 1,681 MW of accumulated wind capacity were installed and operating on the continent corresponding to 964 wind turbines; 7 MW in the Azores archipelago with 28 wind turbines; and 10 MW in the Madeira archipelago corresponding to 43 wind turbines, for a total of 1,698 MW and 1,035 wind turbines. Moreover, there is already 3,073 MW of wind power capacity licensed in continental Portugal, although not all of it is installed, according to the statistics of the official energy board, General Directorate for Geology and Energy (DGGE) (2). Figure 2 represents the total installed wind capacity by the end of 2006.

During 2006, the electric energy generated by wind farms in the continental territory was 2,892 GWh as reported by the annual DGGE statistics. In

Table 1 Key Statistics 2006: Portugal	
Total installed wind generation	1,698 MW
New wind generation installed	634 MW
Total electrical output from wind	2.929 TWh
Wind generation as % of national electric demand	6%
Target:	3,750 MW by 2010 5,100 MW by 2013

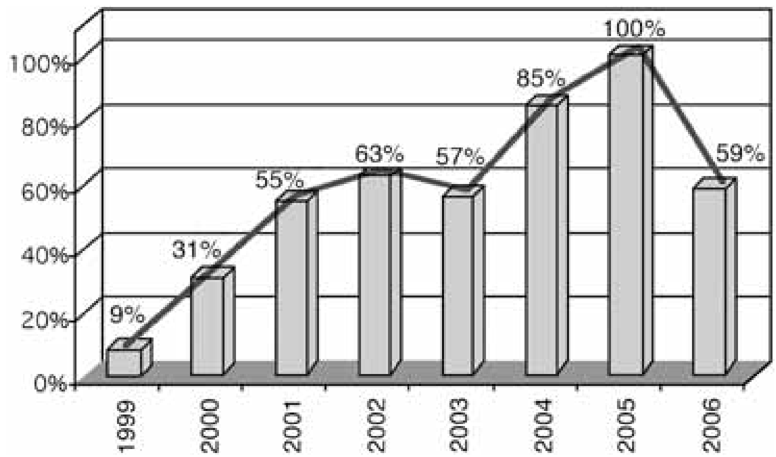


Figure 1 shows the capacity growth rate from 1998 until the end of 2006.

this year, the net electric consumption was in the order of 49.0 GWh. Using estimated production for the Azores and Madeira archipelagos (2000 hours equivalent to nominal power) the 2,929 GWh global generation is obtained. This production would correspond to 2,119 hours of operation at equivalent to nominal power.

Figure 3 shows the evolution of the wind energy generation in the period 1998–2006.

Considering the capacity involved in the call for wind park grid connection and the capacity actually under construction and/or in project, and assuming the annual growth rate until 2010 and 2013 is around 18%, the goals established in the Dec. Law 33-A and in the RCM 169, both published in 2005, will be fully achieved. Figure 4 shows the wind capacity growth rate estimate for the period 2000–2010.

Figure 5 represents a regional distribution of the installed wind capacity in Portugal.

3.0 Benefits to National Economy

3.1 Market characteristics

As a contribution to the 2013 governmental goals published at the RCM 169/2005, by the end of 2006, the first phase of the public call for wind park grid connection opened in July 2005, and corresponding to 1,200 MW was concluded. The winning consortium of developers was lead by the Portuguese electrical utility, Energias de Portugal (EDP) and had as technological partner, the German manufacturer ENERCON.

During 2006, a slight increase of the unit cost of wind turbines was observed. These costs were in the range of 875 to 1,150 €/kW, depending on the characteristics of the wind turbines and/or the country of origin of the manufacturer. O&M costs are approximately 2% of the investment cost, at least for the first decade of the wind power plant operation.

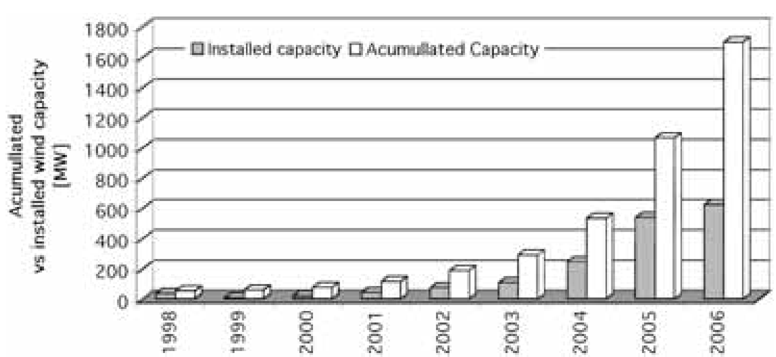


Figure 2 Installed and accumulated wind power capacity (1998–2006).

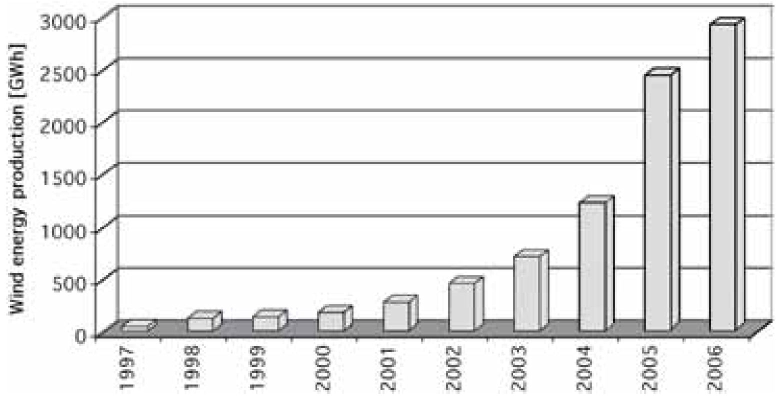


Figure 3 Wind energy production (1998–2006).

The wind farm developers keep reporting that it takes too long to obtain all the required permits and licenses, despite all the official efforts taken in order to simplify the bureaucratic process regarding the installation of renewable power plants.

3.2 Industrial development and operational experience

During 2006, more than 260 wind turbines were installed in Portugal, with a mean nominal power of 2.4 MW, according to DGGE. The turbines range from 0.6 MW to 3 MW. There is a wide distribution in the Portuguese market among the different large manufacturers in this sector. Figure 6 shows this distribution and the share of the main developers of wind farms in Portugal, in 2006.

As a result of the 2005 public call for wind capacity, where indigenous industrial manufacturing capacity was highly valued by the Portuguese government, some foreign industries showed strong interest to establish production facilities in Portugal in the near future. Nevertheless, and in order to respond to the growing national needs of the wind sector, there are several Portuguese high-quality tower manufacturers, already exporting for other foreign markets, as well as specialized construction and electrical companies. Recently, wind energy international consultancy companies have also been observed.

The consortium winner of the 2005 first phase call has large industrial plans for the country and, among other units, has contracted with the Portuguese government the installation of concrete tower and blade factories, these working both for the domestic and the foreign wind markets.

3.3 Economic details

In Portugal, due to terrain orography, together with the fact that sites with suitable wind resource are mostly already taken, turbines with high nominal powers – multi-megawatt – are being installed. This way the total wind farm installation costs, are

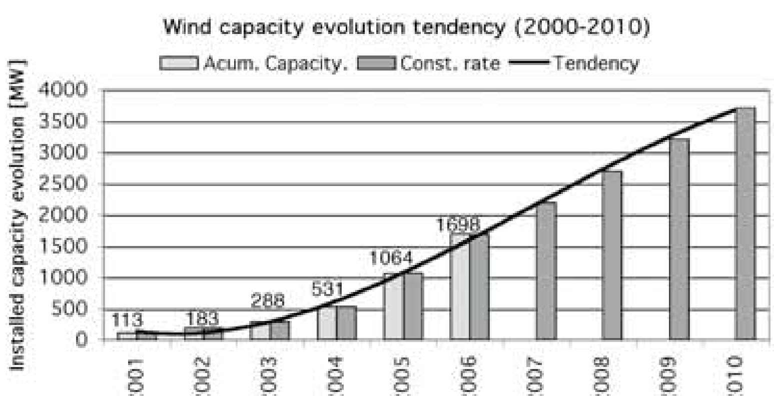


Figure 4 Trend of the wind power capacity installation towards the 2010 national targets.

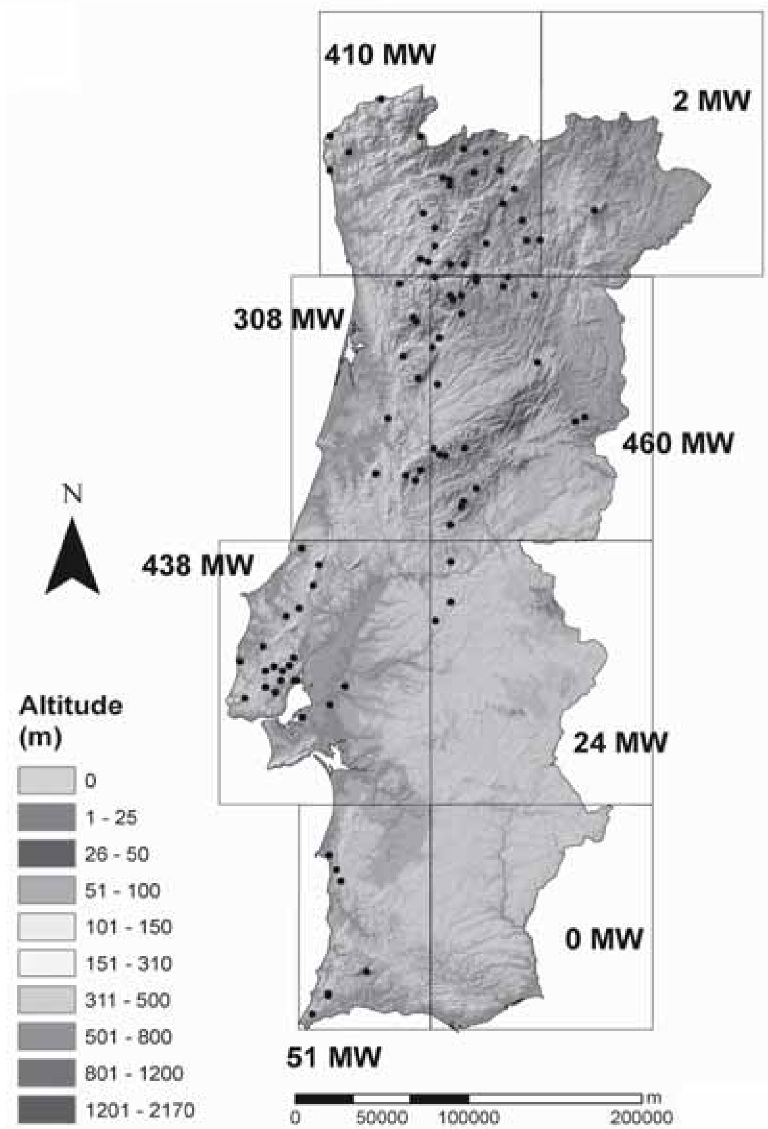


Figure 5 Spatial distribution of the wind capacity in Portugal.

included in the interval 900 to 1100 €/kW, and annual maintenance between 17 and 19 €/MW/year.

Figure 7 represents the tariffs evolution in the period 1998–2006.

Concerning renewable energies tariffs, no new legislation was published. The last one was established in Dec. Law 33 – A/05. This new legislation will only be applied to projects to be installed in the sequence of the 2005 call for wind capacity. The increase in the tariffs seen in the last years is mainly due to the low wind resource that has been characteristic of the Portuguese territory.

4.0 National Incentive Programs

In the last few years, the power capacity installed in Portugal has experienced a steady growth, especially since 2002. This growth was the result of the establishment of several supporting governmental policies published in 2001 to promote national renewable energy production. To reinforce those policies, in 2005 the DL 33-A was also published.

An official call for wind park grid connection was opened by DGGE in the same year, and its first phase was concluded in 2006, with the reserve of 1,000 MW of transmission grid capacity.

There was no new legislation published concerning wind energy in 2006, still the DL33-A prevailed. The changes introduced by this decree of law had as its most relevant measure the reduction of applicable tariffs, resulting in practical terms, on the reduction of national economically sustainable wind power capacity.

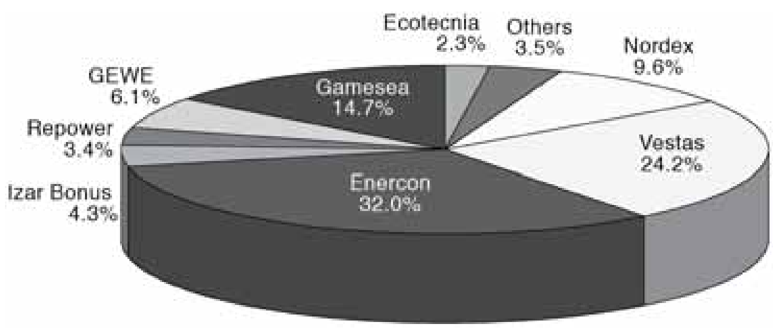
The non-actualization of the electricity tariff with inflation is still the most relevant factor for wind energy developers. It severely limits this sector's revenues for future projects as well as its deployment rate, since new investments in wind power will have less favorable economic indicators than the past projects.

Also, in the area of micro-generation mainly in what concerns interconnection to the low voltage grid and small distributed sources of electrical energy (up to 150 kW), no changes were verified, by the Dec.-Law nº 68/2002 which was the applicable legislation during 2006. This Decree of Law established the mechanisms needed to accelerate administrative and technical procedures associated with the installation of small units.

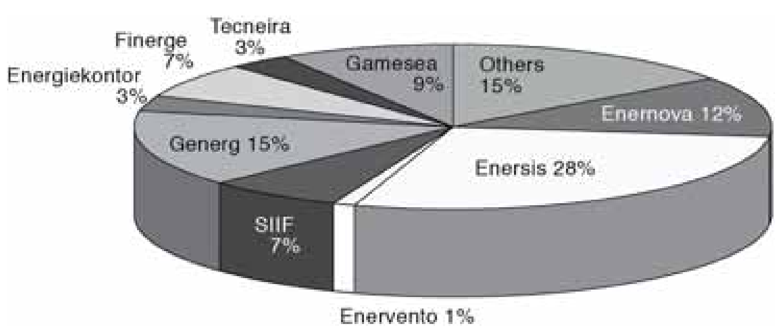
5.0 R D&D Activities

The R D&D activities in Portugal, related to renewable energies in general and wind energy in particular are mainly developed by various active research groups, located in for the most part in Lisbon and Porto. The exception is the Program DEMTEC within Programa de Incentivos à Modernização da Economia (PRIME), which in the 2006 call had a specific line of 5 million € for wind energy related projects. Otherwise there are no specific governmental programs to support the Wind Energy sector.

The R&D groups are mainly included in academic or research institutes, and have their own governmental financing programs and "lines" depending on the international and European Commission projects they are involved with. Moreover, the wind



(a) Wind turbines manufacturers.



(b) Wind park developer group.

Figure 6 Market share of installed capacity.

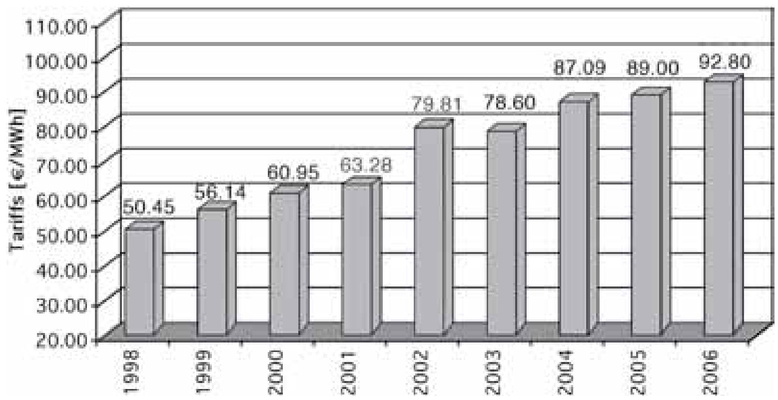


Figure 7 Evolution in tariffs for wind energy based production in the period 1998–2006.

energy developers are slowly beginning to collaborate in academic projects mainly in those concerning doctoral and post-doctoral projects, contributing, although still in a very small part, to the development of research and technology in wind energy in Portugal.

Among R D&D institutes, one of the most relevant regarding the work already developed in this context is the National Institute for Engineering, Technology and Innovation I. P. (INETI). INETI is a part of the Ministry of Economy and Innovation, and its activities and R D&D projects in the wind energy field are partially financed by the national government.

The R D&D needs and trends for wind energy in Portugal were identified as the following issues:

- Wind resource assessment in complex terrain and offshore;
- Wind power production monitoring by economic dispatch and remote operation by clusters of wind parks (DSO – distributed system operator);
- Wind/hydro production correlation and use of pumping facilities for regulation and storage of excess wind power production;
- Wind power applications in urban and constructed environments;
- Development of low-cost small wind turbines;
- New materials and industrial production techniques for wind turbines' cost reduction.

5.1 National RD&D efforts

In the north of Portugal, the main institutes dedicated to R D&D are the Faculty of Engineering of the University of Porto (FEUP) and the Mechanical Engineering and Industrial Management Institute (INEGI) and are part of the research network established by the Portuguese Foundation for Science and Technology (FCT), namely within the associate laboratory INESC Porto (Computers and Systems Engineering Institute of Porto) and the Research Centre for Wind Energy and Atmospheric Flows (RCWEAF).

INETI is developing a small, high-performance and low-cost turbine for urban use – TURBan. This is a national project financed by DEMTEC (70/0201), to be nationally conceived and constructed using Portuguese technology. The project will be completed and operational by mid-2008.

5.2 Collaborative research

In 2005, INETI participated in the identification of sites for offshore wind park installations in the Atlantic coast based on the construction of the Portuguese Wind Atlas. This work has demonstrated that there are several coastal areas with high wind potential. As a result of this study, a measurement campaign is underway.

6.0 The Next Term

In what concerns the Wind Potential Portuguese Atlas, its methodology is being applied to other projects, and will be developed for other countries such as Croatia areas in several African countries. This methodology together with the improvement of the geographic information systems knowledge, will contribute to the construction of wind potential atlases for these countries.

The first phase of the call for wind park grid connection was concluded in the mid-2006. The second phase of this call is still underway and will be finished in the summer of 2007, and then the third phase will begin.

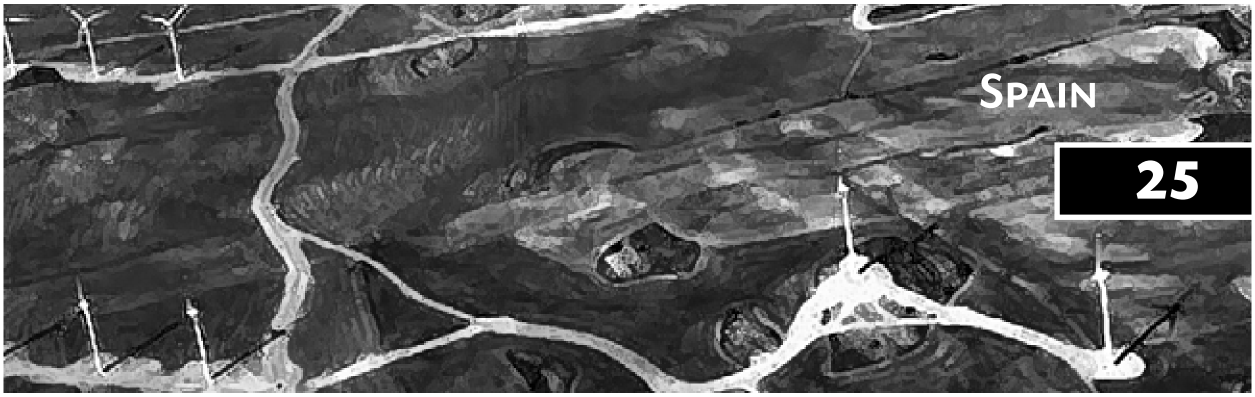
Moreover, during 2007, the TURBan project will continue its development and will be in the turbine dimensioning and construction phase. This project, although it is not yet finished is already causing an impact among the sectors investors.

References:

(1) According to REN – Rede Eléctrica Nacional

(2) According to General Directorate for Geology and Energy (DGGE).

Authors: Ana Estanqueiro and Teresa Simoes, Department of Renewable Energies, INETI – Instituto Nacional de Engenharia, Tecnologia e Inovação.



Spain

25

1.0 Introduction

The installed wind capacity in Spain on 1 January 2007 was 11,615 MW, according to data from the wind-power observatory of the Spanish Wind Energy Association (AEE) and the Association of Producers of Renewable Energies (APPA) (1). During 2006, an additional 1,587 MW were put into operation, which represents an annual growth of 15.8%. This growth rate is similar to the growth rate in 2005. The Spanish wind sector has maintained annual growth rates above 1,500 MW during the past five years making it an important and consolidated industrial activity.

The figures show very clearly the solid contribution of wind energy in Spain. Growth in 2006 was lower than expected and slightly inferior to the rates described in the Plan of Renewable Energies (PER 2005-2010) (2), which expects to reach 20,000 MW connected to network by 2010. Possible reasons to explain this lower growth rate include problems with the connection of wind farms to the electrical grid caused by delays in the construction of electrical infrastructures such as transport lines and high voltage substations.

Spain has not yet experienced the lack of major components (gearboxes, electric generators, blades, and so on) that the wind sector suffers on a global level. This is because many companies in Spain are both wind turbine manufacturers and wind farm developers.

In 2006, annual electricity demand in Spain was 3.6% more than in 2005 (after corrections due to seasonal effects). Installed electrical power had a net growth of 4,213 MW, which assumes an increase in the capacity of the system of 5.7% from 2005 to 2006. This increase comes exclusively from combined-cycle power plants with natural gas and from wind energy. Figure 1 shows the generation of electricity in Spain during 2006. Electricity produced by wind farms met almost 9% of the total electrical demand in Spain.

It is important to note the increase in exports of wind generators during 2006. Spanish-made wind turbines totaling more than 1,200 MW of generating capacity were installed in wind farms in Australia, China, France, United States, and other countries.

2.0 Progress toward national objectives

The current objectives for 2010 for the promotion of renewable energy sources are gathered in Spain's PER 2005-2010. This plan is a revision of the previous one which was revised in 2002. The aim of this revision is to maintain the commitment to use renewable sources to meet at least 12% of total energy use by 2010, while incorporating other indicative targets (29.4% of electricity to be generated from renewable sources and 5.75% of transport fuel needs to be met by biofuels).

The plan was revised for several reasons. First, primary energy consumption and energy intensity have grown more quickly than was expected. This fact alone makes it necessary to increase the growth in renewable energy sources to achieve the 12% tar-

Table 1 Key Statistics 2006: Spain	
Total installed wind generation	11,615 MW
New wind generation installed	1,567 MW
Total electrical output from wind	23.372 TWh
Wind generation as % of national electric demand	9%
Target:	20,155 MW by 2010

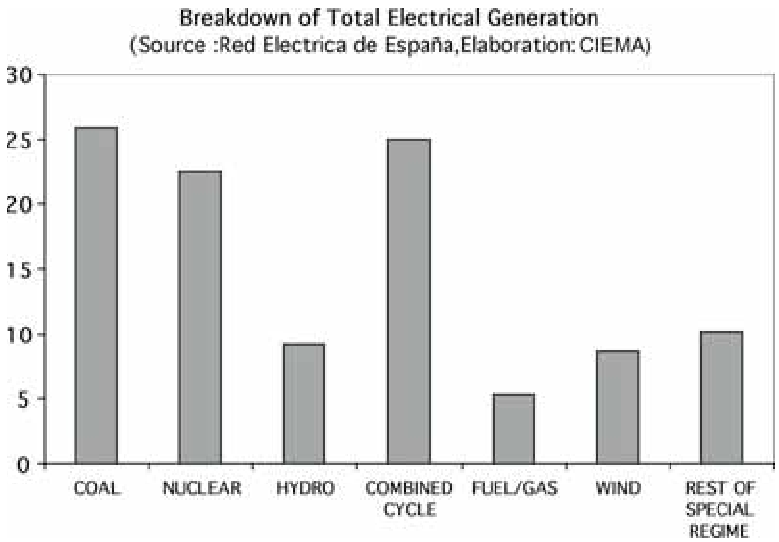


Figure 1 Wind energy and other generation sources for 2006.

get for 2010. Following the approval of the previous plan, two further indicative targets have been set. The new plan also needs to take these into account.

Wind energy is the area that has developed most rapidly and is supported by a range of business initiatives in the market. In line with the general targets of the plan, the new objective for the wind energy sector is an increase in power output of 12,000 MW between 2005 and 2010. This implies ending the decade with a total installed potential of 20,155 MW. In Figure 2, the installed power in Spain is shown, along with the objectives related in the PER.

The increase of installed wind power in Spain during 2006 was lower than expected and slightly below the increase called for by the PER. During the first half of 2006, 913 MW were installed; during the second half of the year, which usually registers a higher increase in installations, fewer installations were completed for a total for 2006 of 1,587 MW. In some cases, grid connection problems delayed installation of the wind plants, which usually occurs in the later months of the year, to the first term of 2007. Completion of the new electrical infrastructure and the new procedure for connecting wind turbines to the grid will allow Spain to regain, during the coming years, a level of growth that will fulfill the PER targets.

Alongside the plans of the central administration, the various autonomous regions have elaborated their own objectives to achieve by 2010 (Table 2). These objectives of the autonomous regions almost double the national target.

Most of the autonomous regions (which have the responsibility for regulation of wind installations) have planned a total installed capacity of about

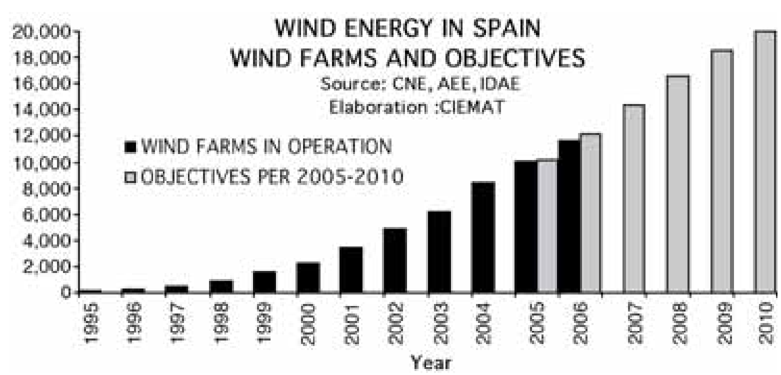


Figure 2 Wind energy in Spain: Wind farms in operation and PER objectives for the year 2010.

Table 2 National and autonomous-region targets for wind energy at 2010			
Autonomous Region	Year	Regional Target (MW)	National Target (MW)
Andalucía	2010	4,000	2,200
Aragón	2012	4,000	2,400
Asturias	2010	900	450
Baleares	2015	75	50
Canarias	2011	893	630
Cantabria	2010	300	300
Castilla y León	2010	6,700	2,700
Castilla - La Mancha	2011	4,450	2,600
Cataluña	2010	3,000	1,000
Extremadura	2010	225	225
Galicia	2010	6,300	3,400
Madrid	2010	50	50
Murcia	2012	850	400
Navarra	2011	1,530	1,400
La Rioja	2011	660	500
Comunidad Valenciana	2010	2,359	1,600
País Vasco	2019	624	250
TOTAL		36,916 MW	20,155 MW

39,000 MW by 2010 through 2012. Taking this situation into account, there is an open discussion to define new targets and describe adequate infrastructures to achieve them.

The total amount of electricity generated by wind energy was 23,372 GWh, about 9% of the total electricity demand in 2006, according to the data from Red Electrica de España, the Spanish transmission system operator, (3). These values make wind power the fifth largest electricity generation technology in Spain after coal, nuclear energy, natural gas, and hydropower. The monthly electricity generated by wind is shown in Figure 3.

The year 2006 was less windy than previous years, and the average equivalent hours of full production were fewer than 2,000 hours for the total wind farms in Spain. Together with the lower price of wind-generated electricity during 2006, this implies an important reduction of the benefits of the sector during the year. Nevertheless, the sector remains very active and in continuous growth. On some occasions, wind-generated electricity in Spain has covered more than 25% of total electricity demand.

The maximum hourly production by wind energy of 8,140 MW took place on 8 December 2006. A full 31% total electricity production at that particular moment was supplied by wind energy. The maximum peak demand during the year took place on 30 January 2006 when the total power produced was 42,100 MW. At this time, wind energy supplied about 8% of the total.

Wind power helped decrease fossil fuel imports, achieving savings of more than 730 million € in 2006, mainly due to the reduction in purchases of natural gas and coal. In addition, the Spanish economy saved around 18 million tonnes of CO_2 and did not have to purchase emission permits that would otherwise have been required in 2006. This represents nearly 360 million € of savings, assuming a price of 20 €/tonne of CO_2 emissions.

Wind power is presently the renewable energy that makes the greatest contribution to the energy supply in the country (around 76% of the total renewables contribution comes from wind). Wind-sector analysts are optimistic that Spanish wind energy targets will be met.

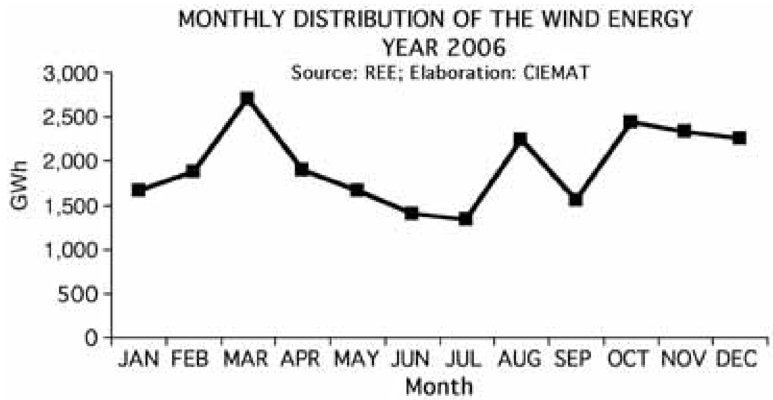


Figure 3 Electricity generated by wind, monthly distribution.

3.0 Benefits to national economy

3.1 Market characteristics

Wind power development and promotion is a well-established activity in Spain. The fact that 11,600 MW are in operation shows the experience and maturity of the sector.

So far, wind farm promotion is carried out by very big entities: utilities, finance companies, civil engineering firms, and industrial developers. There is a strong tendency to consolidate activities among the big promoters of wind farms in Spain; big companies accumulate the main wind farms, and big developers purchase the smaller ones. This process was particularly important for 2006, as remarkable financial operations have taken place in the wind business.

An important new development has been the increasing interest in the foreign market. During 2006, about 1,200 MW of wind turbines "made in Spain" have been installed in wind farms in the United States, China, Australia, and France, among other countries. Following this tendency, Spanish wind developers have begun to promote strategies for establishing even more wind installations in foreign countries.

The distribution of wind installations in Spain is shown in Figure 4.

Galicia, in northwest Spain, has the most installed wind power, with a total of 2,600 MW, including an increase of 233 MW in 2006. Castilla La Mancha is second with 2,310 MW (including an increase of 293 MW in 2006). Castilla León in central Spain has an important amount of wind energy–2,120 MW, including an additional 309 MW during 2006. In relative terms, the most spectacular growth occurred in Valencia in the Mediterranean region, where a new 280-MW wind farm means an increase in capacity of 1,300% from the previous year. Growth rates for Andalucia and Cataluña were 57% and 36%, respectively.

Figure 5 shows the market share of wind farm developers at the end of 2006.

Regarding ownership of installed wind power in Spain, the main utility (Iberdrola) maintains the leading position with a total value of 30.7% of the total wind generating capacity. Acciona has the second position with 17.5% of the wind farms, followed by Neo Energía with 8.4%, Endesa (another big utility) with 7.5%, Eufer with 3.4%, Gas Natural with 3.2%, Enerfin with 2.9%, and others. As mentioned previously, the tendency toward mergers of Spanish wind farms is increasing. It is important to note the financial operations performed by Neo Energía in 2006; it has taken ownership of the wind farms of the smallest promoters DESA and CEASA.

The international nature of the sector can be appreciated in Spain; big foreign investment groups have acquired Spanish wind farms. Their interest is yet more proof of the success of the development of the wind energy.

3.2 Industrial development and operational experience

Regarding manufacturers, Gamesa and its subsidiary company Made (60.4%) remains the leader of the sector in Spain and has a dominant position in the total market. Vestas (which has mainly models from the old Neg-Micon company) is also present in the Spanish market, with a share of 13% of the total capacity. The Spanish manufacturer Ecotecnia maintains represents 8.3% of the total installations.

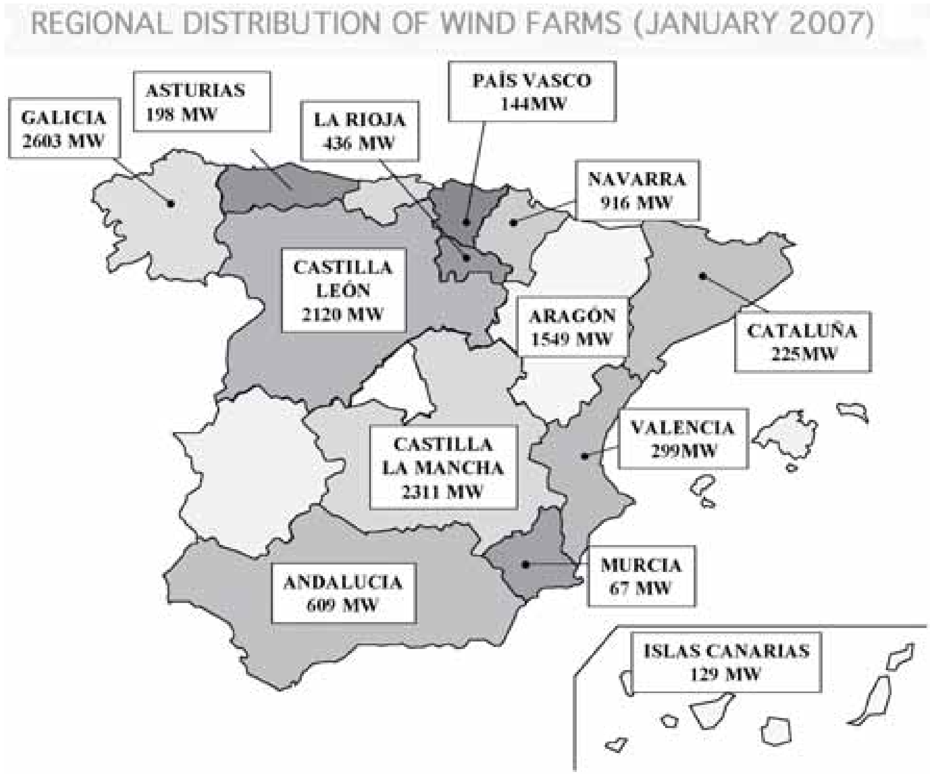


Figure 4 Regional distribution of wind farms.

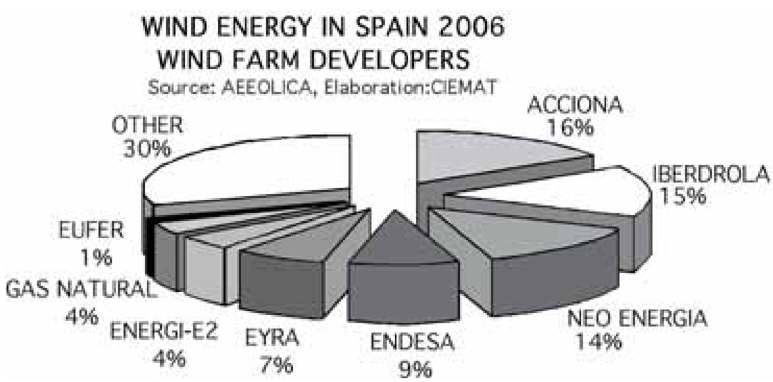


Figure 5 Regional distribution of wind farms.

General Electric (6.6%), Acciona (4.4%), and Navantia-Siemens (4.0%) are also present in the market (Figure 6).

It is important to note the merger of two new manufacturers: Acciona Wind Power, which is part of the Acciona group, one of the major developers of wind farms in Spain, and Mtorres, a company with activity in the aeronautical field. Mtorres has a 1.7-MW upwind, direct-drive, multi-pole generator, that is pitch regulated.

New wind turbines installed in Spain are becoming larger. The average size during 2006 was about 1.4 MW; during 2005, it was around 1.3 MW; and during 2004, it was a little higher than 1 MW.

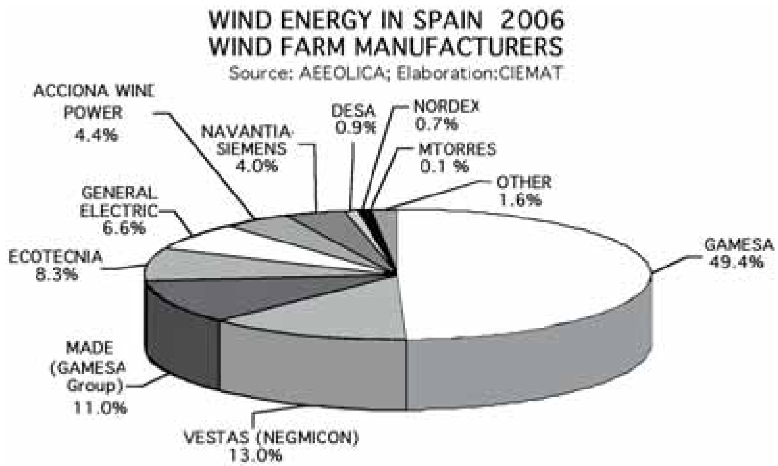


Figure 6 Wind turbine manufacturers represented in Spain.

In Figure 7, the increase in wind turbine size over the years is shown.

3.3 Economic details

A study by AEE and APPA shows the tendency of wind turbines to increase in cost. The increase in size of wind turbines (in fact, the new installations use machines over 2 MW of rated power), the increase in the price of raw materials, the lack of major components, and the excess in demand have combined to increase the cost of wind energy. The average cost during 2006 was about 1,110 €/kW. The forecast of operation costs for the new wind farms and the estimates of production are also part of the study. Study results are shown in Table 3.

4.0 National incentive program

The promotion of renewable energies has been a stable national policy for several years. All political parties have similar policies regarding support of renewable energies.

The main tools within this policy at a national level are:

- A payment and support mechanism enshrined by the parliament through Electric Act 54 /1997: Producers of renewable energy 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.

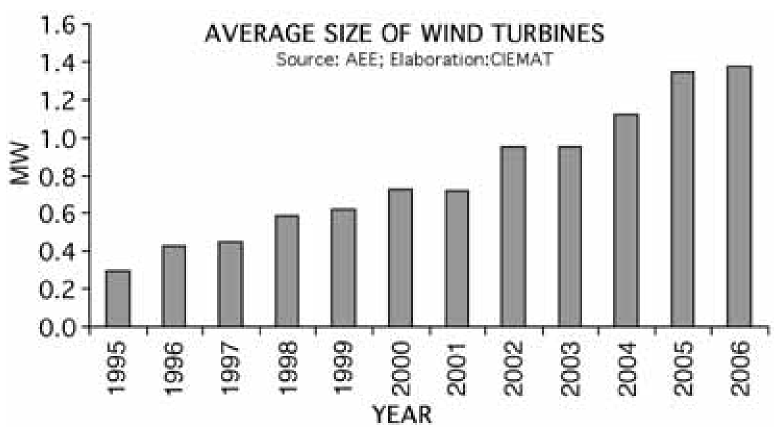


Figure 7 Average size of wind turbines installed in Spain since 1995.

Figure 8 Carballeira Wind Farm in Spain.

Table 3 Evolution of installation costs and electricity production of wind farms in Spain

Parameters	Unit	2004	2005	2006	2007	2008	2009	2010
Average Size of Wind Plant	MW	35	35	35	35	35	35	35
Equivalent hours	hours	2241	2297	2271	2245	2200	2150	2100
Yearly variation	%		2.50%	-1.13%	-1.14%	-2.00%	-2.27%	-2.33%
Total Cost	X1000€/MW	1005	1057	1110	1175.10	1233.41	1290.50	1350.55
Yearly variation	%		5.17%	5.01%	5.86%	4.96%	4.63%	4.65%
Exploitation and manage, costs	€/MWh	15.72	16.58	18.20	18.61	19.10	19.64	20.19
Yearly variation	%		5.47%	9.77%	2.25%	2.63%	2.83%	2.80%
Source: AEE, APPA. The position of Spanish wind sector in the modification of the RD436/2004								

• The Renewable Energy Plan, including mid-term objectives for each technology (PER 2005–2010).

Royal Decree 436/2004, which regulates the price of electricity from renewable sources in Spain, has been a very useful instrument for the development and consolidation of wind energy in Spain. The law allows electricity generated by wind farms access to the electricity market. Remuneration to wind farms consists of the market price plus a bonus established as a percentage of the named "average reference tariff" (an indicator related to the total cost of the overall electrical system).

Figure 9 Faladiora Wind Farm in Spain.

The increasing price of electricity in Spain has caused the remuneration to wind farm operators directed by this procedure to reach high values in 2005 and 2006. For instance, the average price received by wind farm operators that used the market option in 2006 was 91 €/MWh. The benefits of wind investment have been remarkably high.

In mid-2006, Spanish authorities began to write new draft rules concerning renewable energy sources (wind energy in particular) in order to limit the price received by wind farm operators. The general rules of the draft establish a maximum value to be paid to the wind farm owners when the electricity price is excessively high, and a minimum value as a guaranteed compensation when the price is low. The law's intent is to guarantee sufficient profit for wind energy investment without a significant increase in the total cost of the electrical system.

An example of the prices obtained according to the new draft is described in Table 4. For instance, in the case of a wind farm that produces more than 5 MW during the first five years of its operation, the maximum price to be paid to the developer would be 84.7 €/MWh, and the minimum value would be 67.7 €/MWh. Table 4 shows a complete description of the payments.

The new draft rules contain the first mention in Spain of wind energy in offshore wind farms. The draft rules define a bonus of 84.7 €/MWh over the market price and specify that the maximum price to be paid will never exceed 164 €/MWh. No minimum level is defined. Although the wind energy sector has had an overall positive reaction to this regulation, it has expressed the opinion that the payments are not enough to start the offshore market in Spain. Actually, the discussion between the authorities and the industrial sector is still going on. The main criteria used for the development and administration of the rules is to guarantee sufficient remuneration to permit fulfillment of the PER targets in the Renewable Energy Plan (PER 2005-2010).

5.0 R, D&D activities

The Renewable Energy Plan (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 Spanish manufacturers is to make efforts leading toward the following goals:

- Development of advanced systems to control the quality of the power fed into the grid, in particular optimizing how wind farms behave regarding perturbations on the grid
- Development of wind turbines with unit power outputs of more than 2 MW and the incorporation of new materials
- Adaptation of high-capacity wind turbines to the more demanding technical requirements of offshore applications
- Implementation of demonstration offshore wind farms.

The National Energy Program for Scientific Research, Development and Technological Innovation (2004 to 2007) centralized Spanish R&D projects in the energy sector. The target areas defined in the plan for wind energy projects included such topics as these:

- Development of infrastructure and tools for design of new wind turbines
- Improvement of efficiency, availability, reliability, maintenance, and security of operation
- Integration into the electric system
- Design of wind turbines for special sites
- Development of new technologies and systems for the environmental integration of wind energy systems.

Table 4 New draft for the payment of the electricity generated by wind

	< 5 MW		> 5 MW		
		2007		2007	2008
		€/MWh		€/MWh	€/MWh
Tariff	First 15 years Rest of the life	73.10 61.20	First 5 years Year 6 - year 15 Rest of the life	73.10 66.20 61.20	74 67 62
Bonus	First 15 years Rest of the life	17.40 5.50	First 5 years Year 6 - year 15 Rest of the life	17.40 10.50 5.50	17 10 5
Maximum level	First 15 years Rest of the life	89.10 77.20	First 5 years Year 6 - year 15 Rest of the life	84.70 77.80 72.80	86 79 74
Minimum level	First 15 years Rest of the life	70.20 58.30	First 5 years Year 6 - year 15 Rest of the life	67.70 60.80 55.80	69 62 56
Absolute lower level Maximum value		52.80 71.70		50.30 67.30	51 68

Inside of a broadly defined program to improve the technological capabilities of Spain, new strategic lines have been defined, and one of them is the Strategic National Consortiums for Technological Research. The main objective is to increase co-operation between the public sector and the private sector. To do that, a budget for 50% support is specified to start extensive industrial research lines. Participating private and public research groups must sign contractual agreements to maintain at least four years of co-operation.

For wind energy, an initiative called Windlider 2015 has been started. According to this proposal, the Spanish manufacturers Gamesa and Ecotecnia are undertaking an industrial research project aimed at keeping Spain at the forefront of wind technology. The expected budget is around 40 million €. Research objectives include a better understanding of large wind turbine design and shortening the time needed to bring new products to the market.

As part of this research, Windlider 2015 aims to produce a comprehensive simulation of a large wind turbine. This model will be validated and fine-tuned by testing complete wind turbine and critical components (generators, gearboxes, converters, housings, yaw systems, and so on) with a power rating of 5 MW. This will allow extrapolating proven performance data to outputs in excess of 10 MW. Universities and research and technological centers are involved in the initiative. The Spanish Wind Energy Association estimates that 90 million € will be spent by the wind sector (including both public and private research groups) in R&D activities.

During the last call for proposals at the end of 2006, a new consortium called for the development of technological research in the field of the offshore application of the wind energy. The proposal, called Eolia, was presented by the company Acciona Energía. Its main focus is the study of wind technology for deep-water application. A decision about the project will be made in 2007.

In the field of small wind turbines, a national strategic project was approved. The project, called Minieolica, includes all the companies involved in the sector—small wind turbine manufacturers, technological centers, and so forth. The main aims of the proposal are:

- Creation of specific R&D programs for small wind turbines
- Implementation of a certification system useful for small wind turbines
- Establishment of demonstration projects
- Definition of support mechanisms.

The created network called Reoltec (Spanish Technological Wind Sector Network) continues the activities started in 2005. The initiative is promoted by AEE, and its main objective is to maintain the positioning of the national industry through

Figure 10 Installation of wind turbine blade.

the reinforcement of technological knowledge and the selective diffusion of results and experiences. A work plan that covers short-term (2005 to 2007) and medium-term (2007 to 2010) strategies has been issued.

The main research challenges for wind energy in Spain are to reduce the cost of wind-generated electricity, increase the availability of wind turbines, and, in general, increase wind turbine size and redesign wind turbines for special conditions (for example, offshore, extreme climate, and weak electrical networks).

6.0 Next term

The Spanish wind power industry is a solid, established sector. Over the past four years, average installed generating capacity has grown by about 1,500 MW/yr. The objective of Spain's PER for wind power is to reach 20,155 MW of total capacity by the end of 2010. The total objective for the regional plans is more than 39,000 MW (nearly double the national objective) for the years 2010 to 2012. The national legislative framework, regional regulations, and the maturity and competitiveness of the technology used have made it possible to achieve these targets.

Two important steps must be taken to guarantee the fulfillment of wind energy objectives. First, a study of the alternatives is called for in order to increase wind-power penetration in the electricity system in a way that is compatible with the system's security. Second, it is essential that the current legislative framework be retained without substantial changes between now and 2010.

Progress on offshore projects has been slow. During 2006, there were two positive advances—definition by the authorities of the content of the environmental impact study for offshore application and a special mention of offshore wind farms in the new draft rules for the electricity tariffs.

Figure 11 Transport of wind turbine nacelle.

Figure 12 Factory for wind turbine blades. Gamesa.

Figure 13 Test site for small wind turbines on a snowy day.

During 2006, only a few discrepancies occurred in connection with the stated objectives of the Spanish PER. Nevertheless, it is necessary to be alert to guarantee fulfillment of the plan's objectives.

7.0 References

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Author: Enrique Soria Lascorz, Renewable Energy Division, CIEMAT, Ministerio de Educación y Ciencia, Spain.

Sweden

26

1.0 Introduction

The growth of wind power is still rather modest in Sweden, with an increase of only 12% of total installed power in 2006. The situation for the future, however, looks more promising with the electricity certificate system prolonged until 2030.

Sweden had a shift in governments as a result of the September 2006 election, when the majority in the parliament shifted. The Social Democrats had been in power as a minority government with parliamentary support from the Green Party and the Left Party. After 12 years in power, they handed over power to a conservative/center coalition of four parties that now has parliamentary majority. The political climate for wind power, however, seems to be rather unaffected by the government shift. The new government also has a strong commitment to work for an increase in wind-power production in Sweden. The expression of will in the March 2006 Wind Power Bill is endorsed by the new government.

2.0 Progress toward national objectives

In 2002, the parliament adopted a planning target for wind power output of 10 TWh/year before 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 wind power to produce 10 TWh/year by 2015. The Swedish Energy Agency has distributed the national planning target of 10 TWh (4 TWh onshore and within territorial waters and 6 TWh offshore in the Swedish economic zone) by 2015 into regional targets and will follow up on them annually. Regional volume targets take wind energy resources and regional electricity consumption into account. The purpose of the target is to elucidate wind power installations on regional and local planning levels. Moreover, the target will reduce planning and permission obstacles to create opportunities for 10 TWh of wind power by 2015. The municipalities are working toward the goal, and it seems likely that the planning for the 4 TWh onshore and within territorial waters will be met.

For production, there is no goal for wind energy alone. The production goal in the electricity certificate system applies to new renewable energy in general as described in Section 4 below. The electricity mix in Sweden is dominated by nuclear power and hydropower. Hydropower production varies from year to year due to the amount of yearly rainfall. Figure 1 shows the mix during 2005, when production was 155 TWh. The total installed wind-power capacity in Sweden increased by 62 MW, a moderate increase. Figure 2 shows the installed capacity and production for 1991 through 2006.

For offshore wind power, the subsidy system (electrical certificates and the environmental bonus until the end of 2009) is not sufficient for deployments to take off. There are no goals for offshore

Table 1 Key Statistics 2006: Sweden	
Total installed wind generation	571 MW
New wind generation installed	62 MW
Total electrical output from wind	0.986 TWh
Wind generation as % of national electric demand	.7%
Planning Target	10 TWh (unchanged from 2005)
Capacity likely to be built by 2016	7 TWh

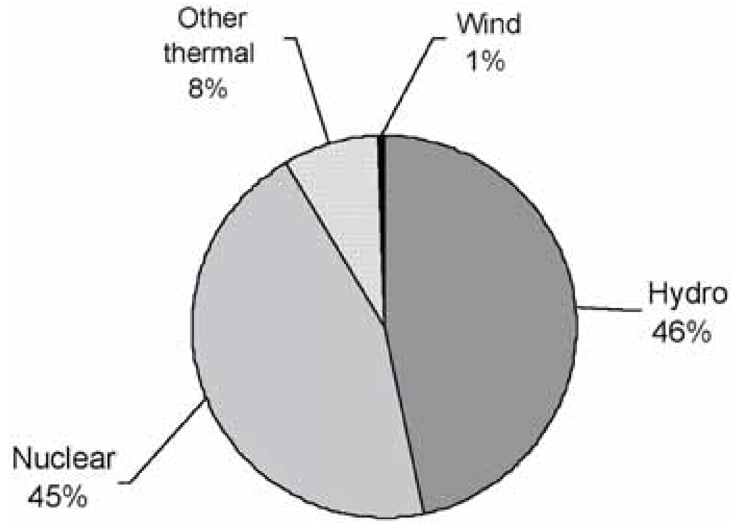

Figure 1 Electricity production mix in Sweden for 2005

wind as such, but the government has had a 350-MSEK special funding program for market introduction for large-scale plants offshore and in arctic areas with the intention to speed up the expansion of wind power in these large areas of Sweden. As described in the section on market characteristics, it seems as if the support given by the market introduction program is not sufficient in all cases.

The government has identified that progress toward a cost-efficient expansion of wind electricity is hindered by a slow permitting process for projects. The government therefore presented a Wind Power Bill in March 2006. The bill reduced the real estate tax for wind-power plants from 0.5% to 0.2% and made several suggestions that would facilitate the progress of wind energy expansion. The suggestions included funding an additional 350-MSEK grant for the market introduction program, setting up a knowledge center for wind energy, providing financial support to municipalities for planning for wind power, defining new planning goals, and suggesting changes in the permitting process.

The permitting process was changed in December 2006. Prior to the change, all projects above 1 MW had to go through application procedures in connection with both the Environmental Act and the Planning and Building Act, with the permits decided by the county administration. The threshold now has been increased to 25 MW. For projects below 25 MW, all permitting matters are now handled by the municipality. Projects bigger than 25 MW are handled by the county administration (onshore permitting) or the Environmental Courts (offshore permitting). The Swedish Energy Agency has been given the assignment to propose, during 2007, a new planning target for wind power for the year 2020.

3.0 Benefits to national economy

3.1 Market characteristics

Vattenfall and E.ON are the leading utilities for offshore wind energy development in Sweden. Smaller, yet also active, utilities include Falkenberg Energi, Göteborg Energi, and Skellefteå Kraft. The utilities develop projects on their own but also buy projects developed by independent developers at various stages of development. Several developers, among them WPD Scandinavia, Vindkompaniet, and RES Scandinavia, have as their strategy selling either portions of the project or the whole project to other investors. New investors are also entering the wind-power market in Sweden. One is Stena Renewable Energy AB, a subsidiary of the Stena shipping group. Other examples are the real estate company Lennart Wallenstam Byggnads AB and Vindin, formed and owned by a group of very large electricity-intensive industries in Sweden (forestry, steel, chemical, and mining industries). Vindin intends to build projects to produce 1 TWh/year, largely using land owned by companies in the group.

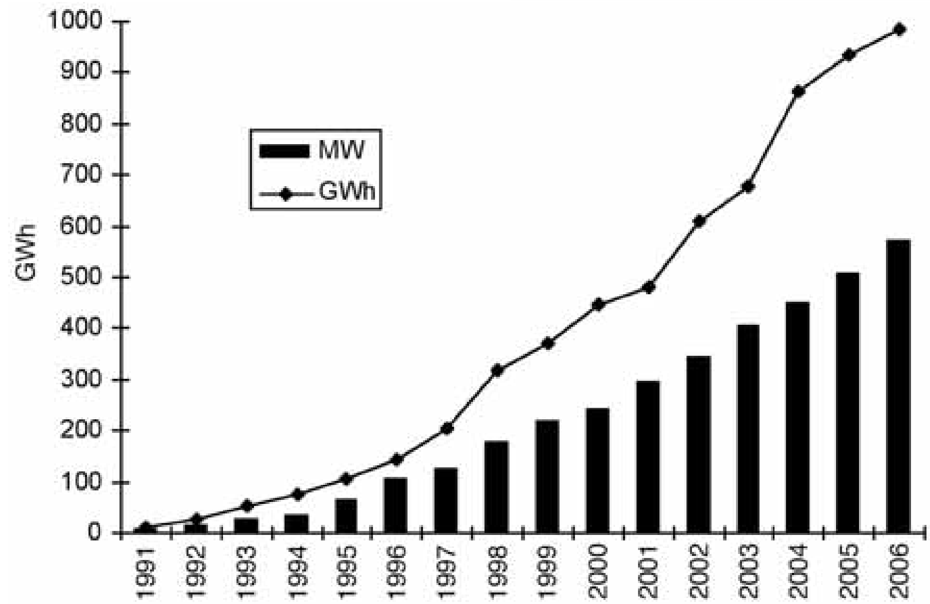

Figure 2 Installed wind-power capacity (MW) and production (GWh)

3.2 Industrial development and operational experience

While few manufacturers of small wind turbines operate in Sweden, the large international manufacturers Vestas, Enercon, and Nordex have sales offices. The Swedish Deltawind AB (formerly Nordic Windpower) has plans to become a player in Sweden, China, and North America. A replacement of the first Nordic Windpower 1-MW prototype was made in 2006. No other deliveries have yet been made.

On the component side (supply chain), the value of manufactured goods is great. The Swedish wind-power market consists of subcontractors such as SKF (roller bearing and monitoring system), ABB (electrical components and cable), Vestas Castings (formerly 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 multinational companies as well as smaller entities that find that their know-how applies to the wind-power market.

One company, Dynawind (a company in the Morphic Group), has started manufacturing towers for the Finnish turbine manufacturer WinWind; it also markets the WinWind turbines in Sweden. During 2006, WinWind erected nine 1-MW turbines in Sweden.

Three offshore projects have (see Figure 3) been partly funded with support from the market introduction program as described in Section 4. One of these projects, Lillgrund, is already under construction and is expected to be connected in the autumn of 2007.

The Lillgrund 110-MW offshore project consists of 48 Siemens 2.3-MW turbines on gravity foundations. The turbines will have a hub height of 68.5 meters and a diameter of 93 meters. Construction of the foundations started in 2006, and the wind farm is planned to be in operation by the end of 2007. (Figures 4 and 5)

The other offshore wind farm planned to be built with support from the market introduction program is Utgrunden II. All necessary permits are in place, and construction was planned to start in 2007. Early in 2007, however, the developer E.ON decided to postpone the building of the wind farm within the intended time plan. After receiving all construction tenders, E.ON concluded that the cost for building the park was too high considering

Figure 3 Offshore projects with support from the market introduction program

their calculated revenue for the electricity and the certificates.

3.3 Economic details

The market electricity price on NordPool was much higher than usual during 2006. The reason was a dry summer, which led to more or less empty hydro storage. Further, the closing of three (out of ten) nuclear power plants during the autumn led to prices of 67 €/MWh in August. However, due to a warm and rainy period from September, the price has come down to a more normal level of a little above 30 €/MWh. The average price for the year was 48 €/MWh. The price for electricity certificates as an average over the year was around 21 €/MWh (191 SEK/MWh). During the high price period for electricity, the price for electricity certificates went down.

Before the electricity certificate system was introduced, Sweden had a subsidy for wind power called the environmental bonus. This system is being phased out and will be removed after 2009. During 2006, the value of the environmental bonus was 7 €/MWh onshore and 16 €/MWh offshore.

Figure 4 Cable-laying work at Lillgrund
(Photo credit: Hans Blomberg, Vattenfall AB)

Figure 5 Lifting of foundation at Lillgrund (Photo credit: Hans Blomberg, Vattenfall AB)

Figure 6 shows an average value of the total revenue for wind-generated electricity onshore in Sweden during 2006. (The price paid to a wind turbine owner can be slightly reduced to cover the balancing cost on electricity price for the grid company.)

4.0 National incentive programs

There are three main incentive programs for the promotion of wind power:

(1) Electricity certificates,

(2) Production support, the so-called environmental bonus, and

(3) Support for technical development in coordination with market introduction for large-scale plants offshore and in arctic areas.

Other soft incentives are (4) the work done in assessing areas of national interest for wind power.

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 of 10 TWh from 2002 to 2010. The tool to meet the target is a quota-based system with electricity certificates. The system came into 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 principle is that there should be sellers and purchasers of certificates and a market to bring them together. There are no specific quotas for wind power. Electricity producers receive a certificate from the state for each megawatt-hour of renewable electricity that they produce. This certificate can be sold to provide additional revenue above the sale of the electricity, improving the economics of electricity production from renewable energy sources and encouraging the construction of new plants for the purpose.

The demand for certificates is created by a requirement under the Act that all electricity suppliers and certain electricity users purchase certificates equivalent to a certain proportion of their electricity sales or use, known as their quota obligation. The size of this obligation is increased from year to year, increasing the demand for renewable electricity. The price of certificates is determined by supply and demand and can vary from one transaction to another. During 2006, the average price was 20 €/MWh.

Until last year, the system had only set quotas until 2010. Uncertainties concerning subsidy levels after 2010, however, led to a slow investment in new production in, for example, wind power. The market and the government recognized this problem, and in 2006 the parliament decided to prolong the system. Originally the quotas were set only until 2010 with the goal of 10 TWh new, renewable electricity compared to the 2002 level. Now quotas are set until 2030. A new production unit can receive certificates only for a period of 15 years. Old units therefore leave the system after 15 years. Around 2012, there is a "notch" in the quotas because several older production units are to be phased out of the system then. The quotas are set to generate 17 TWh of new, renewable electricity from the system until 2016. After 2016, a small increase is estimated (Figure 7). The quota-based electricity production

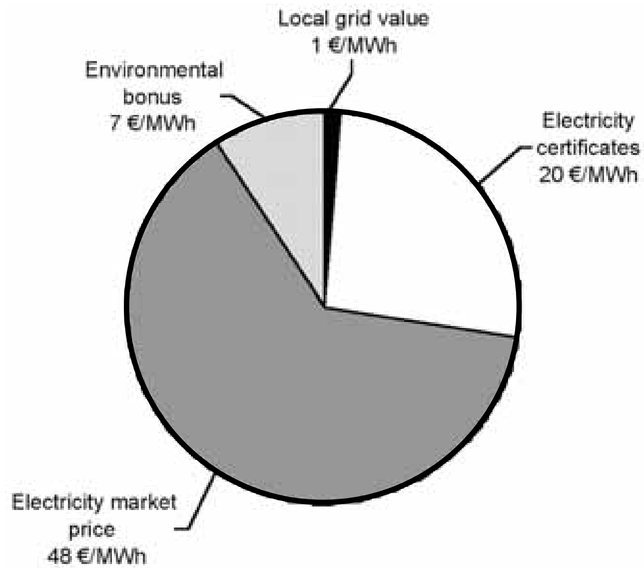

Figure 6 Breakdown of total revenue (76 €/MWh average) for a wind-power plant owner in 2006

in 2006 was approximately 12.1 TWh—9.1 TWh bioenergy, 2 TWh hydropower, and 1 TWh wind power. It is expected that in 2007, the major increase in production will come from wind. A recent study by the Swedish Energy Agency estimates that the wind-power production in 2015 will be around 7 TWh. This estimate is, however, very sensitive to the market and cost for electricity from new wind, new CHP bio-energy, and new hydro.

4.2 Production support

The level of the environmental bonus is declining each year until 2009 and will be zero after 2008 for onshore and after 2009 for offshore wind power. For 2007, the value is 4.2 €/MWh onshore and 15.2 €/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 plants in arctic 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 through 2007, the budget is 350 MSEK (around 38 million €). The parliament has recently voted in favor of a bill in which the market introduction is prolonged another five years with an additional 350 MSEK for the period 2008 through 2012. During 2007, the Swedish Energy Agency will prepare a call for applications for projects for the new period. Projects funded to date are shown in Table 2.

Two other projects are also funded through the program. One is the research program Vindval, and the other is research toward the development of an offshore project at the Swedish part of the Kriegers Flak bank in the Baltic Sea.

4.4 Assessing areas of national interest

Land and water areas shall be used for the purposes for which the areas are best suited in view of their nature and situation and of existing needs according to the environmental code. Priority will be given to use that promotes good management from the point of view of public interest. Different areas of Sweden are in the environmental code designated areas of national interest for different kinds of land use—fishery, mining, nature preservation, outdoor recreation, and so on. The idea is to protect specific areas such that the specific national interest not is jeopardized. An area can be of national interest for several kinds of land use. In 2004, to protect the interest of wind energy, 49 geographical areas in 13 counties were identified as areas of national interest for electricity production from wind energy. During 2007, new areas will be assigned.

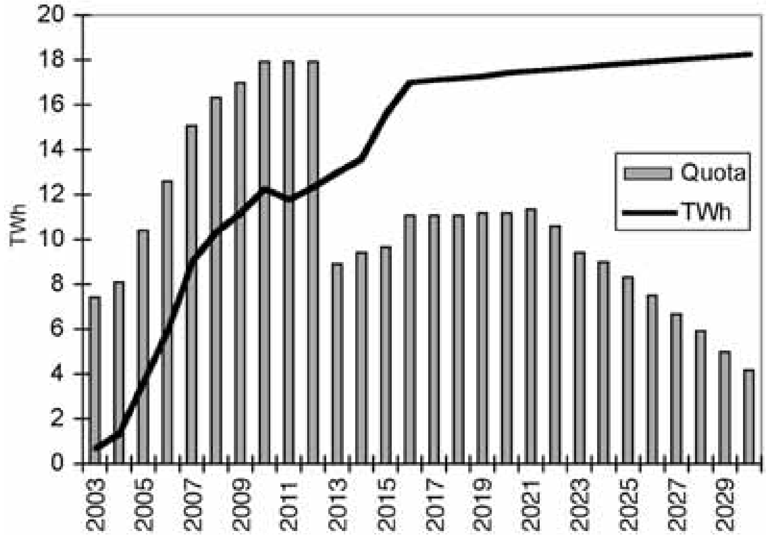

Figure 7 Quotas and production goal of the electricity certificate system

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 (end of 2007)
Utgrunden II	E.ON Vind Sverige AB	70 MSEK (7.6 M€)	Offshore	285 GWh (planned 2008 but recently postponed)
Uljabouoda	Skellefteå Kraft AB	35 MSEK (3.8 M€)	Onshore arctic	100 GWh (2008)

5.0 R, D&D Activities

5.1 National R, D&D efforts

The former wind R&D program Vindforsk was to end on 31 December 2004 but was prolonged during 2005. In January 2006 a new program, Vindforsk II, started. This program runs from 2006 until the end of 2008 with a total budget of 4.9 M€ (45 million SEK). Elforsk, the Swedish Electricity Utilities' R&D company, manages the program. Vindforsk II consists of two parts, one basic research and the other applied research. Basic research projects are funded 100% by the Swedish Energy Agency, with a total budget of 2 million € (18 million SEK). Applied projects are funded 60% by Elforsk and 40% by the Swedish Energy Agency. The program is user-oriented and will have 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, impacts on the environment, and public acceptance. The two latter areas have their own research program, Vindval, which covers such issues more thoroughly. Within the environmental and public acceptance program, six research projects on birds, fish, bats, and artificial structures were initiated during 2005. Vindval is a small part of a program called the Market Introduction and Technology Development Program, which runs from 2003 to 2007 with a budget of 38 million € (350 million SEK). The budget for Vindval is 3.8 million € . The Swedish Energy Agency is responsible for the program, which supports wind-power deployment offshore and in the arctic areas. During the new round of this program, Vindval is likely to be prolonged and new money assigned.

Apart from projects in these programs, other R&D projects are also funded. For example, during 2006, work mapping the wind climate in Sweden was completed. The wind mapping was carried out by Hans Bergström, Department of Earth Sciences and Meteorology at Uppsala University, using a three-dimensional, higher-order, closure meso-scale modeling. Statistics of the geostrophic wind are used for weighting model output together into the final wind climate. The mapping is made on a 1-x-1-km horizontal resolution. The model results have been verified against measurements from various meteorological-masts. The final report including verification will be ready in spring 2007. Results from the mapping are used in allocating areas of national interest for wind energy, by municipalities in their planning processes, and by developers in finding locations for their projects.

Another area of interest is conflict with the military radar reconnaissance, which can stop a lot of projects. Onshore, models of the interaction between radar and wind turbines have been changed to consider terrain effects. This means that, onshore wind energy projects have had fewer problems getting approved. For offshore locations, however, the current model used to determine radar interference is such that the Defense Administration stops most projects. This is incompatible with an expansion of offshore wind in areas with otherwise suitable conditions. Too little is known concerning the real disturbance by the wind turbines. To gain knowledge and to be able to introduce a new model for the calculation of disturbance on radar by wind turbines, the Swedish Energy Agency is funding a project with flight tests over one of the existing offshore wind farms. In a project with 530,000 € of funding, the Swedish Defence Material Administration will carry out tests of radar signals from airplanes and ships with wind turbines in the radar vision field. Plans are for the project to be carried out during 2007.

To improve market competition and to help the development of turbines that can lower the cost of electricity, the Swedish Energy Agency is funding a demonstration project of a 3.5-MW turbine with a new direct-driven generator, NewGen. The recipient of the financial support for the demonstration project is Vattenfall AB. The turbine is expected to be in operation by mid-2009. The turbine is developed by a consortium of the turbine manufacturer Scanwind and the engineering company VG Power. VG Power is developing the generator, which has a configuration of permanent magnets and wire-wound stator, with the bearing of the machine placed in the air gap. The layout is an outer pole machine and the application is for wind power. The technical solution was verified by a pilot generator of 144 kW (maximum 177 kW). The tests show that the concept meets the estimated performance. Development of the full-scale generator is supported by EU funding. Consortium members in the EU project are VG Power, Scanwind, SKF, the technical consultant company Teknikgruppen, and the Finnish power electronics manufacturer Verteco. The generator will cut weight by approximately 70% compared with a conventional direct-driven generator, which is believed to cut generator cost by about half and make the drivetrain investment cost comparable to that for a conventional gearbox/high-speed generator concept. The benefit of the direct driven generator will be a reduced number of components, better reliability, and reduced O&M costs.

5.2 Collaborative research

Research groups in Sweden participate in all currently operating IEA Wind tasks except Task 19. Sven-Erik Thor at Vattenfall AB serves as operating agent for task 11, Base Technology Information Exchange. The participation boosts work in the national programs–for example, by invaluable sharing of expensive data from experiments and measurements.

6.0 Next Term

The growth in wind power in Sweden is expected to gain momentum in 2007. The Lillgrund offshore wind farm alone will almost double the annual installation rate. The wind farm will also add another one-third to the total production in gigawatt-hours over the 2006 level. The second round (with new financing) of the program to support technical developments in coordination with market introduction will announce a call for projects during 2007. The Swedish Energy Agency will designate new areas of national interest for wind power and will suggest a new planning goal for 2020 to the government.

Authors: Anders Björck, Swedish Energy Agency, Sweden; input from Kenneth Averstad, Vattenfall AB, Sweden.

SWITZERLAND

27

1.0 Introduction

The consumption of energy in Switzerland was 247.3 TWh, in 2005 (the most recent numbers available), 1.4% higher than the previous year. The SwissEnergy program was launched on 31 January 2001, by energy minister Moritz Leuenberger, on the basis of the Energy Act and CO_2 Act, referring to SwissEnergy as “a platform for an intelligent energy policy.” (1) The main strength of this program aimed at promoting energy efficiency and the use of renewable energy lies in close co-operation of the federal government, the cantons, communities, and numerous partners from trade and industry: environmental groups, consumer organizations, and public and private agencies.

Right from the start, SwissEnergy has been making a valuable contribution to Switzerland’s climate and energy policies. Without SwissEnergy and its predecessor, Energy 2000, CO_2 emissions would be approximately 7% higher than they are today. Thanks to SwissEnergy, energy efficiency has been significantly improved and the proportion of renewable energy has been greatly increased. This program has become a major driving force behind innovation in Switzerland’s economy.

Despite these successes, it is clear that it will not be possible to achieve the objectives of Switzerland’s climate and energy policies with SwissEnergy alone. In accordance with the CO_2 Act, whose measures are primarily based on the principle of voluntary actions, SwissEnergy will continue to provide initiatives and to support implementation of a clearly defined and credible Swiss energy policy that unites a comprehensive range of energy and climate policy measures. The CO_2 fee and “climate cent” are intended to complement the SwissEnergy program. Only by combining all three packages of measures will Switzerland have a realistic chance of meeting its climate goals.

2.0 Progress toward national objectives

In 2001, SwissEnergy established clear goals that are still valid today. SwissEnergy makes an important contribution toward the following goals:

- Goals for promoting renewable energy (including small hydropower)
- 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 maximum 5% increase of electricity consumption between 2000 and 2010).

The Federal Department of the Environment, Transport, Energy and Communications (DETEC) with the Swiss Agency for the Environment, Forests, and Landscape (SAEFL), the Swiss Federal Office of Energy (SFOE), and the Federal Office for Spatial Development (OSD), elaborated on the Wind Energy Concept (2) in 2003 and 2004. The targets for wind energy production in Switzerland according to that document are 50 GWh to 100 GWh by 2010. In 2006, wind energy in Switzerland produced

Table 1 Key Statistics 2006: Switzerland	
Total installed wind generation	11.594 MW
New wind generation installed	0 MW
Total electrical output from wind	0.0152 TWh
Wind generation as % of national electric demand	0.026%
Target:	100 GWh/yr in 2010

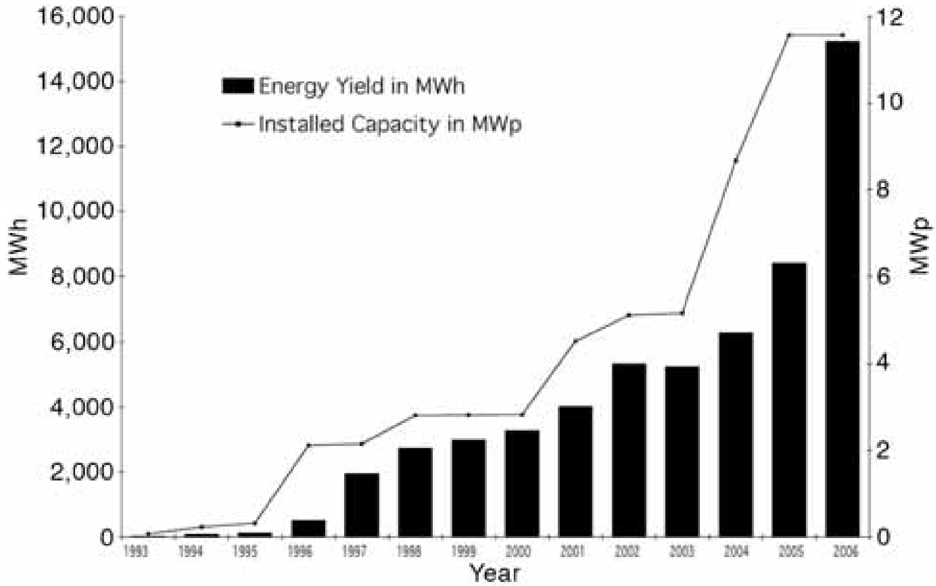

Figure 1 Installed capacity and energy yield of wind turbines in Switzerland, 2006.

15.2 GWh, an achievement of 15% of the 2010 objective.

As a result of this concept, there are now assessments of wind potentials, which were calculated on the basis of 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

The wind potentials include all possible sites from this concept, Wind Energy Switzerland, plus all individual plants which fulfill the criteria of the concept; only sites with wind speeds of an annual mean of ≥4.5 m/s: some 2,850 GWh/yr from individual plants, 1,150 GWh/yr from wind parks.

3.0 Benefits to national economy

3.1 Market characteristics

During 2006, the installed capacity of wind energy in Switzerland did not increase. However, due to a full year's production of all 37 installed turbines (with a total capacity of 11.57 MW), the energy yield in 2006 increased to 15,228 MWh (Figure 1). This brings the average capacity factor up to 15%.

The new 2-MW installation in Collonges (Figure 2) is alone responsible for 4.4 GWh. With a capacity factor of about 25%, this Enercon E70 performs excellently. The wind resources at this site (in-

Figure 2 The Enercon E70 in Collonges. The new workhorse for wind energy in Switzerland performs with a capacity factor of 25% and is responsible for 28% of the total energy yield from wind power. Photo by Suisse Eole (Chevalley)

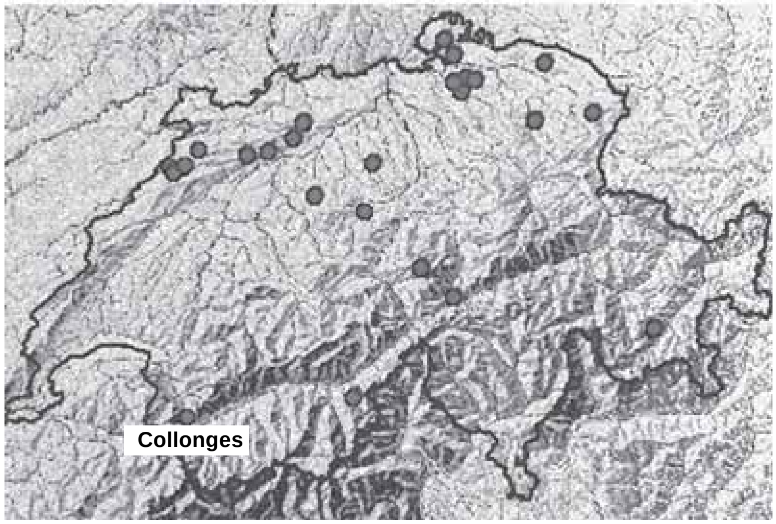

Figure 3 Map of all wind turbine sites in Switzerland. Collonges is situated in a long inner Alpine valley.

ner alpine valley) were clearly underestimated. The owners of this installation are planning to install more turbines near this site (Figure 3).

After more than five years of disputes over the site of a future wind farm, Crêt Meuron, the federal court of Switzerland stated in its decision of 31 August 2006: "Landscape protection has no higher value than clean energy production from wind energy!" Since nearly all wind energy projects in Switzerland are challenged by landscape protection lobbies, this decision is very important for the future development of wind energy in our country.

3.2 Industrial development and operational experience

Switzerland's wind energy research programs place great emphasis on wind energy in cold climates. In 2006, a preliminary study for the use of nano-coatings was carried out. The study's authors presented a proposal for antifreeze coatings based on the effect of antifreeze proteins. Contrary to traditional antifreeze compounds, the effect of antifreeze proteins is not proportional to their concentration. Antifreeze proteins inhibit crystal growth, forcing ice formation to start at much lower temperatures. Synthetically prepared polymers can mimic the effect of antifreeze proteins. Coatings of such polymers could prevent icing.

The authors believe that the proposed project has great potential for the development of stable anti-ice coatings for wind turbine blades. An appropriate coating would bring great advantages for certain locations as, for example, in the Alps. Until now, the tested coatings have shown a reduction in ice adhesion and formation on surfaces, but this reduction is not sufficient. Coatings with antifreeze properties analogous to antifreeze proteins open up new possibilities for reducing ice formation on surfaces.

The project, Alpine Test Site Gütsch, is based on the participation in IEA Wind Task 19, Wind Energy in Cold Climates. Its results and recommendations are currently being verified within the context of the COST 727 project. Relevant results will be published in a handbook. The Gütsch site, at 2,350 meters above sea level is now well equipped with meteorological measurement instruments and with data acquisition systems for power measurements. This location could be a good test site for smaller (<500-kW) wind turbines in alpine conditions.

Detailed investigations of the possible ice throw from wind turbines are an important component of the international research project of the IEA, Task 19. (Figures 4 and 5) Thanks to the well-developed infrastructure on Mt. Gütsch there is the possibility to investigate immediately after freezing events. From this work, Switzerland produces valuable results on the issue of ice throw.

3.3 Economic details

The specific costs of larger wind power plants amount to about 2,000 CHF/kW (1,380 €/kW). Thus, the prime costs at windy locations are lower

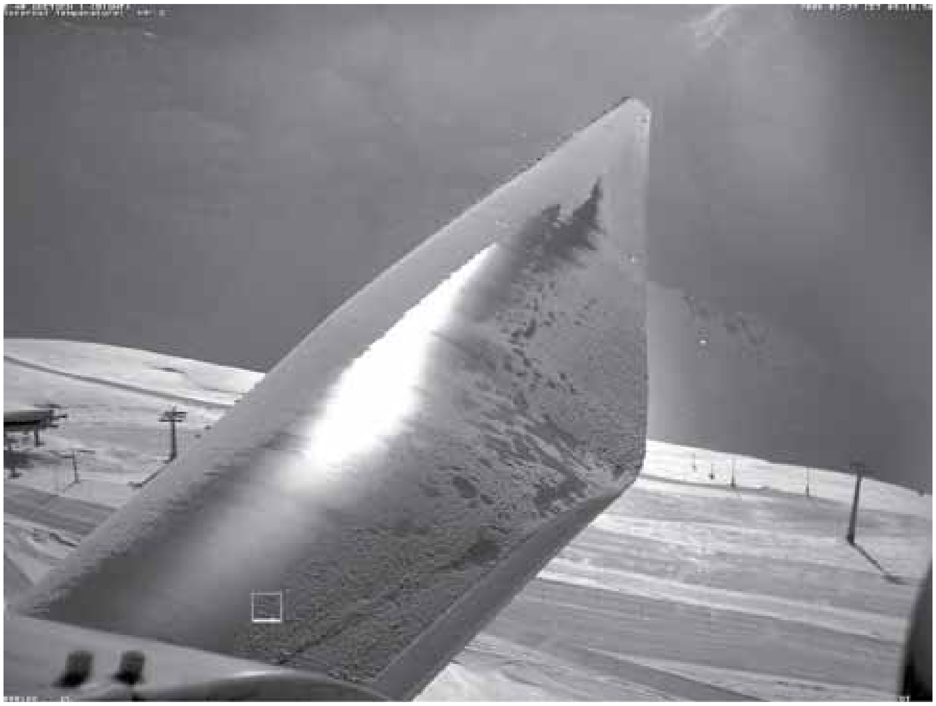

Figure 4 Alpine Test Site Gütsch, live Web cam from the rotating rotor blade http://www.meteotest.ch/cost727/webcam_e40.html Photo by Meteotest (Cattin).

than 0.20 CHF/kWh (0.135 €/kWh). Swiss energy law obliges energy suppliers to buy back the energy produced by independent producers at a price of 0.15 CHF/kWh (0.105 €/kWh). Since 1 January 2005, operators of the high-voltage grid have paid these costs. The Swiss parliament is still discussing a new law for opening up the electricity market. Within this context, there is a debate on changing the fixed feed-in tariff system in the current energy act to cost-covering remunerations, similar to the German Renewable Energies Act. The principle should be approved in spring 2007.

4.0 National incentive programs

Wind energy has managed to be an important mosaic stone within the sustainable energy supply in Switzerland. Participation by big electric supply companies in the research activities of the wind energy program is still relatively low.

Suisse Eole, the Swiss Wind Energy Association, has managed to position itself as the leading authority on the use of wind energy in Switzerland. Suisse Eole coordinates all activities for the use of wind energy in Switzerland 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 (Figure 6).

5.0 R, D&D activities

5.1 National R, D&D activities

Specific focal points in research for wind power generation in hilly and mountainous terrain will provide more know-how to enhance opportunities for Swiss companies in the globally booming wind energy market. In 2006, the budget for wind energy–related R&D projects was 262,000 CHF (175,000 €). For promoting activities, the budget is 425,000 CHF (285,000 €).

5.2 Collaborative research

The concept of energy research of the Swiss government from 2004 to 2007, presented by

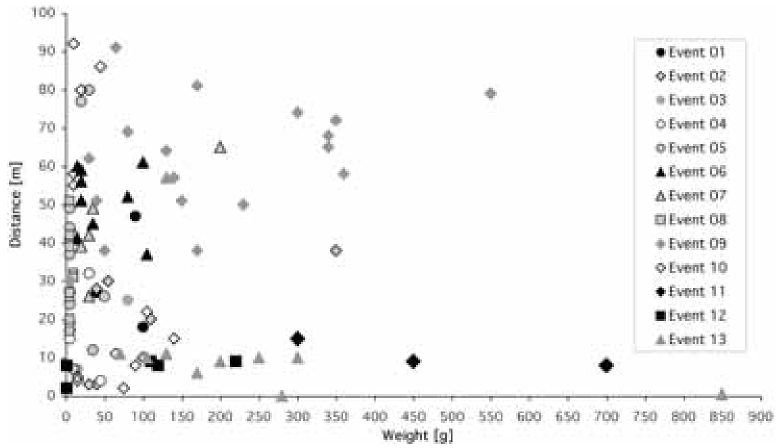

Figure 5 Distance of ice throw from a 600-kW wind turbine and weight of ice pieces in different events.

CORE (Switzerland's federal commission of energy research activities) during the energy research conference in November 2003 highlights the following issues in the wind program:

- "The utilization of wind power in Switzerland is still faced with problems of acceptance as well as with high technological requirements due to mountainous sites.
- "The planned goals of reaching 50 GWh to 100 GWh by the year 2010 should be concretized spatially within a nationwide concept and the necessary planning tools should be developed.
- "The specific problems facing wind plants in mountainous sites and an important local supplier industry of wind plant components justify the resumption of research activities.
- "These activities will also create the possibility to exchange experiences at an international level."

Wind energy is an important part of the national SwissEnergy program. In addition to participating in the IEA Wind Task 19, Wind Energy in Cold Climates, Switzerland participates in IEA Wind's Task 24, Integration of Wind and Hydropower Systems.

Initial discussions within IEA Wind show substantial interest in social acceptance. In May 2007, Switzerland will host an IEA Wind Task 11 Topical Expert Meeting on social acceptance in Lucerne.

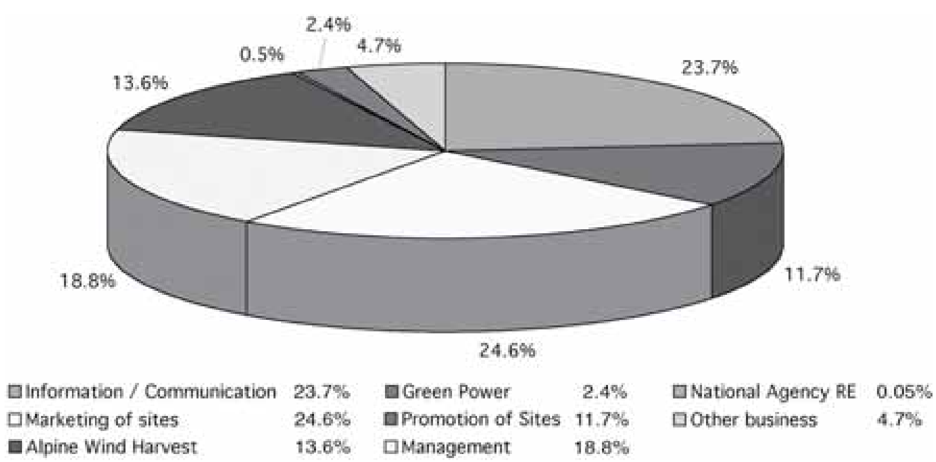

Figure 6 Distribution of financed activities by the Swiss wind energy association Suisse Eole.

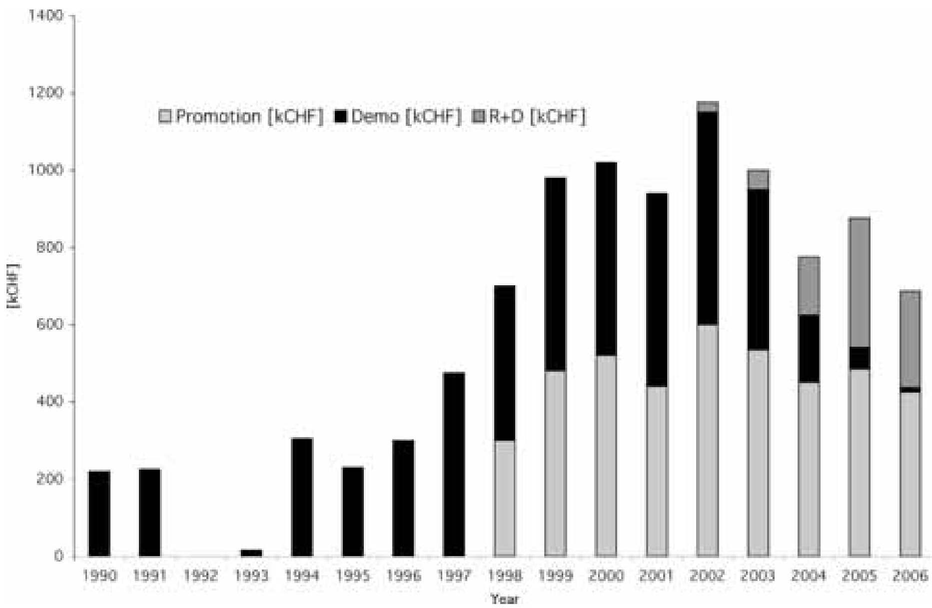

Figure 7 Development of the financing of Swiss R, D&D activities in wind energy.

6.0 The next term

In 2007, an additional energy research program (2008 through 2011) will be approved by the authorities. Special emphasis of the research efforts in the area of wind energy is given to these goals:

- Increase the acceptance of wind energy (social acceptance) with integration of social sciences. Reduce planning time.
- Increase the availability and energy yield at extreme sites (cold climate, high turbulence intensity, and difficult access).
- Develop wind turbine components for the application of this technology under specific Swiss conditions by Swiss industry.
- Increase the value of wind energy (forecasting, now-casting, regulating energy, and so on).

Wind power generation holds enormous potential of great economic importance beyond the small Swiss market. Increased research activities should help to develop business activities in the area of the core competence of the Swiss wind energy industry.

References

(1) Information about SwissEnergy is available at http://www.bfe.admin.ch/energie/00458/index.html?lang=en&dossier_id=00720.

(2) Konzept Windenergie Schweiz, BFE, 2003)

Author: Robert Horbaty, Swiss Wind Energy Program, Switzerland.

United Kingdom

28

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. In the medium term, wind energy is expected to generate 8.8% (onshore) and 9.4% (offshore) of the UK's projected electricity supply by 2020, with a further 0.7% potential from micro and mini wind turbines.

The year 2006 was another record-breaking year, with more than 0.6 GW of wind capacity installed. It was the most productive and successful year in the UK wind sector's history and positions the UK close to the 2-GW landmark. It took 14 years for the UK to reach the 1-GW landmark but only a further 20 months to be close to 2 GW. The rapidly growing UK wind industry will be the single biggest contributor to the government's target of 10% from renewables by 2010. Wind is expected to deliver almost half of the 10% electricity target.

The continuing challenges of energy security and climate change led the UK government to issue two key publications in 2006—the government's Energy Review and the Stern Review. The Stern Review's Final Report, which focuses on the economics of climate change, has received global interest and is seen as a landmark publication in the debate surrounding global warming. The Energy Review, launched in November 2005 by the prime minister, was published in July 2006 and is the most important assessment of the UK's energy policy since the 2003 Energy White Paper. The Energy Review has identified three key areas that require action if the government's current and future renewable energy requirements are to be met: Changes to the Re-

Table 1 Key Statistics 2006: United Kingdom	
Total installed wind generation*	1,962.85 MW (2006) 1,565.0 MW (2005)
New wind generation installed**	630 MW (2006) 447 MW (2005) 241 MW (2004)
Total electrical output from wind	4.591 TWh estimated (2006)*** 2.908 TWh (2005)
Wind generation as % of national electric demand*	1.12% (2006)
Target:	10% of electricity from renewables by 2010

* Estimated from the sum of the Digest of UK Energy Statistics (DUKES) figures for 2005, which includes all known wind generation in the UK and the capacity built in the year recorded by British Wind Energy Association (BWEA). This compares with a BWEA figure for 2006 of 1,963 MW (the figure was 1,332.06 MW in 2005), which only includes turbines greater than ~200 kW in capacity. Turbines less than 200 kW are estimated to account for an additional 4 MW of capacity.
** According to BWEA.
*** Estimated assuming average capacity factors and new onshore capacity added uniformly across year and offshore added when first online.

newables Obligation (RO) to bring forth emerging renewable technologies; Overhaul of the planning system to tackle problems experienced in getting planning consent; and improving access to the grid renewable energy to 2010 and beyond.

Once further consultation on elements identified in the Energy Review is complete, the government will set out its final position in an Energy White Paper to be published in May 2007.

UK renewable energy statistics can be found at the Department of Trade and Industry (DTI) Web site: www.dti.gov.uk/energy/statistics/source/renewables/page18513.html.

1.1 Overview of UK energy market characteristics

In the UK, primary energy supply comes from a range of sources—natural gas (38%); oil and petrol products (36%), coal (16%), electricity (8%), and renewables and other sources (2%) (1). Electricity generation stations use a mixture of energy sources: coal (37%), gas (33%), nuclear (21%), and renewables (4.6%); the remaining 5% comes from other fuels, oil, and electricity imports (2). Renewable energy sources accounted for 4.25 million tonnes of oil equivalent, with 3.77 million tonnes used to generate electricity and 0.48 million tonnes to generate heat. Use of renewable energy grew by 15% in 2005, a rate four times higher than that in 1990. Total primary energy demand was 0.5% higher than in 2004 at 246.9 million tonnes of oil equivalent.

Although the UK is still one of the global top 10 producers of oil and gas and will remain a major player for many years, it is entering a new era for its energy supplies. The North Sea has given the UK self-sufficiency in oil and gas, but that is now changing. So far, 34 billion barrels of oil equivalent (bboe) have been produced; remaining reserves are likely to amount to between 21 and 27 bboe. If the UK makes the most of these resources, maintaining indigenous production as far as possible, production is likely to decline at an average rate of around 7%/yr. If, on the other hand, the UK fails to attract continued investment, the decline in production could be significantly more rapid; studies suggest up to 14%/yr. This would be the difference between meeting half of the UK's oil and gas needs by 2020 and meeting just 10%.

The UK was a net importer in 2005 of 7% of its gas (most recent figures available). This percentage varies throughout the year and is higher at times of peak winter demand. Gross imports—that is, the amount of gas imported without balancing against UK gas exports—accounted for 15.8% of total demand for gas in 2005 (up from 11.8% in 2004). Import reliance will increase over the coming years as output from the UK declines. Imports could be meeting up to 40% of total gas demand by 2010 and 90% by 2020.

The UK's energy sector has a framework that combines competition where it is desirable and regulation when it is necessary. Business and residential consumers are able to choose among competing suppliers of electricity and 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 2006

In 2006, a record-breaking year for development, more than 630 MW of new capacity was commissioned, bringing the UK close to achieving the 2-GW landmark. Total installed capacity now stands at 1,962.85 MW, an increase of 41% above 2005 levels. Included in this new capacity was 90 MW from Barrow, the UK's fifth offshore wind farm, just off the northwest coast of Cumbria, England (Figure 1). This brought the total installed offshore wind capacity at the end of 2006 to 304 MW.

The overall electricity contribution from wind energy was up by a factor of 1.5 at 2,908 GWh (2005), or 1.12% of the total electricity demand for the UK (408,846 GWh in 2005) (3). This contribution from wind is set to rise dramatically over the next few years; predictions are that wind energy could meet between 5% and 8% of the total demand in 2010. The average load factor for onshore wind was estimated as 26.6%. 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.

Offshore wind results for the UK's first large offshore wind farm, the 60-MW North Hoyle development, have been published in the second annual report for the period July 2005 to June 2006. Overall commercial availability was 91.2% (cf. 89.1% in the previous year); overall capacity factor was 34.3% (cf. 36% in the previous year). The second annual report (January 2006 to December 2006) from the UK's second large offshore wind farm, the 60-MW Scroby Sands Offshore Wind Farm, showed that overall commercial availability was 81% (cf. 84.1%

Figure 1 Some of the thirty 3-MW turbines at Barrow Offshore Wind Farm (photo © Barrow Offshore Wind 2005).

in the previous year) and overall capacity factor was 24.1% (cf. 28.9% in the previous year).

These reports will be available in 2007 from http://www.dti.gov.uk/publications/index.html. Previous annual reports for these projects are available from http://www.dti.gov.uk/energy/sources/renewables/publications/page32846.htmland http://www.dti.gov.uk/files/file34791.pdf.

2.0 Progress toward national objectives

2.1 Policy background

The UK government has four long-term goals for its energy policy:

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.
4. To ensure that every home is adequately and affordably heated.

The energy policy is detailed in the February 2003 Energy White Paper "Our Energy Future—Creating a Low-Carbon Economy." The paper

Table 2 Regional capacity factors for wind farms in the UK*

Region	1998	1999	2000	2001	2002	2003	2004	2005	Average 1998-2005
East of England	0.23	–	–	–	–	0.23	0.26	0.27	0.24
Northeast	–	–	–	–	0.23	0.19	0.22	0.23	0.21
Northwest	0.30	0.29	0.27	0.23	0.27	0.24	0.26	0.26	0.27
Yorkshire and the Humber	0.32	–	–	–	–	0.28	0.27	0.27	0.29
Southwest	0.30	–	–	–	–	0.24	0.24	0.24	0.26
Southeast	–	–	–	–	–	–	–	0.18	0.18
England	0.30	0.28	0.27	0.23	0.27	0.24	0.25	0.25	0.26
Northern Ireland	0.40	0.39	0.37	0.32	0.35	0.34	0.36	0.35	0.36
Scotland	0.34	0.29	0.29	0.27	0.29	0.28	0.34	0.30	0.30
Wales	0.29	0.29	0.26	0.23	0.26	0.25	0.26	0.25	0.26
UK average	0.31	0.31	0.29	0.26	0.28	0.26	0.29	0.28	0.29
UK aggregate load factor	0.31	0.28	0.28	0.26	0.30	0.24	0.27	0.26	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.

set out a new strategy for energy policy until 2050. It established a clear long-term framework against which business and domestic customers could plan and make decisions with confidence. An annual progress report on the implementation of the Energy White Paper is published jointly by the Department of Trade and Industry and the Department for Environment, Food and Rural Affairs.

In November 2005, the prime minister and secretary of state for trade and industry announced the review of the UK's energy policy with a view to bringing forward policy proposals in 2006 and to publishing an Energy White Paper in 2007. The review was driven by the two major long-term energy challenges that the UK faces:

- Tackling climate change, along with other nations, as global carbon emissions from human activity continue to grow.
- Delivering secure, clean energy at affordable prices, as the UK becomes increasingly dependent on imports for our energy needs.

In January 2006, the secretary of state and the minister for energy launched the review consultation document "Our Energy Challenge: Securing Clean, Affordable Energy for the Long Term". The terms of reference can be found at: www.dti.gov.uk/energy/review/page31995.html.

The review's conclusions were published in July 2006 in "The Energy Challenge Energy Review Report 2006" (see www.dti.gov.uk/files/file31890.pdf). The review concluded that the UK's energy policy and market framework is sound, but there is a need for new policy initiatives to meet the significant challenges the UK faces in the coming decades. The report sets out the next steps that are needed to respond to those challenges, and proposes a range of measures to promote its growth which, taken together, should mean that the UK can get 20% of its electricity from renewable sources by 2020.

The review identified the following main barriers to the further development of renewables, including onshore and offshore wind:

Renewables Obligation. The main financial instrument for supporting renewable generation has succeeded in bringing forward major developments in onshore wind, landfill gas, and co-firing of biomass in coal power stations. But as a technology-neutral instrument, the RO has been less successful in bringing forward development of more emerging technologies, and so changes to the RO are required.

Planning. The planning system needs to be overhauled to tackle problems in getting planning consent. The government intends to consult on changes to planning inquiry rules to help reduce planning delays to renewable projects while recognizing the rights of people to object to applications.

Access to the grid. Without significant investment in transmission infrastructure and grid strengthening, it is unlikely the government will achieve its targets for renewable energy to 2010 and beyond.

On 9 October 2006, the government published a consultation document, "Reform of the Renewables Obligation and Statutory Consultation on the Renewables Obligation Order 2007" (see www.dti.gov.uk/files/file34470.pdf). Further information on the Government's proposals to strengthen the RO can be found in Section 4.1.

Also, in July 2006 the third annual report on the implementation of the 2003 Energy White Paper "Creating a Low-Carbon Economy: Third Annual Report on the Implementation of the Energy White Paper" was published. The report can be found at www.dti.gov.uk/energy/policy-strategy/energy-white-paper-2003/third-annual-report/page32491.html.

Several key issues facing the wind sector in 2006 include electrical connection, planning, defense, and aviation issues. Additional considerations concerning strengthening and modifying the Renewables Obligation are covered in Section 4.2.

2.2 Access to the grid

The anticipated geographical location of much of the new wind generation coming on stream will require the development of new transmission infrastructure in England, Wales, and Scotland. In addition, capacity of the Scotland/England interconnector will need to be strengthened to enable generation in Scotland to be delivered to demand centers in the south of England. Without this investment, it is unlikely the government will achieve its targets for renewable energy to 2010 and beyond. To enable this, the transmission companies' regulated price control has already been adjusted to allow 530 million £ of network investment in Scotland, the interconnector, and new transmission works in the north of England.

In addition to further investment in the transmission network, the connection of renewable generation to the grid has also been an issue. High user commitment costs known as final sums liabilities have posed a barrier to project development. As a consequence, the system operator has introduced interim alternative arrangements to the final sums liability. The new arrangements provide a greater degree of certainty for developers about the extent of the financial liabilities they commit to when their project triggers reinforcement work on other parts of the transmission network.

2.3 Offshore transmission

The government and Ofgem are establishing an offshore transmission regulatory regime to enable the connection of offshore wind and other marine technologies to the onshore grid. This is a critical requisite for the marine sector. The aim is to have a regime in place by 2008.

The government decided in March 2006 that the appropriate model for the regulation of offshore electricity transmission systems was through a regulated price control approach, extending the principles of the approach to onshore transmission regulation. In practice, this means that transmission operators will be responsible for building the offshore networks and that developers will pay annual use-of-system charges based on the cost of the infrastructure. Following the government's decision in March 2006, in August 2006, the energy minister announced that National Grid Electricity Transmission (NGET)'s role as Great Britain System Operator (GBSO) will be extended offshore.

On 20 November 2006, the DTI and Ofgem jointly published a consultation document on the licensing of offshore electricity transmission. The latter document invited views on two possible models for licensing transmission owner (TO) activities offshore under a price control regime. The two options were:

- A nonexclusive approach whereby potential offshore TO's would compete with each other through a common tender process for the right to build, own, and maintain offshore electricity transmission connections.
- An exclusive based approach whereby a single TO would be exclusively responsible for responding to all future connection requests from generators in a defined geographical area offshore.

In December 2006, DTI and Ofgem jointly published an initial consultation document on a security standard for offshore transmission networks (9). The document summarized the results of the work of an industry subgroup on whether the security requirements offshore would need to be different from those established onshore under the Great Britain Security and Quality of Supply Standard (GB SQSS).

Decisions on this raft of consultations will be announced in 2007 and will set a clear direction for the further development of the regulatory framework to connect offshore wind farms to the onshore grid.

2.4 Planning issues

According to industry statistics, it takes an average of 21 months for wind farms (>50 MW) to secure planning consent under the Electricity Act regime. For smaller wind farms required to secure permission under the Town and Country Planning Act, decisions on average take 10 months in England and 27 months in Wales, against a target to determine 60% for all "major applications" within 13 weeks. Such long consent periods therefore present developers with costs, risks, and uncertainty associated with delays.

The government is committed to fundamental changes in planning systems for major energy projects in England and Wales. The planning system in Scotland is a devolved matter for the Scottish Executive and was also subject to review in 2006.

In the Energy Challenge paper for 2006, the government clarified the strategic importance of energy infrastructure and published a clear statement of need for renewables to provide further support and guidance for decision makers in the planning system in England. This is now to be used alongside Planning Policy Statement 22 (PPS22) in England and Technical Advice Note 8 (TAN 8) in Wales.

The government has also committed to introducing efficient inquiries and will introduce new inquiry rules for applications under the Electricity Act in spring 2007. It will also undertake further work on options to ensure appropriate and predictable timing for decisions on applications for energy developments.

2.5 Defense and civil aviation interests

It is now recognized that wind turbines can adversely affect the aviation domain. Therefore, developments must take place in a way that fully takes into account national air defense and air safety, with the wind energy and aviation communities understanding the needs of each other.

In the UK, the Department of Trade and Industry, 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. One example of close cooperation has led to planning consent for the Whitelee Wind Farm in Scotland. When built, it will have the capacity to generate 322 MW of electricity and will be one of Europe's largest wind farms.

A program has been agreed 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 renewables objectives. Main activities in 2006 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 preparation of planning guidelines, strategic approaches to planning, database and information sharing, and issues surrounding micro generators.

Greater Wash: The Collaborative Offshore Wind Research into the Environment (COWRIE) and DTI, 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. The report from this study will inform relevant stakeholders about whether this is a feasible solution that can be used to accelerate the consent process.

MOD activities: The MOD continues to be active in improving its understanding of the impact of wind turbines on its radar systems. Air Defence (AD) trials were undertaken in June 2006, and the data captured will enable a greater understanding of wind farm issues associated with AD radar. These data will help to direct the MOD's policy on developments in wind turbines and wind farms.

Mitigating technologies: DTI has sponsored several projects with support from the MOD and BWEA to investigate filter technologies for mitigating radar interference attributed to wind turbines. Phase 1 was completed in 2005 and Phase 2 in 2006. In parallel to Phase 2, DTI also funded a study to prepare draft safety cases for a typical radar system mitigated with two different technologies. As part of the DTI's Emerging Energy Technology Programme, two projects are being supported to investigate materials and methods (stealth technology) that will assist in mitigating radar interference from wind turbines. These projects are scheduled for completion in 2007.

2.6 Progress toward national targets

Good progress has been made toward achieving the UK's 10% from renewables generation by 2010 target. As the Energy Review acknowledges, however, a strengthening of the framework that supports the development and deployment of renewable technologies is required. The total generation from RO-eligible renewable sources was around 4% of electricity supply in 2005, up from 1.8% in 2002. Figures for 2006 will be published in 2007. Overall demand for electricity in the UK in 2005 was 408,846 GWh, an increase of 0.50% over 2004. The contribution from wind was 2,908 GWh (2005), up a factor of 1.5 over 2004. Wind energy met 0.71% of the total demand.

Regarding wind generation capacity, BWEA figures show that 2006 was another record year. A total of 22 new projects, including one offshore project, came on stream, representing over 630 MW of new capacity (Figure 2). This raised the total installed capacity to 1,962.85 MW, an increase of 47% on the capacity installed in 2005 (Figure 3). Figure 4 shows the distribution of newly installed capacity by country within the UK. Table 3 details the projects that were commissioned in 2006. Figure 5 shows projects under construction at the end of the year.

In 2006, 35 new projects were approved through the planning system totaling over 1,790 MW. These projects brought the total UK capacity approved but not yet under construction to 3,176 MW; the breakdown by country is shown in Figures 6 and 7.

New projects approved in 2006 represented a project approval rate of 54.7%, down from 59.6% in 2005. That 2005 rate was very close to the approval rate from 2004, but the rates for 2004 and 2005 were down from the 75% approval rate in 2003. However, in terms of approved capacity, the 1,789.55 MW of new capacity approvals in 2006 is about 2.3 times greater than the 767 MW approved in 2005. Worthy of note is the approval of Europe's largest wind farm at Whitelee, south of Glasgow. The 300-million-£ project will consist of 140 turbines with a capacity of 322 MW and will provide 11% of the 2010 Scottish Executive's renewable energy target. Figures 8 and 9 show the wind farm planning application success and failure rates from 1991 to 2006.

2.7 Offshore

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

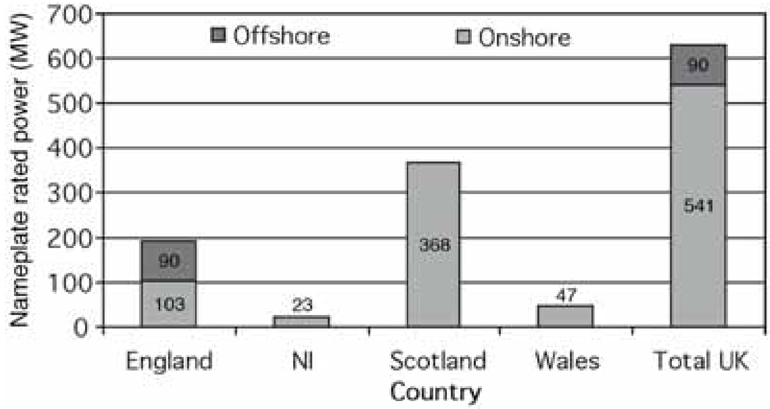

Figure 2 UK wind capacity built in 2006; total 630.8 MW.

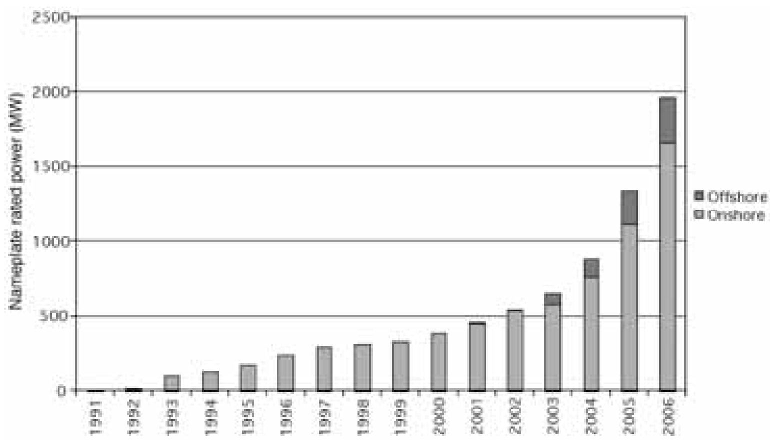

Figure 3 History of UK wind capacity growth built in the UK to the end of 2006: total 1,963 MW.

of a total of 18 sites, limited to 30 turbines per site, grouped at 13 locations around the UK.

Progress with Round 1 of development of the UK offshore wind farms has been slower than anticipated. This is due to a significant increase in the price of steel and copper; turbine availability, with manufacturers preferentially supplying turbines for the onshore market; cable demand; and protracted contractual negotiations as suppliers chose to move away from turnkey contract arrangements. The result is that the economics of projects have been less attractive, long lead times have been needed for the supply of turbines, and protracted re-tendering via multicontract arrangements has been necessary.

However, four of these projects are now generating electricity totaling 304 MW of installed capacity, making the UK second only to Denmark in the development of offshore wind. Installed offshore projects include the 90-MW Barrow Offshore Wind Farm, which was commissioned in 2006. Barrow is located in the Irish Sea, off Barrow in Furness, about 7 km southwest of Walney Island. A fifth offshore project is Burbo Bank, a 90-MW development in Liverpool Bay 6.5 km off the northwest coast of England. This project is under construction, and commissioning is due in late 2007. The Robin Rigg development, which consists of two 90-MW wind farms, signed major supply and installation contracts toward the end of 2006. These developments are due to be commissioned by spring 2009.

Twelve of the Round 1 projects were awarded capital grants to assist the development of what were originally intended as demonstration projects to learn valuable experience offshore. Further details about the capital grant scheme are given in Section 4.

The second phase of offshore wind farm development in the UK, Round 2, allows for much

Table 3: Wind projects commissioned in the UK in 2006

Wind farm	Region	Turbines	Power*	MW	Online
Bambers Farm II	England	6	0.8	4.8	November 2006
Barrow (offshore)	England	30	3	90	July 2006
Beinn Tharsuinn	Scotland	17	1.3	30	September 2006
Black Law B	Scotland	12	2.3	27.6	September 2006
Boyndie Airfield	Scotland	10	2	20	May 2006
Burton Wold Wind Farm	England	10	2	20	April 2006
Callagheen	Northern Ireland	13	1.3	22.75	January 2006
Caton Moor Repowering	England	8	2	16	July 2006
Deeping St Nicholas	England	8	2	16	July 2006
Eastman (Voridian)	England	2	2	4	October 2006
Farr Wind Farm	Scotland	40	2.3	92	May 2006
Ffynnon Oer	Wales	16	2	32	June 2006
Findhorn Foundation	Scotland	4	1	0.75	March 2006
Gedney Marsh (Red House)	England	6	2	12	July 2006
Glass Moor	England	8	2	16	March 2006
Hadyard Hill, Barr	Scotland	52	2.5	120	March 2006
Hafoty Ucha 3 extension	Wales	1	0.85	0.85	January 2006
Michelin Tyre Factory	Scotland	2	2	4	May 2006
Mynydd Clogau	Wales	17	0.85	14.45	April 2006
North Pickenham Wind Farm	England	8	1.8	14.4	November 2006
Paul's Hill	Scotland	24	2.3	55.2	April 2006
Wardlaw Wood	Scotland	6	3	18	April 2006
		300	41.3	630.8	

*Average turbine size: 2.1027 MW

more ambitious project arrangements. Options for site lease agreements totaling as much 7,200 MW were offered to 15 sites. These are to be developed in three strategic areas in and around territorial waters around the UK coastline: the Thames Estuary; the Greater Wash off England's east coast; and in the northwest, including the Liverpool Bay area and the Renewable Energy Zones outside the territorial sea.

Visible progress on the Round 2 projects has been seen; two applications have been granted consent, and five are in the planning process awaiting decisions. The following projects have received consent:

1. The 1,000-MW London Array Limited received consent in December 2006 for the world's largest offshore wind farm to be built in the London Estuary after submitting its application in June 2005. When built, it will be capable of powering one-quarter of all the homes in London.
2. The 300-MW Thanet project also received consent in December 2006 after having submitted its application in November 2005.

These projects submitted their planning application in 2006:

1. The 315-MW Sheringham Shoal project by Scira Offshore Energy Ltd was submitted (S36) in May 2006.
2. 450-MW Walney: Dong was submitted (S36) in March 2006.
3. 500-MW West Duddon: Scottish Power was submitted (S36) in April 2006.

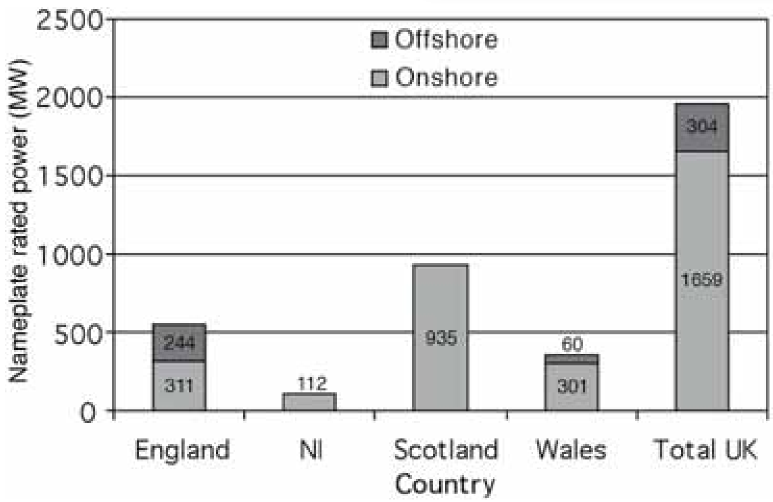

Figure 4 UK wind capacity built to the end of 2006 by country (England 555 MW, Northern Ireland [NI] 112 MW, Scotland 935 MW, and Wales 361 MW).

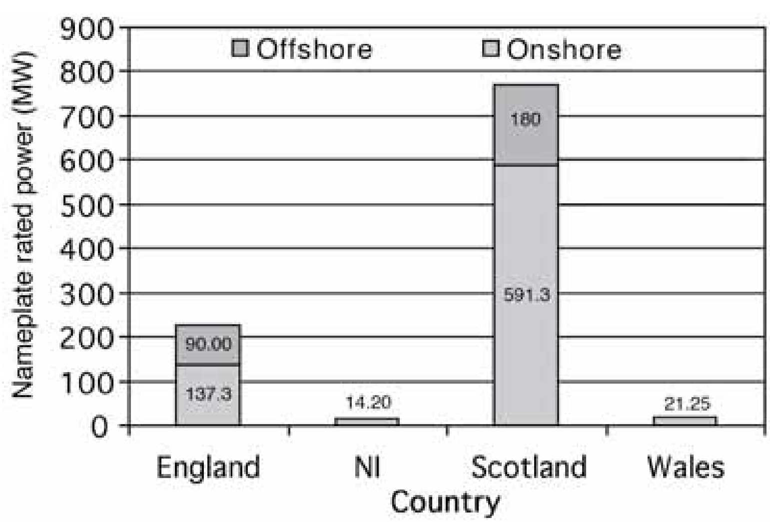

Figure 5: UK wind capacity under construction at the end of 2006; total 1,034 MW.

3.0 Benefits to national economy

3.1 Market characteristics

The high level of project development undertaken in 2006 together with the large number of projects that have gained planning consent underlines the fact that wind energy remains one of the fastest-growing energy sectors in the UK. Currently, about 8,000 jobs are sustained by companies working in the renewables sector, 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. The DTI has estimated that Round 2 of offshore wind development alone could bring a further 20,000 jobs for Britain.

The wind sector covers a diverse range of goods and services to meet the needs of the UK market. The supply chain includes developers, finance, legal, insurance, and consultants. 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, stan-

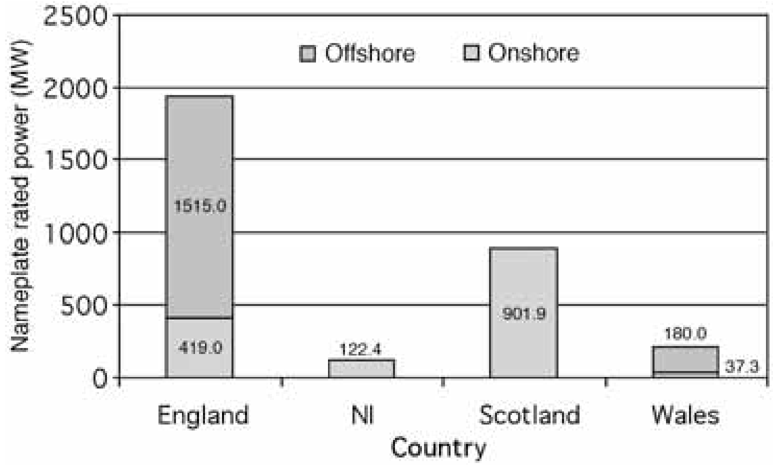

Figure 6: UK capacity approved but not yet under construction at the end of 2006; total 3,176 MW.

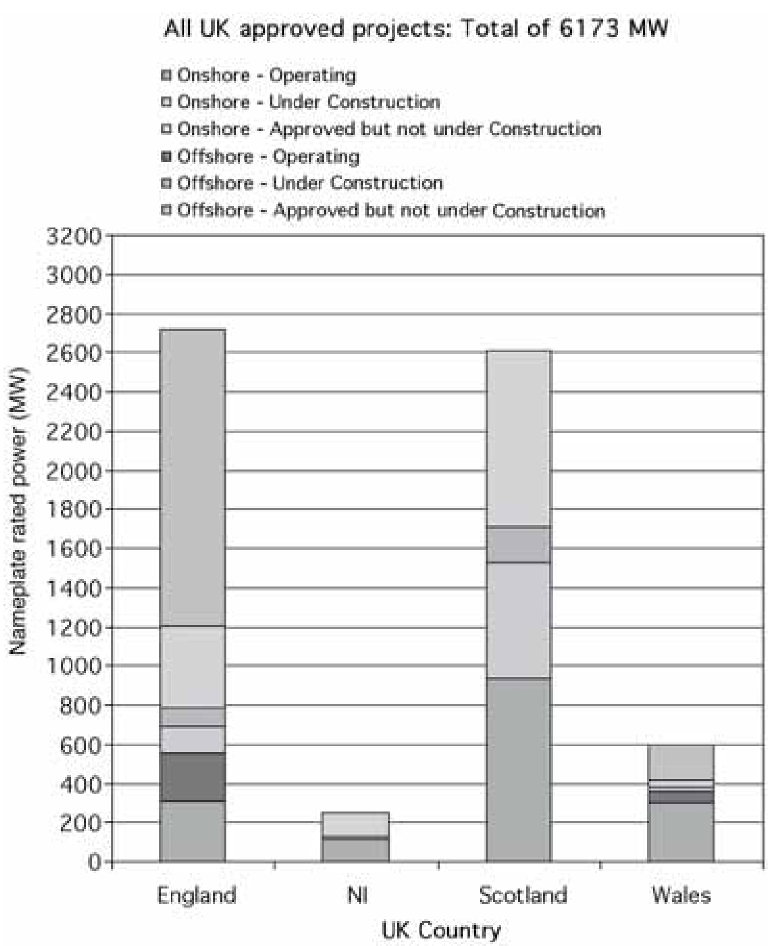

Figure 7 All UK-approved projects at the end of 2006; total 6,173 MW.

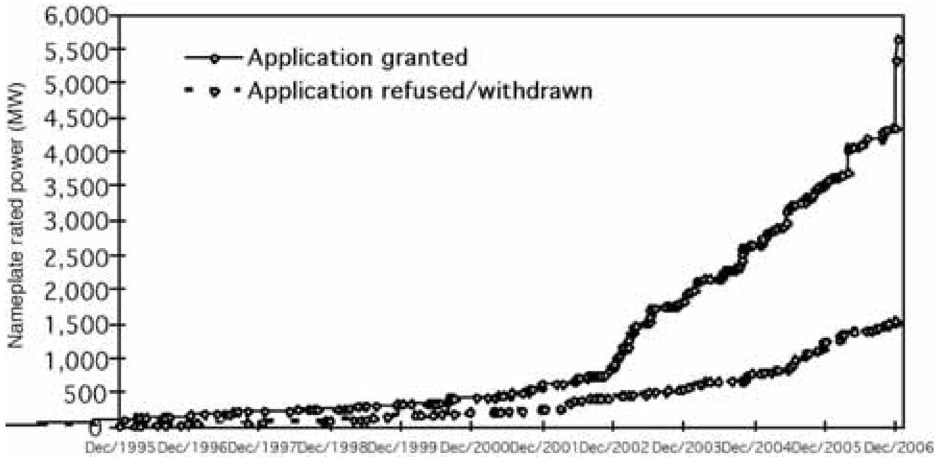

Figure 8 Wind farm planning application success and failure by capacity, UK.

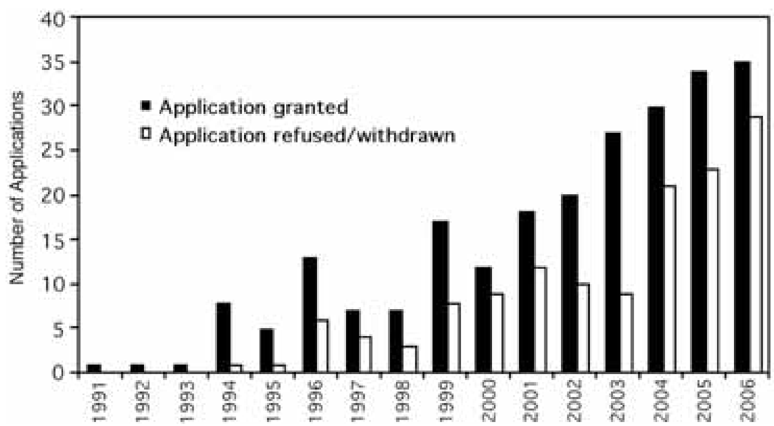

Figure 9: Wind farm planning application successes and failures, UK.

dards/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.

As of 2006, details concerning 450 companies and their services are listed in an open marketing database available from the WindSupply Web site, www.windsupply.co.uk. WindSupply was set up with support from the DTI and several UK regional development agencies to encourage, support, and promote UK businesses to enter the supply chain for wind energy components. WindSupply also has an initiative to reestablish tower manufacturing in the UK.

Ownership patterns are changing to include community ownership. The number of community-owned wind projects is increasing from a very low level (Table 4). Two approaches are being used. The first is to develop entire projects. The second is to piggyback onto a larger project (e.g., Boyndie Wind Farm Co-operative, which is the first wind farm co-operative in Scotland). Based on the price of installed capacity, wind-sector turnover in 2006 was about 965 million €.

3.2 Industrial development and operational experience

In the UK, there are no indigenous manufacturers of large wind turbines, but there are several small and micro turbine manufacturers—e.g., Brumac (50 kW), Gazelle Wind Turbines (20 kW), Proven (0.6 kW to 15 kW), Iskra (5 kW), Marlec (0.06 to 0.72 kW), and Ampair (0.1 kW). Government interest in microgeneration significantly increased in 2006 via the Micro Generation Strategy (April 2006) and by the Climate Change and Sustainable Energy Act 2006 and Budget 2006. The act is designed to increase the installation of micro wind turbines, solar panels, and other local generating technologies. It will prioritize policy measures

Table 4 Community-owned wind projects in the UK

Co-op	Launch date	Location	Wind project status	Total project size (MW)	Co-op fund (million £)	Co-op ownership of project	Members
Baywind	Done	Cumbria	Operational	3.10	2.00	Harlock Hill (two of four turbines, 1997) and Haverigg II (one of four turbines, 1998)	1,300
Findhorn	Loan	Moray	Operational	0.68	0.26	March 2006	Loan
Boyndie	Done	Banff	Operational	14.00	0.70	4%, May 2006	592
Deeping	February 2007	Lincolnshire	Operational	16.00	4.40	Two of eight turbines, 01/07/2006	3,520
Ben Aketil	November 2007	Skye	Constructing	14.00	1.30		1,056
Kil braur	July 2008	Highlands	Constructing		2.00		1,600
Millennium	February 2008	Highlands	Constructing	48.00	2.10		1,690
Westmill	Done	Oxfordshire	Financing received;				
awaiting construction	6.50	3.40	100%	2,300			
Hydro	June 2007	Humber	Financing	2.00	1.40		1,120
Caledonia	September 2007	Scotland	Financing		16.00		12,800
Pates Hill	To be determined						
	West Lothian	Financing	16	7		9,600	
Airfield	To be determined						
	Bedfordshire	Planning application submitted September 2005	21	TBD	One of nine 2.3-MW turbines developed by NUon	To be offered	

to support customer-based microgeneration and aim to overcome existing barriers. It should also make it easier to sell excess energy back to utility companies, which is a key part of the DTI's microgeneration strategy. Finally, it will introduce targets for the take-up of microgeneration.

The utility Scottish and Southern Energy (SSE) has interests in the small wind market, having bought a company share in Renewable Devices Swift Turbines Ltd, which developed the Swift rooftop wind turbine (Figure 10). SSE has been training engineers in installation and service. The utility serves about 6.5 million customers and has more than 3,000 engineers nationwide, and it plans to offer micro wind turbines to several of these customers. SSE is talking with housing companies and retail chains.

A company called Eclectic Energy has adapted a turbine from the sailing and yachting market to the micro/domestic market. Their device, called Stealthgen, is nearly market ready, and when it is available it should provide about one-sixth of a household's electricity needs over the year. The Building Research Establishment (BRE) is testing several building-mounted/integrated wind turbines (BuWTs) to obtain independent data on their performance. Precise details of these tests are subject to commercial confidentiality.

Segen continues to expand its range of small wind turbines, and following the launch of the Southwest Windpower Whisper 3.2 kW in December, they now offer a 20-kW turbine from the long-established Australian manufacturer Westwind (Figure 11).

Figure 10 A typical Swift wind turbine during installation (photo courtesy of Renewable Devices Energy Solutions Ltd © 2006).

Figure 11 The Westwind 20.

Westwind, part of GP&GF Hill Pty Ltd, has recently been purchased by J. A. Graham Renewable Energy Services, which is based in Northern Ireland.

3.3 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 (Figure 12). Because of the high value the obligation places on renewables, corporate investment will yield good returns through an expansion of the core business while reducing exposure to penalty payments. Wind has found particular favor because of its economics, maturity, and ability to deliver relatively quickly. The outcome of the Reform of the Renewables Obligation is expected to be instrumental in securing future investment in wind energy.

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 are due to the increase in size of structures and the logistics of installing the towers. The costs of offshore foundations, construction, installations, and grid connection are significantly higher than onshore. For example, typically, 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.

In April 2006, ODE Ltd was commissioned by the DTI to investigate the scope for cost reduction in the supply chain for offshore wind. The study provides an estimate of the future costs of offshore wind generation and the potential for cost reductions. It identified the cost of raw materials–especially steel, which accounts for about 90% of the turbine and a primary cost driver. The report emphasized that major savings can be realized if turbines are made of lighter, more reliable materials and if major components are developed to be more fatigue resistant. A cost model based on 2006 costs predicted that costs will rise from approximately 1.6 million £ to approximately 1.75 million £ in 2011 before falling by around 20% of the cost by 2020. It reports that perceived cost-reducing impacts of R&D and the "learning curve" far override the cost increase attributed to steel, copper, and supply and demand. This report is available from www.dti.gov.uk/files/file38125.pdf.

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 Renewable Obligations Certificates (ROCs), which are explained further in Section 4.

In the NFFO and SRO (Scottish Renewables Order) power auction no. 1 completed in August 2006, the price for wind was the highest to date at 102.3 £/MWh. This compares with the February 2006 auction no. 11 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 2006 increased slightly from 38.43 £/MWh in January to 39.84 £/MWh in October, a trend that was opposite to that for the electricity-only price. In 2005, the average prices were higher, varying from 39.17£/MWh in October to a high of 47.18 £/MWh in January 2006.

4.0 National incentive programs

4.1 Renewables Obligation (RO)

The RO is the government's main policy measure to stimulate expansion of electricity from renewable sources and to achieve the UK's 10% target by 2010. The RO has stimulated growth and use of the UK's renewable resources by obliging licensed

Figure 12: The UK's largest capacity onshore wind farm, Hadyard Hill, 119.6 MW, located in Barr, South Ayrshire; online in March 2006.

electricity suppliers to source a rising percentage of electricity from renewable sources.

For 2006–2007, the RO percentage target was 6.7%. It will increase each year to reach 15.4% by 2015/16 and then remain at that level until the obligation ceases in 2027. In the 2006 Energy Review, the government further confirmed its commitments to the RO, which it plans to strengthen and modify by eventually extending the target to 20%. The cost of the RO is met by electricity consumers and is limited by a price cap.

The RO was designed to incentivize the most economic forms of renewable generation. Since its introduction it has been effective in achieving this, and it has stimulated significant development of onshore wind, co-firing, and landfill gas. However, more needs to be done to achieve a step change in the UK's share of its energy from renewables. The government has identified the following three steps for strengthening and widening the impact of the RO:

1. Extending RO levels to 20% (when justified by growth in renewable generation);
2. Amending the RO to remove risk of unanticipated ROC oversupply; and
3. Adapting the RO to provide greater support to emerging technologies and less support for established technologies. The government's preferred option for achieving this is through a "banding" system, ensuring that current ROC rights for existing projects and those built prior to implementation of changes are preserved. Any changes would be introduced in 2010.

Following the July 2006 Energy Review, the government announced several proposals for changes to the RO. These changes will potentially provide differentiated support levels to different renewables technologies and give additional certainty on long-term ROC prices. As described earlier, in October 2006 the government published a consultation document on changes to the RO.

The government believes that banding the Renewables Obligation has the potential to advance emerging technologies by providing appropriate levels of additional support without placing extra costs on consumers or taxpayers. .The outcomes of this and other public consultations will feed in to the Energy White Paper in May 2007.

4.2 Climate Change Levy

The government introduced the Climate Change Levy (CCL) on 1 April 2001 to encourage businesses to become more energy efficient. The CCL is a tax on energy use by both business and public sectors. The levy is to encourage nondomestic electricity users to become more energy efficient and so reduce carbon emissions. If you use 33 units or more per day for electricity or 145 kWh per day or more for gas, CCL is applied. The levy package as a whole is expected to save at least 5 million tonnes of carbon a year by 2010.

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 Round 1 offshore wind schemes. The 117 Million £ Scheme awarded grants of 9 million £ or 10 million £ via competitive tranches. The grants provide 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. Progress of projects up to 2006 is shown in Table 5.

5.0 R, D&D activities

5.1 National R, D&D program

A substantial part of the DTI's R&D activities are delivered through the Technology Programme, which provides support to businesses in the form of grants to support research and development in the technology areas identified by the Technology Strategy Board. For the period 2005 to 2008, at least 20 million £ per annum of Technology Programme funding is expected to support research and development into renewables and low-carbon technologies.

In 2006, approximately 3.6 million £ was spent on the wind program to support cost-shared R, D&D with industry. About 2.8 million £ of this amount was allocated to the DOWNVInD 10-MW deep-water wind farm demonstration project.

5.2 R&D priorities

In 2006, the Technology Programme ran two new competitions for funding in April and November, inviting proposals on offshore wind technology. Specifically, the calls focused on the continued need to reduce the costs of offshore wind projects as one of the key factors in improving the economics of this technology. Innovative collaborative R&D proposals were sought aimed at reducing costs in, but not restricted to, the following areas:

- Marine foundations and the cost of transporting and installation;

Table 5 Round 1 status of offshore wind farms and Capital Grant Programme value where awarded				
Round 1 Offshore Wind Farm	Capacity (MW)	Status	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	Constructing	Dec. 2007	10
Inner Dowsing Offshore Wind Farm	97.2	Constructing**	Dec. 2008	10
Lynn Offshore Wind Farm	97.2	Constructing**	Dec. 2008	10
Gunfleet Sands Offshore Wind Farm	108	Approved	Dec. 2008	9
Norfolk Offshore Wind Farm	100	Withdrawn	Withdrawn	Withdrawn
Ormonde	108	Approved	April 2009	0
Rhyl Flats Offshore Wind Farm	100	Approved	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	90	Awaiting FEPA***	Dec. 2009	0
Shell Flats (three projects combined)	270	Submitted (S36)	Dec. 2013	0
Teeside/Redcar	90	Submitted (TWA)	April 11	0
Total	1,666.4			107
* Funded by the Big Lottery				

** Construction of onshore elements started
*** Food and Environment Protection Act

- O&M costs including remote control and monitoring solutions;
- Weight saving, speed of installation, performance, and reliability, recognizing that the move to larger machines offshore using existing scaling-up of technology will likely increase the machines' weight.

In addition, the call recognized that the interaction of wind turbines and radar remains a key barrier to both onshore and offshore development. Proposals were sought to mitigate this problem, including air traffic mitigation solutions.

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 has a two- to three-year duration and requires DTI support in the range of 1 million £ 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 www.dti.gov.uk/innovation/technologystrategy/technologyprogramme/CR&D/page11705.html.

5.3 R, D&D projects

To give a flavor of the R&D project portfolio this year, titles of R&D projects supported by the Technology Programme during this reporting period include:

- Finite-Element Modelling of Offshore Wind Turbine Support Structures
- Improved Performance of Wind Turbines Using Fibre Optic Structural Monitoring
- 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

• Development of Prognostic/Health Management Technologies for Wind Turbines
• Innovative High-Power Direct-Drive Superconducting Generator for Offshore Wind
• Competitive Concrete Towers and Foundations for Future Offshore Wind Farms;
• Cost Reduction and Life Extension of Offshore Wind Farms
• Mobile Wind Lidar for Offshore Wind Farms.

These projects are at various stages of the project cycle from inception to completion. More details about three of the projects that started in 2006 are given in the following sections.

5.3.1 Innovative High-Power Direct-Drive Superconducting Generator for Offshore Wind

This project addresses the design of a direct-drive superconducting generator for use in offshore wind turbines. Such a machine will be more efficient, lighter, cheaper, and more reliable than existing machines. The project focuses on the design challenges and innovation required for the rotor (which houses the superconducting field coils) and on the industrialization/marinization of off-the-shelf cryogenic cooling/refrigeration equipment that will maintain the superconducting state. Significant emphasis is being put on design for manufacture to ensure commercial viability. The leading partner is ALSTOM Power Conversion Ltd.

5.3.2 A Low Cost, Safety Critical Radar Absorbing Material for Wind Turbine Nacelles and Towers

The project aims to create a low-cost radar-adsorbing material (RAM) by combining ultrasonic flow enhancement, magnetic manipulation, and extrusion technologies. The researchers aim to transcend the state of the art by using novel radar-absorbing technologies that will be installed onto turbine towers to radically reduce (by >50%) the incidence of radar shadowing and ghost signals created by wind farms on civilian radars. The leading partner is Hitek Electronic Materials Ltd.

5.3.3 Competitive Concrete Towers and Foundations for Future Offshore Wind Farms

The project will use innovative approaches to the design, construction, and installation of concrete towers and foundations. Compared with current steel tower/monopile solutions, this will substantially reduce construction and offshore installation costs and risk, particularly for the larger turbines and deeper-water locations of Round 2 sites and beyond. The holistic vision includes achievable technical developments in dynamic behavior and durability as well as substantially increased structure life, which together could produce a paradigm shift in system procurement, greater competitiveness in the market, and improved sustainability and life-cycle value management of offshore wind farms. The leading partner is Gifford & Partners Ltd.

5.4 Collaborative research

The UK participates in several research activities with other countries. The DOWNVInD (Distant Offshore Windfarms with No Visual Impact in Deepwater) project consists of two elements. The first is a Research and Technological Development (RTD) project funded by the European Commission (EC) and supported by more than a dozen participants. The second element, the "demonstrator project," has been awarded funding from UK government authorities and the EC, and it has received contributions from the two project partners. The total project budget for both elements is around 28 million £.

Construction began 25 km off the east coast of Scotland in summer 2006. The 10-MW DOWNViND project consists of two 5-MW wind turbines with a hub height of 90 m above sea level located in 44-m-deep water in the Moray Firth adjacent to the Beatrice Field oil platform. By August 2006, both foundation jackets and one turbine had been installed (Figure 13). The second turbine is due to be installed in July 2007. Generation from both turbines is forecast for June and September 2007, respectively.

The UK continues its active involvement in international collaboration through DTI's participation in the following IEA tasks:

Task 11: Base technology information exchange
Task 21: Dynamic models of wind farms for power system studies
Task 23: Offshore wind energy technology development
Task 25: Design and operation of power systems with large amounts of wind power

Figure 13. DOWNVInD: The first of two RE Power 5-MW wind turbines being lifted towards its foundation; the Beatrice platform is visible in the background.

6.0 The Next Term

The government is carefully considering responses to the Energy Review consultation and will set out its steps in the Energy White Paper to be published in May 2007. The proposed changes to the Renewables Obligation are critical to support expansion of the renewables sector and will require the introduction of a bill to pass the legislation. There will be a continued push to deliver the RO targets for energy production. The government will continue to help facilitate the process in such areas as impacts on aviation, electricity networks, and planning.

For industry, there are likely to be increasing opportunities, particularly with increasing activity offshore. In terms of the present development funnel, 1,034 MW are under construction and a further 3,176 MW of capacity are approved but not yet under construction. The offshore Round 1 is expected to add 1,306 MW of capacity by April 2009, and the offshore Round 2 is expected to start construction in 2007. Round 2 will probably begin with the 300-MW Thanet Offshore Wind Farm, followed by the 500-MW Greater Gabbard Wind Farm.

In terms of R&D focus, as identified in the Technology Programme autumn 2006 call, R&D activities will focus on areas that reduce the cost of offshore wind development and solutions to mitigate radar and aviation issues. Reducing the cost for offshore projects is a key driver to achieve the economics required for future investment. An expected trend for future offshore developments is increasing machine capacities to 5 MW and higher.

7.0 References

(1) Digest of UK Energy Statistics (DUKES), 2006, UK Department of Trade and Industry, http://www.dtistats.net/energystats/dukes06.pdf, Section 1.1.

(2) DUKES, 2006, Section 5.4.

(3) DUKES, 2006, Table 5.2.

(4) The British Transmission & Trading Arrangements (BETTA) is the framework by which the network functions and suppliers and generators trade in Great Britain. Projects in Scotland that applied for connection ahead of the introduction of BETTA benefited from transitional arrangements that resulted in them being within an order by date of application.

(5) The GBSO decision announcement is available on the DTI Web site at http://www.dti.gov.uk/files/file32874.doc.

(6) The open letter is available on the DTI Web site at http://www.dti.gov.uk/files/file35598.pdf.

(7) The consultation document is available on the DTI Web site at http://www/dti/gov/uk/files/file35530.pdf.

(8) The consultation document is available on the DTI web site at http://www.dti.gov.uk/files/file35593.pdf.

(9) The consultation document is available on the DTI website at http://www.dti.gov.uk/files/file35530.pdf.

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United States

29

1.0 Introduction

The U.S. wind industry maintained its global lead for new wind energy installations in 2006 with 2,454 MW of new generating capacity. The new capacity brought the total national capacity to 11,575 MW (Figure 1) and put the United States in third place for highest total installed capacity behind Germany with 20,622 MW and Spain with 11,615 MW. Approximately 53 new projects were installed in 22 states that commissioned more than 1,535 turbines in 2006. The average size of the turbines installed in 2006 was 1.6 MW.

With a 27% growth rate in 2006, wind energy was the second largest source of new power capacity in the country, contributing 19% of the total new capacity built. Natural gas was the largest contributor with 9,000 MW of new capacity, and coal was the third with 600 MW. The current capacity will generate approximately 31 million megawatt-hours per year—enough to provide power for 2.9 million U.S. homes—and displace approximately 23 million tons of carbon dioxide that would have been emitted by traditional resources.

Although wind energy is the fastest-growing energy technology, it still constitutes a very small share of total U.S. generation. According to the U.S. Energy Information Administration, as of October 2006, wind accounted for only 0.7% of total generation. Coal-fired plants generate the majority (48.5%) of the nation's electrical power, followed by natural gas (20.5%) and nuclear plants (19.2%). Other renewables, conventional hydroelectric, and petroleum-fired plants constitute the remaining generation sources.

2.0 National objectives

President George W. Bush launched an Advanced Energy Initiative in 2006 that calls for the accelerated development and use of advanced clean energy technologies. According to the initiative, areas with good wind resources have the potential to supply up to 20% of the electricity consumption of the United States. In support of the initiative, the American Wind Energy Association (AWEA) is working with the U.S. Department of Energy (DOE), the National Renewable Energy Laboratory (NREL), utilities, wildlife advocates, environmental organizations, technology companies, foundations, consumer groups, and investors to evaluate credible scenarios for providing up to 20% of U.S. electric demand with wind power. To provide 20% of the nation's electricity supply, U.S. wind capacity would have to increase from its current 11.6 GW to about 350 GW.

A goal of the DOE Wind Energy Program's Wind Powering America (WPA) project is to have 30 states with more than 100 MW of generating capacity by 2010. There are currently commercial wind-power facilities in 30 states. Twenty states have more than 50 MW, and 16 have more than 100 MW. The 5 states with the most generating capacity are:

Table 1 Key Statistics 2006: United States	
Total installed wind generation	11,575 MW
New wind generation installed	2,454 MW
Total electrical output from wind	31 TWh
Wind generation as % of national electric demand	<1%
Target:	NA

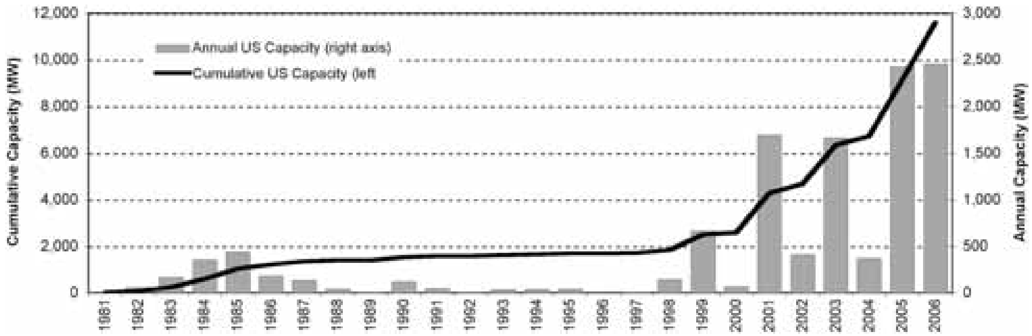

Figure 1 Annual and cumulative U.S. wind energy capacity 1981 – 2006.
Source: Global Energy Concepts database prepared for U.S. DOE and AWEA.

- Texas with 2,739 MW
- California with 2,376 MW
- Iowa with 931 MW
- Minnesota with 895 MW
- Washington with 818 MW

3.0 Benefits to the national economy

The new generating capacity installed in 2006 represents an investment of almost 4 billion USD. The investment provided more than 10,000 new jobs nationwide and 5 to 9 million USD or more in annual payments to landowners.

3.1 Market characteristics

The market trend for consolidation among wind energy developers continued in 2006 with several new major acquisitions, mergers, or joint development transactions. Although private independent power producers (IPPs) continued to dominate the industry, electrical utilities expressed a greater interest in wind asset ownership. Of the total 2006 wind additions, approximately 25% (615 MW) was owned by local electrical utilities, the vast majority of which are investor-owned utilities.

Community projects (projects owned by towns, schools, commercial customers, and farmers) contributed 258 MW to the total national capacity in 2006. This market sector is expected to grow in 2007 as a result of favorable state and federal policies and grants from the U.S. Department of Agriculture (USDA) Section 9006 Grant Program. The program provides grants, loans, and loan guarantees for renewable energy and energy efficiency projects to farmers, ranchers, and rural small businesses. In February, the USDA announced the availability of 11.385 million USD in funding for competitive grants and 176.5 million USD in authority for guaranteed loans in fiscal year 2006.

At the close of 2006, 735 MW of offshore wind energy projects were in the permitting process and about 1,700 MW of offshore projects were proposed in the United States. Of the total potential offshore projects, 1,480 MW are located in federal waters.

3.2 Industrial development and operational experience

In 2006, General Electric (GE), Siemens, and Vestas claimed the majority of the U.S. wind turbine manufacturing market. GE remained the dominant manufacturer, claiming 47% of the market; Siemens claimed 23%, Vestas 19%, Mitsubishi 5%, Suzlon 4%, and Gamesa 2% (Figure 2).

GE Energy sales in the United States continued at a rapid pace in 2006 as a result of the extension of the federal production tax credit at the end of 2005. By the end of 2006, GE had installed more than 5,000 of its successful 1.5-MW wind turbines worldwide, and the company anticipates that the total number of wind turbines operating could reach 10,000 by the end of 2008.

Clipper Windpower of Carpinteria, California, the newest U.S. wind turbine manufacturer, experienced significant growth in 2006 through the sale of its 2.5-MW Liberty wind turbine. The new variable-speed turbine, developed with the support of the DOE Wind Energy Program, incorporates a highly innovative multiple-drive-path gearbox feeding four advanced permanent-magnet generators. Clipper's 2006 transaction announcements represent firm commitments of 875 MW of turbines and more than 5,000 MW of contingent orders for delivery through 2011.

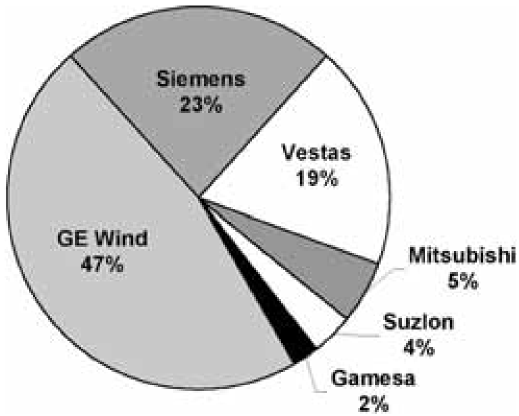

Figure 2 Top five manufacturers contributing to the U.S. market for large-scale wind turbines. Source: Global Energy concepts database prepared for U.S. DOE and AWEA.

The small wind turbine market, which is generally defined by turbines rated at less than 100 kW, also experienced growth in 2006. To date, more than 430,000 small wind units are installed worldwide, representing about 110 MW of installed capacity. Two of the leading U.S. manufacturers of small turbines are Southwest Windpower of Flagstaff, Arizona, and Bergey Windpower of Norman, Oklahoma. Southwest Windpower has sold almost 100,000 small wind turbines. It controls nearly half the world market for small turbines, with 40% of its sales in the United States. The company expected to sell approximately 12,000 units in 2006. Bergey Windpower has produced more than 4,800 1-kW and 10-kW units to date.

3.3 Economic details

According to preliminary data collected by Lawrence Berkeley National Laboratory (LBNL) on behalf of the DOE, capital costs for installed wind projects in 2006 ranged from 1,150 USD/kW to 2,240 USD/kW, with an average cost of roughly 1,480 USD/kW, up from roughly 1,260 USD/kW in 2005 (see Figure 3).

Despite this recent increase, since the start of the industry, capital costs for wind projects have declined dramatically. From the 1980s to the early 2000s, capital costs dropped by approximately 2,700 USD/kW.

Although project costs are influenced by numerous factors, increasing turbine costs are the largest contributor. Turbine prices, in particular, have increased, on average, by over 400 USD/kW since 2001.

The data also show that project size is a factor in capital costs, with installed costs dropping as project size increases. Finally, the data show distinct differences in costs across regions. Higher cost regions include New England, California, and the East, while low-cost regions include Texas and the central United States.

4.0 National incentive programs

Federal tax incentives and state Renewable Portfolio Standards (RPS) and incentives played important roles in the record growth experienced in the United States in 2006. LBNL estimates that 60% of the wind capacity additions in 2006 were motivated in part by state RPS requirements.

4.1 Federal incentive programs

The federal Energy Policy Act (EPAct), enacted in 2005 (1), contains several provisions that benefit the wind energy industry, including the extension of the federal production tax credit (PTC). The PTC provides a 0.019-USD/kWh tax credit for electricity produced by commercial wind generation plants for the first 10 years of production. Project developers and owners are the primary beneficiaries of the credit, which is a production-based incentive, and equipment manufacturers benefit from an active market. In December 2006, the government extended the tax credit through December 31, 2008. In addition to the PTC, EPAct 2005 requires that utility system reliability rules be developed for the nation to be "non-discriminatory" and provides incentives to encourage construction of new and upgraded transmission lines.

Other federal incentives currently offered include:

- Modified Accelerated Cost-Recover Systems (MACRS) – Allows businesses to recover investments in wind energy property through depreciation deductions.
- Renewable Energy and Energy Efficiency Improvements Program – Provides direct loans, loan guarantees, and grants to agricultural producers and rural small businesses to purchase wind energy systems.
- Energy Efficiency and Renewable Energy's Tribal Energy Program – Provides financial and technical assistance to tribes for feasibility studies and installations on tribal lands

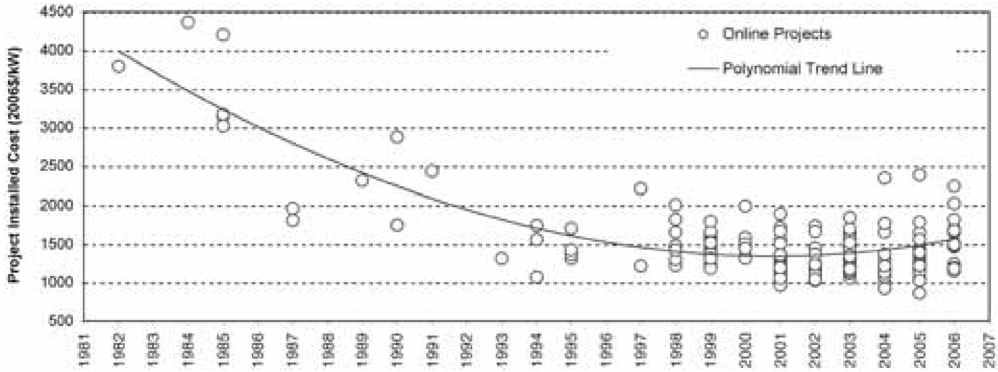

Figure 3 Wind project capital costs, 1982–2006.
Source: Lawrence Berkeley National Loboratory.

- Renewable Energy Production Incentive – Provides annual payments of 0.015 USD/kWh for electricity produced by new wind generation facilities for the first 10 years of operation (renewed under EPAct 2005).

4.2 State incentive programs

The voluntary purchase of renewable or green power through green power or green pricing programs has had a significant effect on wind industry growth. According to a report published by NREL in November 2006 (2), green power purchases totaled 8.5 billion kWh in 2005, representing a capacity equivalent of 2,500 MW of renewable energy, 61% of which was provided by wind energy. For the first time, the majority of the green power sales in 2005 (65%) was made to nonresidential customers. The U.S. Environmental Protection Agency (EPA) offers a Green Power Partnership Program to commercial, industrial, and public sector organizations that tracks green power purchases nationwide. In 2006, the top 25 partners purchased 4.4 billion kilowatt-hours annually. Among the top purchasers are Wells Fargo & Company, 550 MWh or 42% of its total electricity consumption; Whole Foods Market, 463 MWh, 100% of its consumption; U.S. Air Force, 457 MWh, 4% of its consumption; EPA, 330 MWh, 100% of its consumption; and Johnson & Johnson, 306 MWh, 30% of its consumption.

In states with competitive retail electricity markets, electricity customers can often purchase electricity generated from renewable sources by switching to an alternative electricity supplier that offers green power. Through utility green pricing programs, utility customers may choose to purchase green power for a premium to support a greater level of utility company investment in renewable energy technologies. In 2006, more than a dozen states had competitive green power markets, and more than 600 utilities nationwide offered green pricing programs.

As an alternative to switching electricity suppliers, both residential and nonresidential customers may support the development of renewable energy resources by purchasing renewable energy certificates (RECs), which represent the unique or green attributes of electricity generated from renewable energy–based products. Wind energy is the most commonly used resource for RECs. In 2005, total market sales increased by 37%. Much of this growth was supported by REC sales to nonresidential customers, which more than doubled during 2005. As a result, commercial and institutional REC markets now represent nearly half of total green power market sales, surpassing sales in competitive electricity markets and utility green pricing programs.

State policy mandates or Renewable Portfolio Standards (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 2006, 21 states and the District of Columbia had adopted RPS.

Other state programs that provide stimulus for market growth include:

- Grant programs – Grant programs offer support for a broad range of renewable energy technologies; some states focus on promoting one particular type of renewable energy such as wind technology or alternative fuels. Grants are available primarily to the commercial, industrial, utility, education, and government sectors. Some grant programs focus on research and development, while others are designed to help a project achieve commercialization.

- Loan programs – State governments also offer low-interest loans to assist in the purchase of renewable energy equipment. A broad range of renewable energy technologies are eligible. In many states, loans are available to residential, commercial, industrial, transportation, public, and nonprofit sectors.
- Production incentives – Usually funded by a small surcharge on electricity rates, production incentives provide project owners with cash payments based on electricity production on a USD/kWh basis. Production incentives are currently available in 17 states.
- Tax incentives – Supplemental state tax incentives provide an additional, typically modest, stimulus for wind energy development.
- Utility resource planning – As a result of the federal PTC, utilities are starting to include wind energy as a cost-effective resource in their planning efforts. Twelve major utilities in the western United States are planning more than 3,000 MW of wind additions by 2014.

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. Of the incentives offered, the rebates/buy-downs have the highest consumer value. 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. As of January 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

5.1 National R, D&D efforts

The U.S. national R, D&D efforts are guided by the DOE Wind Energy Program. The program is concentrating on improving cost, performance, and reliability of large-scale land-based technology; facilitating wind energy's rapid market expansion by anticipating and addressing potential barriers (for example, integration of wind into the electric transmission system, siting, permitting, environmental issues); and investigating wind energy's application to other areas—from offshore wind technology to distributed and community-owned wind projects.

The program aims to significantly increase wind energy use, thereby increasing and diversifying the domestic energy supply; boosting environmental benefits by avoiding pollutant emissions; and strengthening the nation's infrastructure posture by increasing system reliability while reducing economic effects of fuel price or supply disruptions.

5.1.1 Funding

The total budget for the Wind Energy Program was 39.9 million USD in 2006. The program's budget for FY 2007 was increased to 49.3 million USD.

5.1.2 Large wind turbine research

The performance goal for large wind turbine (LWT) research is to reduce the cost of electricity from large land-based wind systems in Class 4 winds (5.8 m/s at a height of 10 m) to 0.036 USD/kWh by 2012 and to 0.07 USD/kWh for offshore systems in Class 6 (6.7 m/s at a height of 10 m) winds by 2014 (3). Wind turbines are currently capable of producing electricity costing between 0.04 USD/kWh and 0.09 USD/kWh in the Class 4 wind regimes that are broadly available across the United States, depending on many factors, including project financial structure. The strategic goal of the LWT activity is to increase the commercial viability and deployment of wind energy by improving the reliability and performance of existing technology while setting the stage for future wind technologies advanced through applied research and market assessment.

One program project that started to demonstrate commercial viability in 2006 is the new 2.5-MW turbine (Figure 4) manufactured by Clipper Windpower. In 2006, the program completed performance and acoustic tests on Clipper's 2.5-MW prototype installed in Wyoming. This turbine, produced in partnership with DOE, is already proving to be a commercial success.

The program also engaged in several partnerships to improve the performance of system components in 2006. NREL and Northern Power Systems (NPS) completed a very successful partnership to produce a modular, highly efficient power electronics package that can be scaled for use in a wide range of wind turbines, from small to multi-megawatt systems. According to the company, the new converter improves wind turbine reliability, energy capture, and grid performance, and it was chosen by the American Wind Energy Association for its 2006 Technical Achievement Award. Tests completed on both the converter and the NPS 1.5-MW direct-drive generator developed under the WindPACT drivetrain studies (4) demonstrated high-quality power output.

Global Energy Concepts (GEC) fabricated a 1.5-MW single-stage drivetrain with a planetary gearbox and a medium-speed (190-rpm) permanent-magnet generator. The simple gearbox design and moderate-sized generator show potential for reducing tower-head weight and drivetrain costs. The company completed initial testing of this drivetrain at NREL's 2.5-MW dynamometer test facility. The generator is currently being upgraded, and a second phase of testing is planned for 2007.

Genesis Corporation is testing a new tooth form for gearboxes that promises major improvements in power density while reducing the costs of these devices. The company completed the first round of testing with positive results and is now working to refine its design.

Knight & Carver produced the first in a series of wind turbine blades. Called the STAR for its sweep-twist adaptive rotor, the 27.4-m blade is curved to relieve pressure on both the blade and the turbine. Manufactured at Knight & Carver's blade division in San Diego, California, the new blade is designed to passively reduce loads, thereby allowing a larger, more productive rotor. This concept also shows potential for significant cost and manufacturing advantages.

As part of an effort to investigate the potential for offshore development, the program began working on an initiative to evaluate existing offshore technology and its potential for long-term cost reductions. This effort, to be completed in 2009, will focus on developing a mature technical, financial, and regulatory basis for a U.S. offshore wind market.

In another 2006 offshore project, NREL developed and verified a fully coupled simulator for offshore turbines (5). The simulator addresses the limitations of previous frequency and time domain studies and can perform an integrated loads analysis. It is universal enough to analyze a variety of wind turbine, support platform, and mooring system configurations, including floating systems. NREL shares much of its offshore modeling work on an international level through the program's participation in the International Energy Agency Task 23, Offshore Wind Energy Technology and Deployment. The objective of this Task 23 activity is to compare and validate the existing computer models for analyzing and evaluating offshore wind turbines on various types of foundations.

5.1.3 Distributed wind technology research

The program is expected to achieve the performance goal for its distributed (small) wind technology research to produce electricity at between 0.10 USD/kWh and 0.15 USD/kWh in a Class 3 resource (5.32 m/s at 10 m) in 2007. The program is refocusing its efforts on increasing the market for distributed wind systems to meet a growing demand for community-owned projects and local power generation.

To meet the 2007 goal, the Wind Energy Program continued working with several small wind industry partners in 2006 to develop and test new systems and components. Working with Southwest Windpower, researchers at NREL's National Wind Technology Center (NWTC) conducted performance optimization and blade-fatigue tests on the company's new Skystream wind turbine. The 1.8-kW turbine, developed in partnership with DOE, won the Best of What's New Award from Popular Science magazine and was listed as a best invention for 2006 by Time magazine. The new turbine has fully integrated electrical components, costs less, is easier to install, and operates more quietly.

Northern Power Systems is working with the program to reconfigure its 100-kW cold-weather turbine for agricultural and community applications in temperate climates. The company began building the machine in 2006 and will start testing the prototype at the NWTC in 2007. The new machine will

Figure 4 The 2.5-MW Liberty wind turbine developed by Clipper under the DOE Wind Energy Program is proving to be a commercial success.

cost less to produce, and it shows good potential for filling a market gap in mid-size wind turbines.

As part of its small wind components research, the program worked with Windward Engineering to conduct tests on its 3.75-kW Endurance wind turbine developed to demonstrate a furling control system. Windward's machine is currently being tested at the NWTC to International Electrotechnical Commission (IEC) standards for duration, power performance, and acoustics.

Another component project completed in 2006 was the Princeton Power Systems 50-kW AC-AC converter. This new component has higher conversion efficiency and it produces excellent power quality, uses fewer components, and reduces cost.

5.1.4 Systems integration and transmission research

The systems integration activities work to facilitate the adoption of equitable grid access and operational rules for wind in all major regional wind markets and to ensure that wind's needs are considered in regional transmission planning processes. The goal of this activity is to have established by 2012 complete program activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to compete without disadvantage to meet U.S. energy needs.

In 2006, NREL researchers continued to gather the data needed to predict the physical impacts and costs of wind generation on grid operations and to identify transmission constraints. A paper presented by NREL at the European Wind Energy Conference in March 2006 (6) summarized the results of recent studies conducted by a variety of utilities in the United States. The results showed that the additional operating costs of wind energy would be moderate at the large penetration levels expected in the next five to ten years and that large diverse balancing areas with robust transmission tend to reduce wind's impact and ancillary service cost.

Another study published by NREL in 2006 (7) analyzes system and wind-power data recorded by the Western Farmers Electric Cooperative (WFEC) and evaluates the effects of wind energy on utility system operations. This study showed that at a 6% penetration level (based on WFEC peak load; 16% penetration level during low-load periods), the system operations are hardly impacted by wind-power variations. The WFEC continued to meet the control performance standards, and the data show that fluctuations of control-area load and market conditions have much more influence on the system area control error.

The Wind Energy Program is also working with industry to improve transmission access, develop new transmission, and reduce the impacts of wind integration. Two of the studies conducted in 2006 examined the impacts of wind energy at the 20% integration level. The Minnesota Wind Integration Study (8) completed in November examines the impacts of wind variability on power system operation in the Midwest, and a study with Xcel Energy in Colorado (9) assesses the technical and economic impacts of adding a significant amount of wind generation to Xcel's energy portfolio.

In addition, DOE is working with the Western Area Governors Association (WGA) and the Clean and Diversified Energy Advisory Committee (CDEAC) to help achieve the WGA's goal of 30 GW of clean power by 2015. In 2006, the CDEAC Wind Task Force developed a set of supply curves based on extensive wind-map GIS data paired with GIS transmission data. The findings of the study indicate the wind resource in the WGA region is more than enough to economically achieve the WGA 30-GW target for clean energy development. CDEAC also submitted a report (10) to WGA containing a series of recommendations designed to meet the goals of the 30-GW initiative, many of which are directed at improving transmission.

Figure 5 The 1.8-kW Skystream manufactured by Southwest Windpower has fully integrated electrical components.

5.1.5 Technology acceptance research

The goal of the program's technology acceptance research is to identify and remove barriers that inhibit wind energy development. To mitigate the barriers to wind energy growth, the program's Wind Powering America (WPA) project works on a regional level with federal agencies, state and local energy offices, Native American agencies, rural agencies, electrical cooperatives, and utilities, providing information about the technology and the benefits of wind energy (11). The goal of this activity is for 30 states to have 100 MW of wind installed by 2010. By the end of 2006, 16 states had more than 100 MW of installed capacity.

To achieve its goal, WPA supports the formation of state wind working groups, providing stakeholders with timely information on the current state of wind technology, economics, state wind resources, economic development impacts, and policy options/issues. Group members include landowners and agricultural-sector representatives, utilities and regulators, colleges and universities, advocacy groups, and state and local officials. In 2006, WPA launched three new state wind working groups in Alaska, Georgia, and Indiana, bringing the total number of state wind working groups to 29. WPA also supported events in 11 states and convened its fifth annual All-States Summit in Pittsburgh, Pennsylvania, in June. The summit provided participants with an opportunity to share strategies and lessons learned and to visit with experts on topics that included avian and wildlife issues, siting, transmission, community wind, small wind, Native American projects, operating impacts, utility myths, regulators, radar, interconnection, and wind resources and mapping.

In another effort to facilitate deployment, the program worked with the AWEA and the National Wind Coordinating Committee (NWCC) to develop solutions to the radar issues. In 2006, issues related to the interaction between wind power and radar affected more than 1,000 MW of planned installations. These issues gained national attention in 2005 when a few radar operations in the United States were interrupted by wind turbine interference. Interference occurs when radar signals are reflected back by wind turbines, causing clutter on the radar screens. In July, more than one hundred experts, including representatives from AWEA, DOE, the Department of Defense, and the Federal Aviation Administration attended a Wind Power and Radar Issue Forum briefing convened by the NWCC to discuss the influence of wind energy on aviation radar and possible mitigation strategies (12). The collaboration led to the eventual release of 950 MW of the projects put on hold, and the agencies have agreed to continue to work together with radar experts from the United States and the United Kingdom to develop mitigation strategies.

The Wind Energy Program also works to resolve environmental issues that may hinder the deployment of wind energy technologies. In 2006, the program supported two collaborative efforts, the Grassland Shrub Steppe Species Collaborative, a four-year effort to study wind turbines in prairie chicken habitat in Kansas, and the Bat and Wind Energy Collaborative, which investigates the interaction of bats and wind turbines. In addition, the NWCC hosted its sixth Wildlife Research Meeting in Texas in November. The purpose of the meeting was to bring participants up to date on research being conducted to understand the interaction of birds, bats, and other wildlife with wind energy development; examine what has been learned about ways to minimize or mitigate wind energy's impacts on wildlife; and identify gaps in knowledge and research needs.

5.1.6 Collaborative research

In addition to working with industry partners, universities, and special-interest groups, DOE supports the IEA Wind Energy agreement by being an active member of its executive committee and by providing operating agents for several IEA tasks. The United States participates in the following five tasks, is the operating agent for three of the tasks, and provided technical experts for the Topical Expert meetings held under Task 11, Base Technology Information Exchange.

Task 20: HAWT Aerodynamics and Models from Wind Tunnel Measurements – The objective of Task 20 is to increase understanding of the aerodynamics of horizontal-axis wind turbines by using data from a full-scale wind tunnel experiment conducted in 2000. The United States is the operating agent for this task. In 2006, task participants continued research activities previously initiated, and the results were presented and discussed at the Task 20 Annual Progress Meeting hosted by Professor Peter Schaffarczyk at the Kiel University of Applied Sciences April 25–27, 2006.

Task 21: Dynamic Models of Wind Farms for Power Systems Studies – The purpose of Task 21 is to coordinate the development and validation of wind farm models that are suitable for evaluating power system dynamics and transient stability. In 2006, the United States completed the validation of a model for a small wind farm (four 180-kW wind turbines) in Alsvik, Sweden, using data provided by task participants. Results of the validation were submitted to the IEA and will be published with the task reports.

Task 23: Offshore Wind Energy Technology and Deployment – The purpose of Task 23 is to give participants an overview of the technical and environmental assessment challenges encountered in offshore applications and to help them understand the areas of further R&D needed. As one of its operating agents, the United States supports this task by leading a research effort in wind turbine technologies for applications in water deeper than 30 m. In 2005, participants formed a working group named Offshore Code Comparison Collaboration (OC3) to focus on coupled turbine/substructure dynamic modeling. In 2006, U.S. OC3 participants completed the development of dynamics models for an offshore wind turbine with monopile support structure. They made basic model-to-model comparisons of the wind-inflow, wave kinematics, and wind turbine response. They are currently focusing on comparisons of the monopile geotechnical response and are defining a tripod support structure to be used in the next phase of the project. The code comparison work has established a procedure and database that can be used for future code verification activities and analyst training exercises. In addition, the EU-integrated UpWind research program has adopted the NREL offshore 5-MW baseline wind turbine model, which is used in the OC3 project as its reference wind turbine. The model will be used as a reference by all UpWind Work Package teams to quantify the benefits of advanced wind energy technology.

Task 24: Integration of Wind and Hydropower Systems – The primary purposes of Task 24 are to conduct co-operative research in the areas of generation, transmission, and economics of integrating wind and hydropower systems and to provide a forum for information exchange. In addition to being operating agent for this task, the United States is sharing the following three case studies that address each area of research.

- Missouri River Wind Integration Study – The purpose of this project is to assess the impact of integrating wind power with the Missouri River hydropower generation resources on the Western Area Power Administration (WAPA) control-area operations in the Upper Great Plains Region. The main conclusion of the study was that wind has little impact on the various metrics (regulation, load following, ramping) at 100-MW or 200-MW penetration levels. At 500 MW, some of these impacts became noticeably larger, and they were further magnified at the 1,000-MW penetration level. At penetration levels up to about 15% of peak control-area load, wind generation would have quantifiable but still modest impacts on the characteristics of the control-area demand.
- Mid-Columbia River Study: Grant County Public Utility District – The goals of this study, initiated in 2004, are to develop an understanding of the impacts and costs of Grant County's current efforts at integrating wind and hydropower and to assess the potential for future expansion of wind integration. This project progressed significantly in 2006 with the completion of the statistical analysis for the 2004 study year. Results indicated that the impact of wind on system regulation was very small but was more significant for load following and meeting system hydrological constraints. Two important conclusions from the load-following results were that the system already deals with a significant amount of variability and appears to have sufficient physical resources available, but that the ability to handle the modest increase in overall variability must be dealt with in the day-ahead planning operations to ensure that system flow and reliability constraints are met. The need to study the system with hydrological constraints has moved the focus of the study to the 2006 study year, from which sufficient data is available to allow addressing the questions surrounding the impact of wind on meeting system flow constraints.
- Lower Colorado River: Arizona Power Authority (APA) – The purpose of this study, initiated in 2005, is to provide APA an opportunity to investigate the feasibility of integrating wind energy resources with APA's federal allocation of hydroelectric power produced at Hoover Dam. There are two long-term goals: 1) to develop a template to assist with future integration of renewable energy resources into the present or future generation resource pool and 2) to actually develop the resources identified in this study as feasible. There are three major components of this project: developing realistic wind generation scenarios, assessing the impacts of integrating

this wind into APA's operations, and assessing the related hydropower and hydrological impacts and issues. Significant progress was made on the wind-power scenarios and power production profiles with the initiation of a wind modeling project with 3Tier Environmental Forecast Group. The system and hydro impact aspects of the project also progressed via a collaboration with an Arizona utility and work with the U.S. Bureau of Reclamation and WAPA, and the project stands a good chance of completion in 2007.

In addition to the effort put forth on these case study projects, the United States hosted a Web meeting for the task members in June 2006 and organized and attended an R&D meeting in Tasmania, Australia, hosted by Hydro Tasmania.

Task 25: Power System Operation with Large Amounts of Wind Power – The goal of this task is to provide information to facilitate the highest economically feasible wind energy penetration within electricity power systems worldwide. The task supports this goal by analyzing and further developing the methodology to assess the impact of wind power on power systems with an emphasis on technical operation. As its contribution to this effort, the United States is reviewing U.S. studies in progress and recently completed, which include the following:

- A wind integration study by Xcel Energy and the Minnesota Department of Commerce on wind resource in the upper Midwest (13) examined 20% and 25% penetration scenarios and found that large market areas and broad wind geographic variability reduce the cost of integration.
- Xcel Colorado Study has published results for 10% and 15% penetration scenarios (14) and is currently working on a scenario for 20% penetration. Interesting features of these studies include the examination of the use of expanded natural gas storage and cycling of pumped hydro facilities to mitigate incremental system variability due to wind.
- A study on wind variability statistics and grid operational issues due to wind began in 2006 and should be finished in 2007.

The U.S. also hosted the Task 25 meeting in Oklahoma City, Oklahoma, in association with the Utility Wind Interest Group annual meeting in November 2006.

6.0 The Next Term

AWEA, DOE, and NREL have formed a collaborative with 75 participating companies and organizations to evaluate credible scenarios for providing 20% of U.S. electric demand with wind. To support this high-penetration vision, the program will focus on four basic areas:

1. Improve reliability and performance of turbine technology
2. Reduce barriers to wind project development
3. Enhance critical energy infrastructure
4. Advance national and state policies in support of wind.

The program's future R, D&D efforts will pursue three development paths: land-based, distributed, and emerging applications. The land-based development path, which is an important focus of the current Wind Energy Program, is expected to result in cost-competitive, highly reliable 2-MW to 5-MW turbine technology. It will also work toward the high-penetration scenario by increasing its outreach efforts to reduce barriers, investigating the potential for increasing transmissions and making it more accessible, and advancing national and state policies in support of wind.

The distributed wind development path will investigate technology options such as off-grid water pumping for crop irrigation, residential-scale wind turbines, community wind, and hybrid wind/diesel applications, which show great potential for engaging local populations in addressing America's energy future. Community projects and larger distributed wind applications require turbines that range in size from 100 kW to 1 MW; because these are not currently available in the United States, the program will consider future activities to help develop technologies for this market.

The emerging-applications path leads toward the design of wind technology tailored for applications such as offshore installations in deeper water, hydrogen production, the production and delivery of clean water, and integration with other energy technologies (for example, hydropower). The huge offshore wind resource provides a great opportunity for the production of power that is close to load centers and yet out of public sight and with low environmental impacts. This opportunity can be realized if the resouce can be developed at a competitive cost and with acceptable operational risk. Hydrogen production offers an opportunity for wind to provide low-cost, clean energy for the transportation sector.

Finally, as the U.S. population grows, it places greater and greater demand on water supplies, wastewater services, and the electricity needed to power the growing water services infrastructure. Water is also a critical resource for thermoelectric power plants. Water is quickly becoming a critical issue in America's West, providing an opportunity for wind technologies both on and off the grid. Wind offers an energy source that uses limited water when compared to thermoelectric generation, and it can play a role in supplying energy for municipal water supplies and process.

All of these applications present new challenges to the wind community, and cost and infrastructure barriers are expected to be significant. The program's vision is that this evolution pathway will begin to have an impact on the marketplace in the post-2020 time frame.

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Appendix B

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Appendix C

Currency Conversion Rates IEA Wind Annual Report 2006			
Country	Currency	1 €	1 USD
Australia	AUD	1.674	1.268
Austria	Euro	1.000	0.758
Canada	CAD	1.538	1.165
Denmark	DKK	7.454	5.648
Finland	Euro	1.000	0.758
Germany	Euro	1.000	0.758
Greece	Euro	1.000	0.758
Ireland	Euro	1.000	0.758
Italy	Euro	1.000	0.758
Japan	JPY	157.071	119.020
Korea	KRW	1227.321	930.000
Mexico	MXP	14.252	10.800
Netherlands	Euro	1.000	0.758
Norway	NOK	8.220	6.229
Portugal	Euro	1.000	0.758
Spain	Euro	1.000	0.758
Sweden	SEK	9.019	6.834
Switzerland	CHF	1.609	1.219
United Kingdom	GBP	0.674	0.511
United States	USD	1.320	1.000
Source: Federal Reserve Bank of New York (www.x-rates.com) 30 December 2006			

Appendix D

Glossary of terms and abbreviations.

AUD	Australian dollar
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
DKK	Danish Kroner
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
EU	European Union
ExCo	Executive Committee of IEA Wind
FY	fiscal year
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
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
USD	U.S. dollar
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

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