



IEA WIND ENERGY ANNUAL REPORT 2005



Executive Committee for the

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

International Energy Agency

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IEA WIND ENERGY

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Front cover: Wind Park Candeeiros with 3-MW turbines in the Serra de Aire and Candeeiros natural park in the center of Portugal. Photo Courtesy of Prof. Sa da Costa, President of APREN - Portuguese Association of Renewable Energies Developers.

Back cover: A 900-kW Wind Turbine at 930 meters above sea level in Entlebuch, Switzerland. Photo Courtesy of Suisse Eole.

FOREWORD

The twenty-eighth IEA Wind Energy Annual Report reviews the progress during 2005 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 2005, 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 23 contracting parties from 20 Member Countries and the European Commission. This IEA Wind Energy Annual Report for 2005 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, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Korea, Mexico, the Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

Peter GOLDMAN
Chair of the Executive Committee
2004-2005

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

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



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Peter Goldman, Chair of the Executive Committee, 2004 to 2005. (Retired)

This has been a year of multiple and difficult challenges for the world's energy sector. Having reached its technological maturity, wind energy can now contribute in many different aspects and is regarded nowadays just as any other energy source in modern power systems equipped for 21st century needs and constraints.

We are pleased to report that 2005 has been a year of continued growth for the wind industry. The world's wind energy generation capacity is now nearly 60 gigawatts. Electrical output in the IEA Wind Member Countries accounted for 87% of worldwide wind capacity generating nearly 100 TWh of electricity. In eight countries, the contribution of wind generation to the national electrical supply has exceeded 1% and reached as high as 18.5% in Denmark. Eleven of our member countries experienced growth rates above 35% with the Portugal and Korea exceeding 100%.

Along with this good news of significant generation capacity and expect continued growth of the industry, we face a new set of challenges. Members of the IEA Wind agreement are addressing these challenges through international cooperative research. For example, our research in dynamic models of wind farms for power system studies (Task XXI) has been working on some of



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

the challenges of electrical system operation and will issue a report in 2006. The issues of installing wind turbines offshore are being identified and research is being designed to allow greatly increased capacity (Task XXIII). To address the need for storage and regulation of time-variable production, participants in Task XXIV are exploring issues around the correlation between wind and hydropower systems. Our experts meetings (Task XI) have shown that in many of the countries with high expectations from wind energy, large-scale integration into the electricity distribution system is a potential constraint. The design and operation of power systems with large amounts of wind power is being addressed in Task XXV, begun in 2005. And while implementation issues are being addressed, the cooperative R&D on turbine and component design continues in Tasks XIX, XX, and XXI.

Continuing our efforts in 2006, we will look at opportunities to address several issues raised in our experts meetings, including developing methodologies for assessing the costs and benefits of wind generation.



MESSAGE FROM THE CHAIR

EXECUTIVE SUMMARY

1.0 INTRODUCTION

At the close of 2005, 87% of the 59.2 GW (1) of worldwide wind generating capacity was located in the member countries of the IEA Wind Implementing Agreement. The 20 IEA Wind Member Countries reported about 51.4 GW of total installed wind generation capacity, which represented a greater than 20% increase in total capacity over 2004 (Table 1). Located in Europe, North America, Asia, and the Pacific Region (1), the member countries view wind energy as an important energy source for this reporting year (2005) and are planning activities and setting targets (stretching out to 2015 in some cases) to increase the contribution of wind energy to their electrical generation mix.

In this 2005 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 to

increase its contribution to the world energy supply. This Executive Summary synthesizes the information presented for 2005 by the IEA Wind Member Countries (Chapters 10 through 29) and in the reports of the Research Tasks (Chapters 2 through 8). As background for 2005, data from the last 10 years as reported in documents of IEA Wind are also included.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

2.1 WIND GENERATION CAPACITY

Since 1995, total electrical generation capacity from wind in the IEA Wind Member Countries has increased from about 4 GW to more than 51 GW in 2005 (Figure 1). In 2005, the member countries added 8,927 MW of new wind generating capacity; 14 of these countries added more than 100 MW of new capacity and 3 added more than a gigawatt each of new capacity: the United States (2,431), Germany (1,808), and Spain (1,630). Total generating capacities of each

Table 1 Key statistics of IEA Wind Member Countries 2005*

Total installed wind generation (onshore and offshore)	51,364 MW
Total offshore wind generation	686 MW
Total new wind generation installed	8,927 MW
Total electrical output from wind	98.74 TWh
Wind generation as % of national electric demand	1.2%
* includes estimates (see Table 2 for country specifics)	

country varied greatly from Germany with 18,428 MW to Mexico with 2.2 MW (Table 2).

While overall installed capacity increased by more than 20% in the IEA Wind Member Countries, growth in some countries was well above that: Australia 86%, Canada 54%, Greece 25%, Ireland 58%, Italy 35%, Korea 233%, Norway 69%, Portugal 100%, Switzerland 34%, the United Kingdom 48%, and the United States 36%. Also many countries report significant amounts of capacity in the “planning stages” ranging from waiting final connection to the grid to successful acquisition of land leases. Installations offshore are increasing at about the same rate as overall installations. More than 686 MW of capacity in the IEA Wind Member Countries was located offshore compared with about 578 MW in 2004 for a 19% increase.

2.2 CONTRIBUTION TO ELECTRICAL DEMAND

Since 1995, total electrical generation from wind energy in the IEA Member Countries has increased from less than 10 TWh to nearly 100

TWh in 2005 (Figure 1). For the member countries, the contribution of electrical generation from wind energy to the national electricity demand has increased from under 0.2% overall in 1995 to about 1.2% in 2005 (Figure 2). Within the member countries, contribution to national electrical demand varied from the barely detectable in several countries to 18.5% in Denmark. Eight countries (Australia, Denmark, Germany, Greece, Ireland, the Netherlands, Portugal, and Spain) exceeded the 1% mark for contribution of wind energy to national electricity demand. However, the contribution (penetration) of wind energy varies greatly within countries as well. For example, in Finland the Åland islands received 7% of electricity consumption from wind, while the national average for Finland was 0.2%.

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. For example, Denmark concluded that the nearly stable output in 2005 over 2004 was due to a change in the wind index for the two years. Finland also reported production along with the

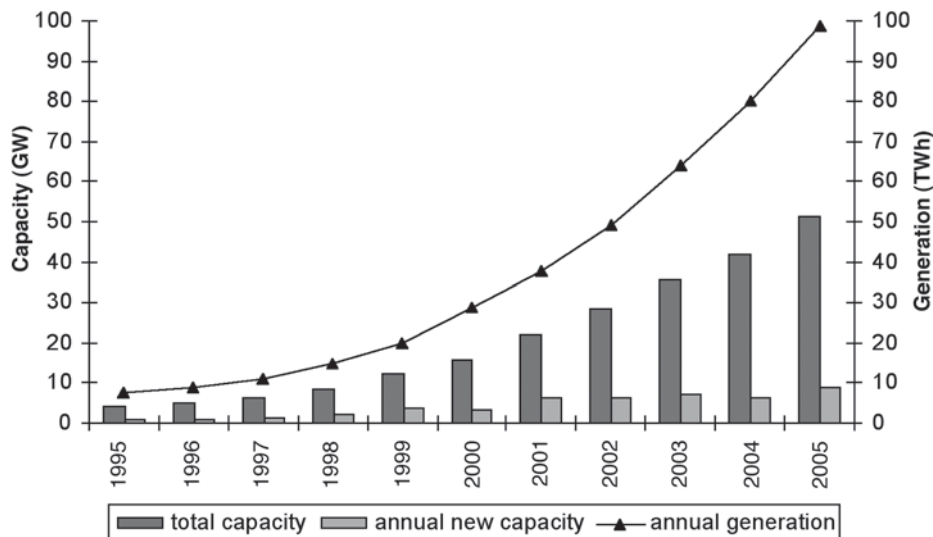


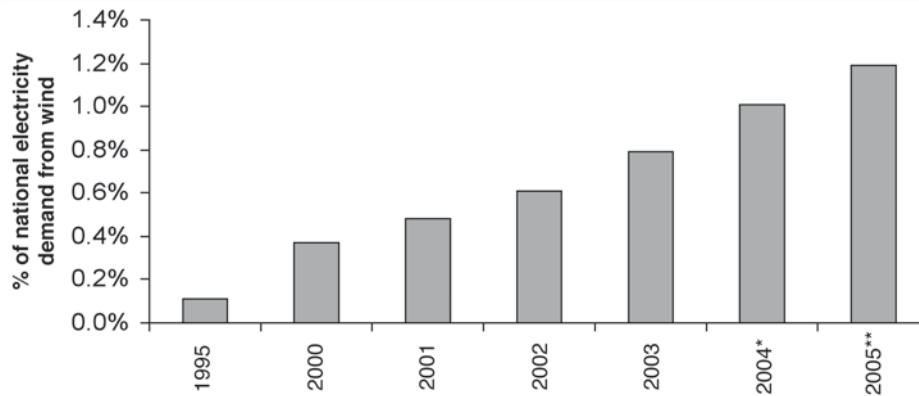
Figure 1 Annual installed capacity, cumulative installed capacity, and annual generation from wind in the IEA Wind Member Countries.

Table 2 National statistics of the IEA Wind Member Countries for 2005
 Values in [] are estimates. Values in bold italic are for 2004. NDA means no data available.

Country	Total installed wind capacity (MW)	Offshore installed wind capacity (MW)	Annual new wind capacity (MW)	Total No. of Turbines (turbines)	Average new turbine capacity (kW)	Wind generated electricity (GWh)	National electricity demand (TWh)	% of national electricity demand from wind*
Australia	708.00	0.0	328.00	447	1,750	2,171.0	190.00	1.143
Austria (I)	819.00	0.0	212.00	NDA	NDA	NDA	NDA	NDA
Canada	683.00	0.0	239.00	681	1,700	[1,800.0]	538.00	[0.34]
Denmark	3,128.00	423.0	4.00	5,293	1,200	6,614.0	35.72	18.50
Finland	82.00	0.0	0.00	94	1,030	170.0	84.90	0.20
Germany	18,428.00	0.0	1,808.00	17,592	1,723	[26,500.0]	611.00	[4.34]
Greece	605.40	0.0	121.10	926	1,188	1,270.0	51.00	2.49
Ireland	492.7	25.2	204.60	321	1,000	655.0	26.01	2.52
Italy	1,717.00	0.0	452.00	2,258	1,196	2,140.0	329.00	0.65
Japan	1,077.70	1.2	150.80	1,048	1,300	1,438.7	865.40	0.17
Korea	100.00	0.0	70.00	41	1,700	[146]	[359.31]	[0.04]
Mexico	2.20	0.0	0.00	8	0	4.2	183.90	0.002
Netherlands	1,213.00	0.0	140.00	1,733	1,358	[2,000.0]	118.00	[1.695]
Norway	270.00	0.0	110.00	129	2,300	504.0	126.00	0.40
Portugal	1,060.00	0.0	529.00	743	2,100	1,773.0	47.97	3.70
Spain	10,028.00	0.0	1,630.00	NDA	1,320	20,236.0	259.95	7.79
Sweden	452	23.0	48.00	759	1,000	864	146	0.59
Switzerland	11.59	0.0	2.92	34	584	[8.4]	[61.30]	[0.014]
United Kingdom	1,337.16	213.8	446.80	1,445	1,730	[2,394.0]	[421.90]	[0.48]
United States	9,149.00	0.0	2,431.00	7,200	1,500	[28,051.0]	3,838.60	[0.73]
Totals	51,363.75	686.2	8,927.22	40,752	1,352	98,739.3	8,293.96	1.19%

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

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* National demand data from Australia and Austria are not included in calculation

** Annual generation from wind and national demand data from Ireland are values from 2004.

Figure 2 Wind generation's contribution to total electrical demand in IEA Wind Member Countries, 1995 and 2000 through 2005.

wind energy index since 1992. Sweden reported the wind index for 2005 was about 94% of a normal year.

2.3 NATIONAL TARGETS

Establishing national objectives or targets is a key tool used in all IEA Wind Member Countries to define goals, develop policies to facilitate reaching the goals, measure progress toward the goals, and revise policies and goals as needed along the way. The way of expressing national objectives varies considerably as follows.

- Wind generating capacity (MW) targets to reach by a certain year have been established by Finland, Greece, Italy, Japan, Korea, Mexico, Portugal, and Spain. The year to achieve the targets varies from 2005 to 2012.
- Target percentages of generation, consumption, or purchases by utilities (%) from renewables have been set by Germany, the Netherlands, and the United Kingdom for the year 2010. The contribution from wind energy to this goal is estimated based on local conditions.

- Electrical production from wind energy (TWh/yr) targets have been set by Norway, Sweden, and Switzerland, ranging from 2010 to 2015.

- Some countries have chosen approaches other than setting specific national governmental targets for wind energy or renewables. However, discussion of targets did inform policy in these countries in 2005. For example, Australia's nationwide Mandatory Renewable Energy Target (MRET) requires large energy users and energy wholesalers to purchase 2% of their energy from renewable sources by 2010. Other countries such as the United States had such policies (purchase mandates or portfolio standards) at the regional or state level. Canada had a target of 4,000 MW to be installed by 2010 under its federal Wind Power Production Incentive program; Denmark had general strategies to reduce CO₂ emissions, and increase energy security; and the United States had a goal of having more than 30 of its states with more than 100 MW of generating capacity by 2010. Japan also had a Renewables

Portfolio Standard that encouraged utilities to buy electricity from wind and other renewable generators.

- Specific goals or aspirations for offshore deployment were present in Denmark, Germany, and the Netherlands.

Countries are linking wind energy electrical production to reduction of hydrocarbon consumption. For example, Australia estimates that electrical production from wind energy is the equivalent of taking 651,720 cars off the road. Germany estimates wind generation reduced CO₂ emissions by 24.8 million tonnes. The Netherlands estimates that wind generation in 2005 saved 16.85 PJ of primary energy. Spain estimates that wind generation in 2005 saved the economy about 15 million tons of CO₂, a savings of about 300 million €. The United States reports that the 9,149 MW of wind capacity operating at the end of 2005 will reduce natural gas use for power generation by approximately 5% during 2006.

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 is underway to address some of these issues. (See also section 5.0 RD&D activities)

2.4.1 GRID CAPACITY, INTEGRATION, AND TRANSMISSION

Several countries mentioned the lack of grid capacity in good wind locations as a constraint on growth (Greece, Japan, and Spain). Upgrades and expansions of the transmission and distribution grids are being planned or completed in some countries (Greece, Portugal, and the United Kingdom), and issues arise about how these will be financed.

In addition to the lack of capacity, questions about the effects of wind projects on the distribution grid have been raised and the uncertainty surrounding this issue has slowed wind development in some countries. To address this uncertainty, work to raise the level of wind farm modeling has been underway in the IEA Wind research task XXI Dynamic Models of Wind Farms for Power Systems Studies. Participants 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 2006, will provide an overview of the available wind farm models and present a systematic approach for model benchmark testing. Denmark, Finland, Ireland, Netherlands, Norway (operating agent), Portugal, Sweden, the United Kingdom, and the United States participated in this task.

Integrating wind energy into weak grids is a concern for transmission system operators (TSOs). For example in Japan, the ratio of allowable wind capacity to grid capacity ranges from 3.5 to 5%. TSOs are concerned about impacts of wind power on reliability. Responding to the need to explore this issue, the IEA Wind research task XI Base Technology Information Exchange held a Topical Experts Meeting in 2004, and 28 participants from 11 countries agreed that a new research task could make progress in this area. In 2005, Task XXV Design and Operation of Power Systems with Large Amounts of Wind Power was begun with Finland (operating agent), Denmark, Germany, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States participating.

Special issues for transmitting electricity from offshore wind farms are being explored in Task XXIII Offshore Wind Technology Development. Constraints for offshore approval of cable connections, financing, and technical challenges of high sea and deep water conditions are being addressed. This is of particular concern to the United Kingdom, which has conducted analyses about distribution of transmission charges and

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regulation of offshore transmission. Denmark (operating agent), Germany, Korea, the Netherlands, Norway, the United Kingdom, and the United States (operating agent) participate in this task.

For countries with hydropower production, the possibility of integrating wind energy and taking advantage of storage capacity has been raised. The IEA Wind task XXIV Integration of Wind and Hydropower systems continued research and conducted a forum for information exchange about the potential benefits of combining wind and hydropower to provide a stable supply of electricity to the grid. Australia, Canada, Finland, Norway, Sweden, Switzerland, and the United States (operating agent) participate in this task.

2.4.2 AVAILABLE LAND, COMPLEX TERRAIN, AND LOCAL ENVIRONMENT

Many countries report a shrinking supply of good wind sites near load centers, and this is one reason many cite for interest in offshore development. Another approach to limited onshore sites is repowering, removing smaller turbines and replacing them with larger machines on taller towers. This has the effect of increasing production on land without developing new projects. In the Netherlands, 66 turbines were decommissioned in 2005. Of the decommissioned turbines, 20 with a total capacity of 4.1 MW were replaced with 17 turbines with a total capacity of 19 MW for a net “repowering” effect of adding 15 megawatts. In Denmark, 129 turbines were removed and the 18 new turbines installed still resulted in a 4 MW gain in capacity. Although total capacity increased, the number of wind turbines decreased, illustrating the success of the re-powering scheme. Repowering is being encouraged in Denmark with a premium price paid to factory-new onshore wind turbines provided that the owner has a re-powering certificate from a decommissioned turbine of 450 kW or less. Repowering has its own set of issues such as new permitting, and Germany reports a slow beginning to the process during 2005 with 18 (9 MW in total) turbines removed and replaced by 6 (12 MW in total) new turbines.

Repowering is providing a market in used machines. For example, Finland reports that used turbines from the first demonstration projects in Finland and from the Netherlands has encouraged some farmers to acquire a second-hand turbine.

Complex terrain and special local conditions pose challenges for wind turbine design and installation of wind projects in some countries. For example, Japan is developing standards for a J-class turbine that can withstand typhoon force winds and high-energy lightning strikes that have damaged turbines there.

For countries in northern climates, cold weather causes icing, which can reduce energy production. These countries have joined together in IEA Wind research task XIX Wind Energy in Cold Climates to assemble information and develop recommended practices for project developers. In 2005, the final report for the first period, which includes guidelines regarding cold climate issues of wind energy (2), was approved by the IEA Wind ExCo. In the next 3-year period, the work will address anti-icing techniques and the effects of icing loads on wind turbine components. Canada, Finland (operating agent), Germany, Italy, Norway, Switzerland, and the United States participate in this research task.

2.4.3 PLANNING APPROVAL AND ENVIRONMENTAL CONCERNS

The planning and approval process is lengthy in most countries and efforts are reported to ease this burden on developers. Spain attributed the lower growth rate of wind energy in 2005 to administrative delays including permit procedures, availability of grid connection points, and new definitions of the strategic plans of the local authorities.

Public information efforts and legislation to streamline the planning and approval process have been reported in several countries. For example, the UK commissioned a study in 2005 which recommended making community benefits

transparent by following a strict interpretation of EU procurement rules. Procedures would involve planning best practice guidelines to legitimize community benefits within planning process; providing guidance on community engagement; reviewing the potential for taxes to accrue locally; researching the impact of new planning policy framework; and establishing bankable models for community ownership.

The effect of local opposition should not be underestimated. In Finland, effective growth in capacity was zero in 2005 because two 2-MW turbines installed in a 6-MW wind farm were removed and returned to the manufacturer due to local opposition.

2.4.4 RADAR AND RADIO INTERFERENCE

Wind turbines have the potential to interfere with radar and navigational systems. In the United Kingdom and other countries, this issue has been raised in opposition to wind project siting. In response, the IEA Wind research task XI Base Technology Information Exchange sponsored a Topical Experts Meeting in 2005 on the topic and invited experts from government agencies, R&D establishments, private companies, and developers. Representatives from the Netherlands, Norway, Sweden, the United Kingdom, and the United States attended the meeting. The presentations concluded that mitigating technologies and computer software solutions such as radar filters and intelligent processing of multiple sensor data are available. The challenge is to find solutions to the radar problem that are acceptable to aviation regulators.

3.0 BENEFITS TO NATIONAL ECONOMY

IEA Wind Member Countries recognize the environmental benefits of meeting a portion of national electrical demand with a generating source that is not carbon based. This is illustrated above by the countries that link their wind energy tar-

gets to reducing emissions and offsetting primary energy consumption. Additional benefits to the national economies by wind energy development are reported in many different ways, from rural development to increasing export income.

3.1 MARKET CHARACTERISTICS

3.1.1 WIND SECTOR TURNOVER

One indicator of economic benefit from wind energy development is the value of all economic activity related to such development. This is often referred to as economic turnover or total turnover. It includes payments to labor, cost of materials for manufacture and installation, transportation, sales

Table 3 Wind Sector Turnover and Total Wind Capacity reported for 2005 by IEA Wind Member Countries

	Turnover million €	Total capacity (MW)
Australia	100.0	708
Denmark	4,400.0	3,128
Finland	250.0	82
Germany	7,300.0	18,428
Italy	450.0	1,717
Netherlands	168.0	1,213
Portugal	154.0	1,043
Spain	20,000.0	10,028
Switzerland	4.0	11
United Kingdom	500.0	1,380
Total	33,326	37,738

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for export, and value of electricity generated. For 2005, 10 countries representing nearly 38 GW of wind generating capacity reported more than 33 billion € of economic turnover (Table 3).

Employment and export income figured prominently when countries reported economic benefits from wind energy development. At the close of 2005 almost 1,000 Australians were employed by the wind energy industry. With climate change increasingly affecting Australia's rural and regional areas, hosting wind turbines is a desirable rural enterprise for many landholders looking for a drought-proof source of income. Denmark estimates about 25,000 people are employed in activities of wind energy including the manufacture of turbines for an estimated 4.4 billion €. Of the estimated 7 billion € of turnover in Germany, one third was plant operation and two thirds was attributed to the manufacturing and supply industry. About 64,000 people were employed in the wind sector in Germany. In Italy, the total turnover of about 450 million € included about 3,000 people employed.

Mexico has recognized the economic benefits possible from developing wind energy. The United Nations Development Programme and Mexico's Electrical Research Institute (IIE) achieved sponsorship in 2003 from the Global Environmental Facility to move toward full-scale implementation of wind power in Mexico. The first phase of this project, in 2005, promoted wind energy at the national and regional level, developed necessary human resources, and supported studies.

Statistics from 2004 showed that in the United Kingdom around 4,000 jobs were sustained by companies working in the wind sector and this was projected to increase as the industry grows. Around 1,500 of these jobs are in Scotland, with the balance located in the rest of the UK. The Department of Trade and Industry has estimated that Round 2 of offshore wind developments alone could bring a further 20,000 jobs for Britain.

In the United States, the American Wind Energy Association (AWEA) reports that the capacity added in 2005 provided clean power to the equivalent of 700,000 homes, an investment of approximately 2.5 billion € in power generating equipment, an estimated 10,000 new job-years nationwide (10,000 one-year jobs or 1,000 long-term, 10-year jobs), and 4.2 million € in annual payments to landowners. According to the U.S. Renewable Energy Policy Project, approximately 90 companies in 25 states were manufacturing wind turbine components in 2005.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

3.2.1 TURBINES

The IEA Wind Member Countries contain turbine manufacturers that serve global as well as national markets. Countries reporting a national manufacturer of 1-MW or larger turbines include Denmark, Finland, Germany, Italy, Japan, the Netherlands, Spain, and the United States. Three German manufacturers developed turbines in the 4.5 to 6-MW class and more than 10 prototypes have been erected at coastal or near-shore locations. The 3-MW prototype wind turbine Näsudden II on Gotland, Sweden, set a new world record for accumulated electricity generation by a single wind turbine. By 9 January 2006, it had generated 57.2 GWh of electricity from startup. Several countries not yet in the manufacturing business, are developing prototypes and testing machines for local manufacture and export (Korea and Norway). However, wind turbine manufacture is becoming less a national and more a multinational enterprise, through acquisitions and the establishment of subsidiaries in countries with substantial markets.

Several countries that do not have local turbine manufacturing capabilities report the manufacture of supporting components (Australia, Canada, Greece, Portugal, Switzerland, and the United

Kingdom). These include blades, control systems, electricity inverters, generators, nacelle assembly, or towers.

To encourage new wind developments to use local manufacturing, several countries use special incentive programs. For example in Canada, the winning bid by GE Energy for a 1,000-MW project in Quebec, Canada, stipulated that 60% of the components or services will be supplied or assembled in the local region.

The average rated capacity of new turbines installed in 2005 continued the trend toward larger machines. The average rating in 2005 rose to nearly 1.6 MW (Figure 3).

In addition to MW-scale wind turbines, smaller turbines also represent a growing industry. Medium-sized turbines 660 to 850 kW are being manufactured in several countries for single turbine installations or small wind power plants (Italy and the United States). Small-sized turbines less than 100 kW are also being manufactured in Italy, Japan, Mexico, Spain, Sweden, the United Kingdom, and the United States. The market for these is expected to grow in Italy since the

threshold energy amount for obtaining a green certificate has been lowered to 50 MWh. In the United States, a first Small Wind Industry Market Study published by AWEA found that nearly 43,000 small wind turbines with a total of approximately 30 MW were operating in 2005. Almost 4,700 turbines totaling 5 MW were sold in the United States in 2004, and AWEA expected that to increase to 8,300 turbines in 2005. According to the study, four U.S. companies supply about one third of the global demand for small turbines.

Nearly every member country reports trade associations and organizations promoting wind energy. For example the Japanese Wind Power Association had more than 100 member companies in 2005. Suisse Eole, the Swiss Wind Energy Association, coordinates promotion of wind energy with the cantonal institutes of energy, energy suppliers, and energy planners.

3.2.2 OWNERSHIP PATTERNS

Major utilities are active in development of wind energy in several countries. For example, IBERDROLA, the second largest power utility in Spain, is very active in the promotion of new

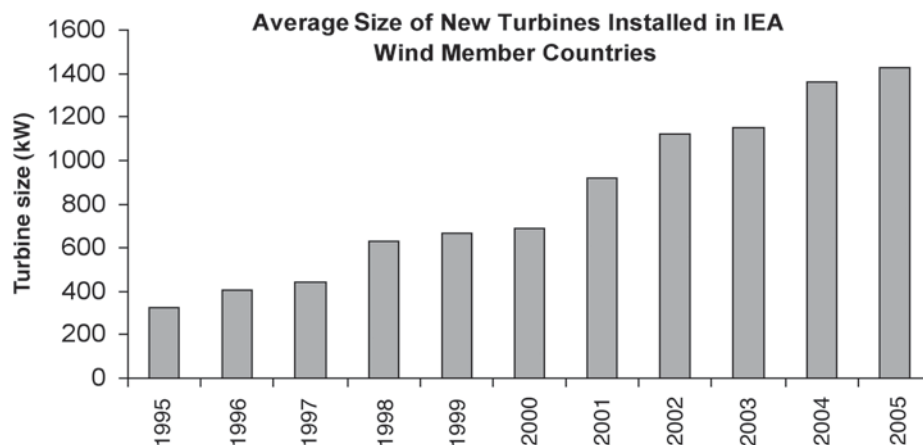


Figure 3 Average size of new turbines installed in the IEA Wind Member Countries for 1995 through 2005.

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installations in several countries including Brazil, France, Greece, Italy, Mexico, Portugal, and the United Kingdom. The company operates a renewable energy operations centre (CORE) with the specific objective of improving the integration of renewable energy systems in the grid.

In Sweden, a little more than 50% of installed capacity is owned by public wind energy companies and Wind Energy Associations, 20% by utilities, 18% by individuals, and the rest by non-energy related companies. There is a trend however, for utilities to purchase projects from the developers. Vattenfall, a large Swedish utility, acquired about 460 MW of wind power in Denmark, England, and Poland during 2005, including four offshore wind farms (Horns Rev (60%), Kentish Flats, Utgrunden 1 and Yttre Stengrund).

3.2.3 OFFSHORE INSTALLATIONS

By the close of 2005, more than 686 MW of capacity was located offshore in five IEA Wind Member Countries: Denmark, Ireland, Japan, Sweden, and the United Kingdom. Although no offshore projects were operating in Germany, the German industry initiated an Offshore Wind Energy Foundation to promote offshore development and support technological and deployment projects.

3.2.4 OPERATIONAL EXPERIENCE

Average availability is high in all countries, ranging between 94 to 100% with most reporting 98% or higher. The reports indicate that larger wind turbines and offshore turbines have generally higher capacity factors. For the United Kingdom, the average capacity factor for onshore wind has been estimated as 26.6% during 2005. The first large offshore wind farm, the 60-MW North Hoyle Offshore Wind Farm that began operation in 2003, had from July 2004 to June 2005 an overall availability of 84% and an overall capacity factor of 36%. The following countries reported average capacity factor estimates: Australia 35%; Finland 25%; Italy 17%, and Mexico 31%.

3.3 ECONOMIC DETAILS

3.3.1 TURBINE COSTS

The IEA Wind Member Countries reported a range of average turbine costs from a low of 630 €/kW (Spain) to a high of 1,170 €/kW (Greece) for 2005. A study carried out by the Spanish Wind Business Association (AEE) about the history of wind farms in Spain (with 10,028 MW of total wind capacity in 2005) shows an average cost of wind turbines of around 630 €/kW with a minimum value of 544 €/kW and maximum of 818 €/kW. In Portugal, the unit cost of wind turbines remained constant in 2005 at about 750-850 €/kW.

3.3.2 PROJECT COSTS

Reported average total project costs ranged from a low of 970 €/kW (Spain onshore) to a high of 2,075 €/kW (UK offshore). Several countries report the cost of wind projects rising in the last few years although others report no increase in costs. The Spanish report attributes the rising costs to, among other factors, the increasing size of wind turbines. In Portugal, the cost of installations depended on the country of origin of the turbines, the turbine's rated capacity, and the ratio of this capacity to the turbine diameter. The Canadian report attributes rising costs to demand outstripping supply in North America because of the very large demand in the U.S. market. Other factors influencing the increase in cost of installed wind farms are increases in:

- Commodity prices such as fuel and steel
- Costs for interconnection with increasing requirements from most jurisdictions
- Engineering costs
- Installation costs due to skilled trade shortfall
- Environmental assessment costs due to increased presence of wind farms but low understanding of impacts.

Some member countries have reported how costs of wind projects are distributed. For example, Italy estimates the cost of electrical and civil work is

about 30% of total investment for turbines under 1 MW and about 20% of total investment for turbines larger than 1 MW. In Spain, the wind turbine represents approximately 74% of the total investment cost, the electro-mechanical equipment including the transmission line 17%, the civil work 5%, and the rest of components such as environmental impact study, promotion, engineering, and taxes 4%. In the United Kingdom, costs of installing wind energy in 2005 were from 894 to 1,161 €/kW onshore rising to 1,407 to 2,075 €/kW offshore. The additional costs of offshore installation include around 145 €/kW for the electrical connection to shore and 218 €/kW for inter-turbine cabling.

3.3.3 O&M COSTS

Operation and maintenance costs (O&M) including service, consumables, repair, insurance, administration, lease of site, etc. for new large turbines are rarely reported. Of the reporting countries, estimates of O&M costs ranged from 7 €/MWh (Spain and Sweden) to about 10 €/MWh (Italy). Of the countries reporting, O&M costs decreased or remained the same in 2005.

3.3.4 COST OF ENERGY

As noted in Section 5.0 RD&D, calculating the cost of energy (COE) from wind turbines is approached in different ways, which makes comparisons difficult. In addition to the lack of standard methodology, the information needed for calculating COE is difficult, if not impossible to obtain. Yet another set of variables determines the price of competing generation and the price paid for electricity by the end user. There are many ways to figure “cost” depending on who is paying. However in several IEA Wind Member Countries, the cost of wind energy is considered close to some other competing sources. Please refer to the country chapters for specifics.

Related to COE, some countries report the “income” to wind projects. Some of the rates per kilowatt hour take account of price support incentive programs. These can include environmental

bonuses, green certificates, and other innovative schemes. In other countries, incentives operate apart from the price per kilowatt hour to increase the effective income to wind projects. (See country reports for details.) For the reporting countries, the price paid to wind project operators ranged from 0.025 €/kWh to 0.16 €/kWh.

IEA Wind Member Countries within the European Union refer to EU directive 2001/77, which has helped set targets for 2010. Individual countries have developed their own rules and systems to reach the targets. Their feed-in tariffs or quota/green certificate programs affect the income to wind projects and the cost of electricity in Europe.

4.0 NATIONAL INCENTIVE PROGRAMS

As can be seen in Table 4, the four most popular incentives are: direct capital investment as subsidies or grants for projects; providing a premium price for electricity generated by wind (tariffs or production subsidies); obliging utilities to purchase renewable energy; and providing a free market for green electricity.

4.1 CAPITAL INVESTMENT

Countries often provide direct grants for portions of wind project developments to get new projects started. For example, in Finland an investment subsidy of up to 40% is available depending on the novelty of the project. In Greece, the OPC public aid accounts for 30% of the eligible cost of projects and goes up to 50% in the case of transmission lines to connect renewable energy generation with the grid. In the United Kingdom, the Offshore Wind Capital Grants Programme launched by the Department of Trade and Industry and the Big Lottery Fund in early 2002 stimulated the early development of Round 1 offshore wind schemes. The £117 Million Scheme (179 million €) provides the additional financial support required to get early projects started and should allow developers to gain experience and confidence to help reduce generation costs for subsequent future projects.

Table 4 Incentive programs offered in IEA Wind Member Countries for 2005. NDA indicates no data available

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

Note: see country chapters for more detail

4.2 PRICE SUPPORT

Price incentives (feed-in tariffs) are paid to operators according to the amount of electrical generation of the wind project, thus rewarding productivity. In Spain, the price paid for the electricity generated by the wind farms is guaranteed during the life of the installation and is related to the Average Electricity Tariff. In Portugal, the wind tariffs have greatly accelerated wind development (100% increase in capacity for 2005). Changes at the end of the year included a reduction of the tariff and removal of the provision to increase the tariff with inflation.

Tariffs can also be used to promote specific national goals. For example, in Sweden, offshore wind power installations received a higher environmental bonus in their tariff than for onshore wind.

Related to price support, the U.S. Federal production tax credit (PTC) provides a tax credit per kilowatt hour for the first 10 years of production. This incentive is collected at the end of the tax year and is applied to reduce tax liability. Originally enacted in 1992, the PTC has expired three times in the past six years. Increased activity in 2005 is attributed to extension of this incentive. The PTC is up for renewal at the end of 2007.

4.3 GREEN ELECTRICITY MARKET

Green electricity has become a tradable commodity apart from mere electricity. To prove “greenness,” certifying organizations have sprung up in several countries. Wind energy is one of several renewable energy sources that can be certified as green. Once certified, blocks of green energy can be purchased for several purposes, including meeting the utility purchase obligations described in section 4.3 above. Detailed trading rules have evolved in Australia, Finland, the Netherlands, Sweden, the United Kingdom, and the United States to prevent abuses and keep the incentive directed at the goal of increasing the use of renewable energy sources.

Green certificate programs have had an impact in several countries. In Italy, the green certificate program in operation for four years is proving to be attractive to investors. In the United States, utility “green pricing” programs encourage utility customers to purchase green power at a premium price to support utility company investment in renewable energy technologies. Since 1999, nearly 600 utilities in 34 states have either implemented or announced plans to offer a green pricing option, and 330,000 customers were participating in utility green pricing programs nationwide. U.S. consumers may also purchase power generated by renewable resources through competitive markets and Renewable Energy Certificates (RECs). Wind energy is the most commonly used resource for RECs. Residential and nonresidential consumers can purchase RECs from more than two dozen suppliers nationwide via the Internet. By the end of 2004, approximately 200,000 consumers had purchased green power or RECs from competitive suppliers.

4.4 UTILITY PURCHASE OBLIGATIONS

Often referred to as renewable portfolio standards (RPS) or mandatory renewable purchase targets (MRET), this type of incentive requires utilities to purchase a certain percentage of their overall generating capacity from renewable resources. Often a target year is specified or the required percentage increases over time.

Utility purchase obligations for renewables are very effective at encouraging wind energy development because it is usually the most cost effective option for utilities to meet the obligation. The Australian wind energy capacity has grown almost ten-fold under the Federal government’s Mandatory Renewable Energy Target (MRET), which requires large energy users and energy wholesalers to purchase 2% of their energy from renewable sources by 2010. Capacity increased from 74 MW in 2001, when the scheme was introduced to 708 MW in 2005. Due to the success of the MRET scheme, Australia’s renewable en-

ergy target has been filled almost twice as quickly as expected. In response to the MRET's success, and recognizing the potential for the further deployment of wind energy technology, several state governments have introduced their own targets to ensure the continued growth of the renewables sector.

In the United States, by the end of 2005, 20 states and the District of Columbia had adopted RPS and almost half of the 2,431 MW installed in 2005 resulted directly from state RPS policies.

As more wind projects are established in a country, the subsidy schemes are evaluated and often revised to meet changing political and economic environments. For example in the Netherlands, the Ministry of Economic Affairs was asked by Parliament to conduct a detailed social cost/benefit analysis of offshore wind energy. This request was the result of concerns about the costs of production subsidies for offshore wind as planned under the MEP scheme for 2005 through 2007. The result has been a tender for the lowest price per kilowatt hour of MEP production subsidy. In the United Kingdom, the Prime Minister and Secretary of State for Trade and Industry announced a Review of UK energy policy to bring forward policy proposals in 2006.

4.5 OTHER SUPPORT MECHANISMS

An array of innovative support mechanisms is present in the IEA Wind Member Countries. For example, to facilitate the deployment of wind power the Swedish Energy Agency assessed 49 geographical areas for wind power in 13 counties. For the most suitable areas for wind power production, a national interest for wind power will be assigned. This will allow wind energy to be compared with other national interests such as environment protection, fisheries, and navigation.

In the United Kingdom, the Offshore Production of Energy (part of the Energy Act 2004) puts in place a comprehensive legal framework for offshore renewable energy projects (wind, wave, and tidal) and extends the boundary for such projects

beyond the UK's territorial waters to the 200 mile point. The Act establishes a Renewable Energy Zone, adjacent to the UK's territorial waters, within which renewable energy installations can be established.

In the United States, energy legislation 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.

5.0 RD&D ACTIVITIES

5.1 SETTING PRIORITIES

In 2003, the IEA Wind Implementing Agreement issued its Strategic Plan (3) which listed five priority research areas. While developing this 2005 Annual Report, the authors of the country chapters ranked the research areas for importance in their countries.

- Increase value and reduce uncertainties;
- Cost reduction;
- Enable large-scale use (system integration);
- Minimize environmental impacts;
- Wind within future energy supply systems (storage, hydrogen, and other renewables);
- Others

The accumulated rankings displayed in Figure 4 illustrate that all of the research areas identified in the Strategic Plan are still important. Reducing cost and increasing value are still very important.

Two important issues to evaluating the direction of RD&D activities were raised in 2005 and discussed in the 47th Topical Expert Meeting (TEM) on Methodologies for Estimation of Cost of Wind Energy and the Methodologies to Estimate the Impact of Research on the Cost. Regarding COE calculations, the TEM presentations concluded that cost analyses intended for the same purpose may have different ways of estimating the cost of energy. Some may include or exclude external factors and would yield different results, as would parameter variations of turbine

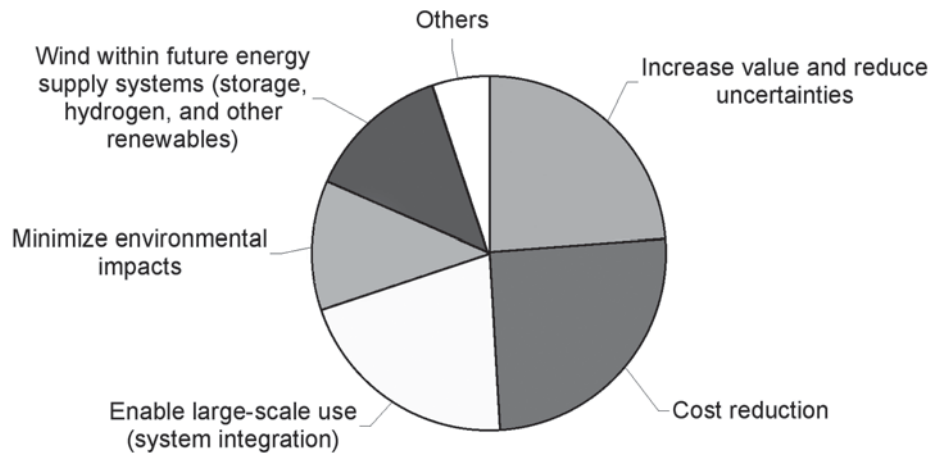


Figure 4 RD&D priority ranking resulting from a survey of IEA Wind Member Countries 2005. [Rankings were assigned a value, totaled, and % share was calculated. Fifteen countries reported.]

lifetime, discount rate, including/excluding the cost of the export cable, etc. In 1983, the IEA Wind Agreement issued the Recommended Practice Estimation of Cost of Energy from Wind Energy Systems, and the second edition was published in 1994 (4). However, participants in the TEM concluded that it is still difficult to determine the cost of wind power, and installing turbines offshore has added a new dimension of uncertainty. Participants rejected the idea of updating the recommended practice and suggested raising the modeling of COE to a higher level than the IEA Wind Implementing Agreement.

Regarding the ability to assess the impact of RD&D on cost, participants concluded that industry cost reductions in the near future may be discouraged by government incentives and the lack of competition among turbine manufacturers due to high demand. As a result, they argued for increased focus on government RD&D programs for cost reduction. One route would be to work toward cost reduction of project components such as foundations, grid connection, export cable, etc. These cost components make up half the investment cost of new wind projects. Another route would be to evaluate the cost versus the benefits of government RD&D programs. A well-developed

methodology to evaluate RD&D proposals on their contribution to cost reduction should yield effective RD&D to reduce costs. Participants agreed that developing a methodology to evaluate RD&D proposals would be appropriate for a new annex to the IEA Wind agreement. To this end, an ad hoc group (Denmark, the Netherlands, Sweden, and the United States) was set up to formulate a proposal to the IEA Wind ExCo for a new research task.

5.2 FUNDING TRENDS

Aggregated RD&D funding for the IEA Wind Member Countries is a difficult number to achieve because of the great variation in approaches among the countries to accounting for RD&D support. Of the countries that reported a government RD&D budget, the United Kingdom reported the largest increase from 2.43 million € in 2004 to 29.04 million € in 2005. This increase represents a concerted effort to reduce the costs of offshore wind generation. Reported research budgets in Germany and Norway more than doubled, and Korea and Mexico also had increased spending. RD&D budgets in Canada and the United States remained about the same, while budgets in Denmark, Finland, Italy, and Switzerland went down slightly. Sweden's budget for energy R&D

declined by nearly 50% for 2005, however at the end of 2005, funds were restored for 2006 comparable to 2004 levels.

5.3 TEST SITES

A number of test sites are now operating for multi-megawatt wind turbines. Advances in test sites are needed as the size of new models increases. The Danish test site at Høvsøre for multi-megawatt wind turbines can accommodate turbines of 5 MW and leases test stands to manufacturers. Germany operates the North Sea test site FINO 1 research platform to gather data for offshore wind development. A test site adjacent to FINO 1 is in the planning phase to prove the capabilities of 5-MW class turbines and their foundations under high sea conditions. The test site is supported by the German federal government and the Offshore Wind Energy Foundation in Germany. The Netherlands' Energy Research Center of the Netherlands (ECN) test field in Wieringenmeer was hosting prototypes of the GE Wind 2.3-MW turbine with a hub height of 100 m and the Siemens 3.6-MW turbine with a hub height of 80 m. In Norway, SINTEF Energy Research, the Institute for Energy Technology (IFE), and the university in Trondheim (NTNU) took a joint initiative in 2001 to develop a test station for wind turbines at the western coast of Mid-Norway. The test site was opened summer 2005.

Additional test sites are used to test turbines under special local conditions. For example, Mexico is developing a Regional Wind Technology Centre which will provide test facilities for turbine manufacturers in the La Ventos high-wind region. Switzerland operates the Alpine Test Site Gütsch based on the performance guidelines of IEA Wind research task XIX Wind Energy in Cold Climates. Meteorological measurements and wind turbine performance analysis will be made available to the wider public. Canada operates the Atlantic Wind Test Site, which is becoming the foundation for the new Wind Energy Institute of Canada.

5.4 COOPERATIVE RESEARCH

The IEA Wind Member Countries each have RD&D programs and projects in line with national priorities for wind power development (See Section 5 of Chapters 10 through 29). In addition, all countries participate in at least one of the research tasks listed below (See Chapters 2 through 8).

Task XI Base Technology Information Exchange: Participants 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. One part of this activity has developed recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. Another part of this activity conducts 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 last part of this activity organizes Topical Expert Meetings on topics decided by the IEA Wind ExCo. Proceedings are distributed to attendees and to the countries that pay fees to participate in Task XI. In 2005, 14 of the IEA Wind Member Countries participated in task XI.

Task XIX Wind Energy in Cold Climates: Participants work to collate information on available adapted wind turbine technology and to formulate recommended practices for project developers. These recommended practices 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.

Task XX HAWT Aerodynamics and Models from Wind Tunnel Measurements: Participants work to increase understanding of the aerodynamics of horizontal axis wind turbines (HAWT) by using new data from a full-scale wind tunnel experiment conducted in 2000 to develop and validate model subcomponents that can then be used to improve comprehensive aerodynamic models. During 2005, participants continued research activities and shared research results.

Task XXI Dynamic Models of Wind Farms for Power Systems Studies: Participants develop wind farm models that are suitable for evaluating power system dynamics and transient stability and develop validation techniques. In 2005, the annex participants released a report that provides an overview of the available wind farm models and presents a systematic approach for model benchmark testing.

Task XXIII Offshore Wind Energy Technology and Deployment: Participants gain an overview of the technical and environmental assessment challenges encountered in offshore applications and identify areas for further R&D. In 2005, a series of workshops resulted in a research activity called Offshore Code Comparison Collaboration (OC3). Participants in this activity work to develop better computer models for analyzing and evaluating offshore wind turbines on various types of foundations. This working group determined that at least six structural dynamic codes are under development or modification for more accurate prediction of support structure load modeling. Model comparison is the first step in quantifying and reducing load prediction uncertainties. More research projects on different aspects of offshore development are expected in 2006.

Task XXIV Integration of Wind and Hydropower Systems: Participants develop case studies to identify the potential benefits of combining wind and hydropower to provide a stable supply of electricity to the grid.

Task XXV Power System Operation with Large Amounts of Wind Power: Participants analyze and further develop methodologies to assess the impact of wind power on power systems with an emphasis on technical operation.

IEA Wind Member Countries also participated in other international cooperative RD&D efforts, most notably those of the European Commission, which is a participant in the IEA Wind Agreement.

The Concerted Action for Offshore Wind Energy Deployment (COD) project aims to accelerate the deployment of offshore wind energy within the European Community by streamlining legislation, consenting procedures; environmental impact assessment; and grid integration. Information was exchanged between the national energy agencies of most sea-bordering member states in the European Commission including Belgium, Denmark, Germany, Ireland, the Netherlands, Poland, Sweden, and the United Kingdom. This represents 90% of the offshore wind energy potential within the European Union. (4) Garrad Hassan and Partners produced the Principal Findings Reporting.

The Distant Offshore Windfarms with No Visual Impact in Deepwater (DOWNVIND) project will be the world's first deep water wind farm and is due to be constructed 25 km off the east coast of Scotland by late 2006.

6.0 THE NEXT TERM

Most countries expect growth in the next term. Some countries with little or no growth in 2005 expect big additions in 2006. For example, Mexico expects an 83-MW wind plant to be completed in 2006. All countries have projects in various stages of the development process from feasibility assessment to waiting approval to connect to the grid. The countries with offshore capacity plan to increase it and have efforts underway to bring costs down: Denmark, Ireland, Japan, Sweden, and the United Kingdom. Plans to install the first

EXECUTIVE SUMMARY

projects offshore or to clear away the technical and administrative barriers are underway in Canada, Finland, Germany, Japan, Norway, Spain, and the United States.

With reference to national targets for wind energy, many countries plan to address the issues slowing development either through research or application of research results to: grid capacity and integration issues, community concerns, impacts on aviation, regulatory issues, permitting process, resource assessment, and technology costs. To reach the national targets, many countries have plans to revise, expand, or improve incentive programs.

And finally, most countries have technical research activities both at home and in cooperation with other countries to develop the next generation of wind turbines, components, and tools to decrease the cost and improve the performance of wind generation.

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IEA Wind

CHAPTER 1

IMPLEMENTING AGREEMENT

1.0 INTRODUCTION

IEA's commitment to wind energy dates back to 1977, when the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA Wind) began.

The past 28 years have seen the development and maturing of wind energy technology. This process has been possible only 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, 23 contracting parties from 20 countries and the European Commission participate in IEA Wind. Australia, Austria, Canada, Denmark, the European Commission, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, 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 European Wind Energy Association will join in 2006 as a Sponsor.

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 2005, a representative from Russia has attended a meeting.

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 of national program activities in 2005 is presented in the Executive Summary of this Annual report. Individual country 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

IMPLEMENTING AGREEMENT

Table 1 Contracting parties in 2005 to the International Energy Agency Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind)

Country	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
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

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 program coordinated by an Operating Agent. By the close

Table 2 Active cooperative research tasks defined in Annexes to the IEA Wind implementing agreement (OA indicates operating agent that manages the task)

Task XI	Base technology information exchange OA: Vattenfall, Sweden (1987 to present)
Task XIX	Wind energy in cold climates OA: Technical Research Centre of Finland - VTT. (2000 to 2005)
Task XX	HAWT Aerodynamics and models from wind tunnel tests and measurements OA: NREL, the United States (2003 to 2007)
Task XXI	Dynamic models of wind farms for power system studies OA: Sintef Energy Research, Norway (2003 to 2006)
Task XXIII	Offshore wind energy technology development OA: Risø National Laboratory, Denmark and the National Renewable Energy Laboratory (NREL), United States (2004 to 2008)
Task XXIV	Integration of wind and hydropower systems, OA: NREL, United States (2004 to 2008)
Task XXV	Design and operation of power systems with large amounts of wind power. OA: Technical Research Centre of Finland – VTT, (2005-2008)

of 2005, 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.

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.

The ExCo meets twice each year to exchange information on the R&D programs of the member countries, 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. Member countries 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 2005, Peter Goldman (United States) served as Chair and Ana Estanqueiro (Portugal) and Sara Hallert (Sweden) served as Vice-Chair. At the 56th Executive Committee (ExCo) meeting, Goldman was elected Chair continuing in 2006 and Ana Estanqueiro (Portugal) and Sara Hallert (Sweden) were elected as Vice-Chairs. In December 2005, Goldman retired from his position in the U.S. Department of Energy and Ana Estanqueiro assumed the role of Chair.

PARTICIPANTS

In 2005, Korea accepted the invitation to join the agreement bringing total membership to 23 participating organizations. Germany rejoined the agreement effective 1 January 2005. (See Appendix B for an updated list of Members, Alternate Members, and Operating Agent representatives.) During the year, the Executive Committee invited representatives from Russia and the European Wind Energy Association who attended the ExCo meetings as observers.

MEETINGS

The ExCo normally meets twice a year for Members to review ongoing tasks; plan and

IMPLEMENTING AGREEMENT

Task I	Environmental and meteorological aspects of wind energy conversion systems OA: The National Swedish Board for Energy Source Development. (1978 to 1981)
Task II	Evaluation of wind models for wind energy siting OA: U.S. Department of Energy - Battelle Pacific Northwest Laboratories. (1978 to 1983)
Task III	Integration of wind power into national electricity supply systems OA: Kernforschungsanlage Jülich GmbH, Germany. (1978 to 1983)
Task IV	Investigation of rotor stressing and smoothness of operation of large-scale wind energy conversion systems OA: Kernforschungsanlage Jülich GmbH, Germany. (1978 to 1980)
Task V	Study of wake effects behind single turbines and in wind turbine parks OA: Netherlands Energy Research Foundation. (1980 to 1984)
Task VI	Study of local flow at potential WECS hill sites OA: National Research Council of Canada. (1982 to 1985)
Task VII	Study of offshore WECS OA: UK Central Electricity Generating Board. (1982 to 1988)
Task VIII	Study of decentralized applications for wind energy OA: UK National Engineering Laboratory. (1984 to 1994)
Task IX	Intensified study of wind turbine wake effects OA: UK National Power plc. (1984 to 1992)
Task X	Systems interaction. Deferred indefinitely.
Task XII	Universal wind turbine for experiments (UNIWEX) OA: Institute for Computer Applications, University of Stuttgart, Germany. (1988 to 1995)
Task XIII	Cooperation in the development of large-scale wind systems OA: National Renewable Energy Laboratory (NREL), USA. (1990 to 1995)
Task XIV	Field rotor aerodynamics OA: Stichting Energieonderzoek Centrum Nederland (ECN), the Netherlands. (1992 to 1997)
Task XV	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 XVI	Wind turbine round robin test program OA: the National Renewable Energy Laboratory (NREL), the United States. (1995 to 2003)
Task XVII	Database on wind characteristics OA: RISØ National Laboratory, Denmark. (1999 to 2003)
Task XVIII	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 XXII	Market development for wind turbines. On hold.

Table 4 Participation of member countries in Annexes during 2005. (OA indicates operating agent that manages the task)

* Expect to join in 2006.

Country	XI Base Technology Information Exchange	XIX Wind Energy in Cold Climates	XX HAWT Aero- dynamics and Models from Wind Tunnel Tests	XXI Dynamic Models for Wind Farm Power Systems	XXIII Offshore Wind Energy Technology and Deployment	XXIV Integration of Wind Hydropower Systems	XXV 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						
Finland	x	OA		x		x	OA
Germany	x	x			x		x
Greece	x		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	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	2007	2007	2006	2008	2008	2008

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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 55th ExCo meeting was hosted by the Government of Portugal and INETI in Porto, Portugal 3, 4, and 5 May 2005. There were 33 participants from 16 of the contracting parties, three operating agent representatives of the tasks, and observers. The ExCo reviewed and approved technical progress reports of ongoing tasks XI, XVII, XIX, XX, XXI, and XXIII; approved extension of task XIX through 2007; approved progress on the new annex XXIV Integration of Wind and Hydropower Systems, operating agent NREL, United States; and approved in principle a new annex XXV Design and Operation of Power Systems with Large Amounts of Wind Power and authorized the operating agent VTT (Finland) to move forward to develop a detailed work plan and list of participants to be approved at the next meeting. The audit report of 2004 accounts of

the Common Fund was approved. On 5 May 2005, the ExCo visited the Cabreira (Eolenerg/Enerconan) wind farm, the Barroso (Enernova/Vestas) wind farm, and the EDP Venda Nova hydropower station.

The 26th issue of the IEA Wind Annual Report was published in June 2005.

The 56th ExCo meeting was hosted by the Swiss Federal Office of Energy, in Lucerne, Switzerland on 27, 28, and 29 September 2005. There were 28 participants from 16 of the contracting parties, three operating agent representatives of tasks, and observers from Russia and the European Wind Energy Association. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2006. Final approval for Annex 25 Design and Operation of Power Systems with Large Amounts of Wind Power was granted based on the workplan and budget presented. On 29 September 2005, the ExCo visited the highest wind turbine in the Alps (0.6 MW) at Andermatt and the 1,062-MW Grimsel Hydropower and pumping plant – together with attendees of the meeting of Annex 24.

CHAPTER 2 TASK XI

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.

2.0 OBJECTIVES AND STRATEGY

The task includes activities in two sub-tasks. The first sub-task 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 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 XI. 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 Annex XXV 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 annex proposal.

Over the 25 years since these activities were initiated to promote wind turbine technology through information exchange, the task has published 47 volumes of proceedings from Expert Meetings (Table 2) and 26 volumes of proceedings from Joint Action Symposia (Table 3).

3.0 PROGRESS IN 2005

According to the work plan approved by the ExCo, the following activities were planned for 2005:

45th Topical Expert Meeting on Radar, Radio, Radio Links and wind turbines

46th Topical Expert Meeting Obstacle Marking of Wind Turbines

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	Superceded 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. For a complete list of meetings, see www.ieawind.org

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	Critical 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

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 1995 see www.ieawind.org under Annex XI

47th Topical Expert Meeting on Methodologies for Estimation of Cost of Wind Energy and the Methodologies to Estimate the Impact of Research on the Cost.

Topical Expert Meeting on Wind Energy for Clean Water. This last meeting had to be cancelled, at a late stage, due to too few participants.

The Joint Action Symposium on Aerodynamics was arranged in 2005 as a part of the Task XX work. See more information in Chapter 4.

All documents produced under Task XI are available to organizations within the countries that participate in the task: Canada, Denmark,

Finland, Greece, Ireland, Italy, Japan, Mexico, the Netherlands, Norway, Spain, Sweden, the United Kingdom, and the United States. Organizations within these countries can receive documents from the Operating Agent representative, listed in Appendix B.

3.1 RADAR, RADIO, RADIO LINKS, AND WIND TURBINES

The 45th Topical Expert Meeting on Radar, Radio, Radio Links, and Wind Turbines was hosted by DTI in London, UK. A total of 27 participants attended this meeting with representatives from The Netherlands, Norway, Sweden, the UK, and the US. A broad spectra of organizations were present encompassing government agencies, R&D establishments, private companies, and developers.

Presentations were centered around the following topics:

- National policies, experience and regulations
- Radar interference and related issues
- Other topics including radio links and direction finding
- Mitigating technologies/preventive measures.
- Proposed rules for aviation marking in Sweden
- Aviation Marking of Wind Turbines - in a Danish Perspective
- IALA Recommendation O-117 on the Marking of Offshore Wind Farms
- Offshore Wind Farms Conspicuity Requirements
- Proposed lighting configuration for wind turbines.

Most presentations focused on the potential problems of wind turbines and surrounding radar and navigational systems with supporting technical background. These presentations concluded that mitigating technologies and computer software solutions such as radar filters and intelligent processing of multiple sensor data are available. These initiatives are being advanced with the aim of finding workable solutions to the radar problem that are acceptable to aviation regulators.

There was general agreement that the meeting highlighted the quite varying approaches and attitudes, throughout the IEA member countries, towards wind power and how this has shaped policies, procedures and developments. The meeting provided the opportunity to identify possible future research needs, and it stimulated comments on the validity of existing models and evolving mitigating technologies. There is a potential for international collaboration to further increase knowledge and understanding.

3.2 OBSTACLE MARKING OF WIND TURBINES

The 46th Topical Expert Meeting Obstacle Marking of Wind Turbines was hosted by FOI in Stockholm, Sweden. A total of eight participants attended this meeting with representatives from Denmark, Ireland, and Sweden. The participants represented both maritime and aviation interests as well as manufacturers and developers.

Five presentations were given on the following topics:

The two different recommendations from ICAO (International Civil Aviation Organization) and IALA (The International Association of Marine Aids to Navigation and Lighthouse Authorities) for obstacle marking were discussed and evaluated. It was concluded that aviation marking recommendations are far more demanding than the corresponding rules for maritime markings. However, the aviation recommendation does not cover every detail of how the actual marking is to be implemented.

All participants agreed that a holistic approach must be applied in this area, where many interests have to be dealt with. The holistic approach should include: Safety, Public acceptance; Cost within reason; and International standards and harmonization.

Adequate promulgation is the main means to announce the presence of an obstacle. All aviation pilots and mariners should make themselves aware of the most up-to-date information. Because of this, it is of the utmost importance that relevant data on all obstacles, including wind turbines, are kept updated in Aviation Information Publications (AIP) and Notices to Mariners (NtM). The visual marking is only to inform about the presence of an obstacle that already should be known. The Irish participant emphasized that the role of marking is to give visual information to aviators and mariners, in addition to what they already are supposed to know. This caused the remark that, if written information were to be considered sufficient, no markings whatsoever would be needed. The



Figure 1 Attendees at the Topical Expert Meeting 47, on methodologies to estimate the cost of wind energy and the impact of research on cost.

comments reflected the interest to go to the fundamental basics of markings.

3.3 METHODOLOGIES FOR COST ESTIMATION OF WIND ENERGY AND TO ESTIMATE THE IMPACT OF RESEARCH ON THE COST

The 47th Topical Expert Meeting on Methodologies for Estimation of Cost of Wind Energy and the Methodologies to Estimate the Impact of Research on the Cost was held at IEA Headquarters in Paris, France. A total of 11 participants attended this meeting with representatives from Denmark, Germany, Ireland, Italy, the Netherlands, Sweden, the UK, and the US. The participants represented national research centers, investor and developer organizations, consultancy companies, and utilities.

3.3.1 RECOMMENDED PRACTICE ON ESTIMATION OF COST

The presentations concluded that cost analyses intended for the same purpose may have different ways of estimating the cost of energy. Some may include or exclude external factors and would yield

different results, as would parameter variations of life length, discount rate, including/excluding the cost of the export cable, etc.

In 1983, the IEA Wind Recommended Practice “Estimation of Cost of Energy from Wind Energy Systems” was developed, and the second edition was published in 1994. There still exists great difficulty in answering the question of what the cost of wind power really is. Going offshore has added a new dimension of uncertainty in how to answer this question. Participants considered updating the recommended practice. This would be one way to be certain that the meeting results would be distributed to all IEA Wind (Task XI) member countries rather than being limited to those who attended the meeting.

The two most significant benefits from updating the Recommended Practice were found to be: 1) Using an update as a way of sharing the results of this expert meeting with others and 2) Being able to determine what the cost of wind power really is. However, the vast amount of effort required for an update should be taken into consideration, and the Recommended Practice should not be updated unless enough benefits from doing so are

seen. Updating the Recommended Practice would require a modeling activity. The issue of modeling the cost of wind energy can be split into two separate tasks:

1. Modeling the COE in general and
2. Addressing wind power specific issues

Another idea suggested was to raise the modeling of COE to a higher level than the IEA Wind Implementing Agreement, allowing input from other energy sources as well. This would enable the IEA Wind group to focus on the wind specific issues. The result of this workshop and the aftermath would not be an update of the Recommended Practice but an entirely new document.

3.3.2 COST BENEFITS OF R&D PROPOSALS

Wind power generation has come to an “historical” point where investment cost per megawatt, and hence the cost per generated kilowatt hour, is increasing for new wind turbines. Some reasons for this increase are believed to be the increasing price of raw material, especially for steel and the turbine manufacturers’ focus on meeting orders rather than on cost performance (lack of competition). Current signals from the US market indicate possibilities of future onshore investment levels around 1,800 USD/kW.

National support systems with a fixed high tariff or increasing quotas for renewable energy systems are driving higher cost for the end consumer because the quotas are currently not being met. The high revenue levels for producers of renewable energy were believed by participants not to encourage focus on cost performance for the manufacturers of wind turbines. As a consequence, the production costs are unlikely to drop in the near future.

Since cost reductions in the immediate to near future may be discouraged by the current support systems in combination with the lack of competition among turbine manufacturers, there is an increased need to focus on RD&D programs for

cost reduction. One route is to look at cost reduction possibilities of components other than turbines such as foundations, grid connection, export cable, etc. These cost components make up half the investment cost and are potentially a source of future cost reduction.

Another route is to evaluate the cost benefits of RD&D programs. Despite the imminent need for cost reduction, not all countries seem to take this parameter into consideration when evaluating RD&D proposals. A well developed methodology to evaluate RD&D proposals on their ability to contribute to overall wind power cost reduction should yield much more effective RD&D in terms of reducing cost. Inviting turbine manufacturers to take part in a working group that looks at cost reduction may yield insights on where the greatest potential can be found.

Because the value of evaluating RD&D proposals is significant, the question may be better dealt with within the framework of a new annex to the IEA Wind agreement. An annex is a good way of investigating the issue further, due to its simplicity, speed, and its way of operating around a specific theme. It was unanimously agreed to set up an ad hoc group with responsibility to formulate such a proposal. Participating countries are Denmark, the Netherlands, Sweden, and the United States.

4.0 PLANS FOR 2006 AND BEYOND

In 2005, Task XI was extended through 2007 and a new workplan was proposed to continue coordinating Topical Experts Meetings and Joint Action Symposia. Four meetings of this type will be arranged every year. Examples of meetings (but not limited to these) are:

- Operation and maintenance of wind power stations
- State of the art of remote wind speed sensing techniques, e.g. sodar and satellites
EU-ACCUWIND
- Challenges of introducing reliable small scale wind turbines

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- Micro meteorology inside wind farms
- Deep water technologies
- Joint Action Symposium #1 on Radio, Radar and wind energy Research at Offshore Platforms and Wind and Wave Characteristics.

More information can be found at
www.IEAwind.org

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CHAPTER 3 TASK XIX

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 XIX to the IEA Wind Implementing Agreement was officially approved in 2001. The resulting Research Task began in May 2001 and continued for three years. In 2005, after the first three-year period of the task was completed, the participants planned activities for another three years, and extension of the task was approved by the IEA Wind ExCo. The main driver for extension was the need to better understand cold climate wind turbine operation and also to gain benefit from the results of the national projects that were launched during the first three years of the task.

In the state-of-the-art report resulting from the first three years of the task, the expression “cold climate” was defined to mean sites where turbines are exposed to low temperatures outside the standard operational limit and where turbines face icing, which retards energy production in the winter. Typically such sites are elevated from the surrounding landscape or located in high northern latitudes. (1)

2.0 OBJECTIVES AND STRATEGY

The goal of Task XIX is to collate information on available adapted wind turbine technology and to formulate recommended practices for project developers. These recommended practices 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. 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 will supply information and attend task meetings.

The activities will be aimed at solving the most evident issues that are causing uncertainty regarding cold climate wind development. These activities are intended to match well with the national activities that the possible participants have planned for the next two years. Participants in Task XIX will conduct measurements during the national projects. The measurements will include site assessment and follow-up measurements, which enable the verification of a method that will be developed for the estimation of production losses. Measured information regarding the performance of anti- and de-icing methods will be available as well. Information from the ongoing anti- and de-icing system development projects will be available for the task.

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Statistical data on production and on failure events are being collected in several participating countries. Analysis regarding the production figures and the effects of applied cold climate technology on it will be performed on the basis of this data. Information will be collected also with direct contacts to wind energy producers and with a questionnaire on the project Internet page.

The current production estimation tools will be reviewed in order to find out how the effects of atmospheric ice have been recognised or could be recognised in these methods. A simple method that can be used in estimation of ice-induced production losses will be formulated. Up to now, no such method exists, which has led to high production losses due to the underestimation of the effects of ice.

The recommended method for production estimation needs to be easy to use and allow coarse estimation of ice problems at the early stages of wind project development in order to enable better preparation for actual site assessment. Standard meteorological data from national meteorological offices will be considered as an input. The developed method will be verified with ice measurements and power performance data, which will be collected in connection to the national projects of the participants. The on-going ice measurement campaigns and development of ice detectors in participating countries will also support the work.

The significance of ice-induced extra loads will be determined partly on the basis of computer simulations. Results from simulations with dynamic MBS (Multi Body System) models such as ADAMS will be used in the determination process. Results of load measurements from different wind turbines (both pitch and stall regulated) will be considered as well. The final aim is to conclude the significance of ice-induced loads to wind turbines and assess how large wind turbines in the future are likely to be affected by atmospheric icing.

Participants in Task XIX also are active in several international projects and co-operations. Some participants 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 directly benefits the work of the IEA Wind Task XIX.

The co-operation will continue to disseminate the research results through the internet page of the Task XIX (<http://arcticwind.vtt.fi>) and in conferences and seminars (1-6). The final report containing updated state-of-the-art of technology and updated recommendations regarding the use of wind turbines at sites where winter conditions prevail during a significant amount of a year will be published at the end of the ongoing task period.

One important dimension of this work will be the initiation of conversation about whether the cold climate issues should be recognized in future standards that set the limits for turbine design.

3.0 PROGRESS IN 2005

During 2005, participants in Task XIX continued research activities started previously. Ongoing activities and results were presented at the first of the two annual meetings which was held in Lapland, Finland in connection with the Boreas VII conference. The focus of the Boreas conference was cold climate wind turbine operation. Conference participants from Germany and Italy expressed their interest to join Task XIX in the course of the Boreas conference. A paper describing the work of the Task XIX was presented in Boreas VII conference by the Operating Agent Representative in March 2005 (6).

The second meeting of the task was held in Bubendorf, Switzerland at the end of August. The program of the meeting focused on planning the work for 2006 and 2007.

The final report of the first Task XIX period, the guidelines regarding cold climate issues of wind energy (7), was approved by the IEA Wind ExCo spring 2005. The report has been placed for free downloading to the project Internet page in a PDF format.

In 2005, the following organizations participated in Task XIX activities.

- Natural Resources Canada, Canada
- VTT, Finland
- Kjeller Vindteknikk, Norway
- ENCO, Switzerland
- NREL, USA
- University of Trento, Italy
- ISET, Germany

4.0 PLANS FOR 2006 AND BEYOND

Interest in cold climate specific issues has increased during recent years. One of the driving forces for that is improving cold climate wind turbine technology and thus the improving competitiveness of cold climate sites compared to other sites. The primary goal for the second period of Task XIX is to respond to those issues that have been recognised to slow down the development of wind energy in areas covered by the scope of Task XIX. The objectives for the continuation period 2005-2007 are shown below.

- Determine the current state of the cold climate solutions and especially anti- and de-icing solutions that are in or are entering the market.
- Review the current standards and recommendations from the cold climate point of view and identify the possible needs for updates. Possibly recommend updates. Include comments from planners and operators.

- Find and recommend a method to estimate the effects of ice on production and thus reduce the amount of incorrect estimates and the risks that are involved in cold climate wind energy projects currently. Verify the method on the basis of data from national projects according to the possibilities.
- 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 state-of-the-art report and update the expert group study on applying wind energy in cold climates to guidelines.

Results will be disseminated through the internet page of Task XIX (<http://arcticwind.vtt.fi>), in conferences, and during seminars. A final report containing updated state-of-the-art of technology and updated recommendations regarding the use of wind turbines at sites where winter conditions exist during a significant amount of a year will be published.

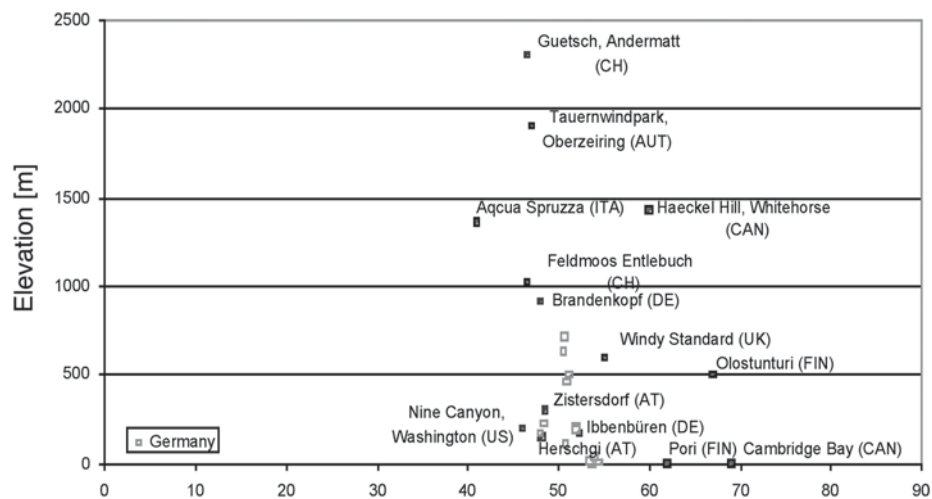


Figure 1 Location of selected cold climate sites that experience cold climate conditions annually.

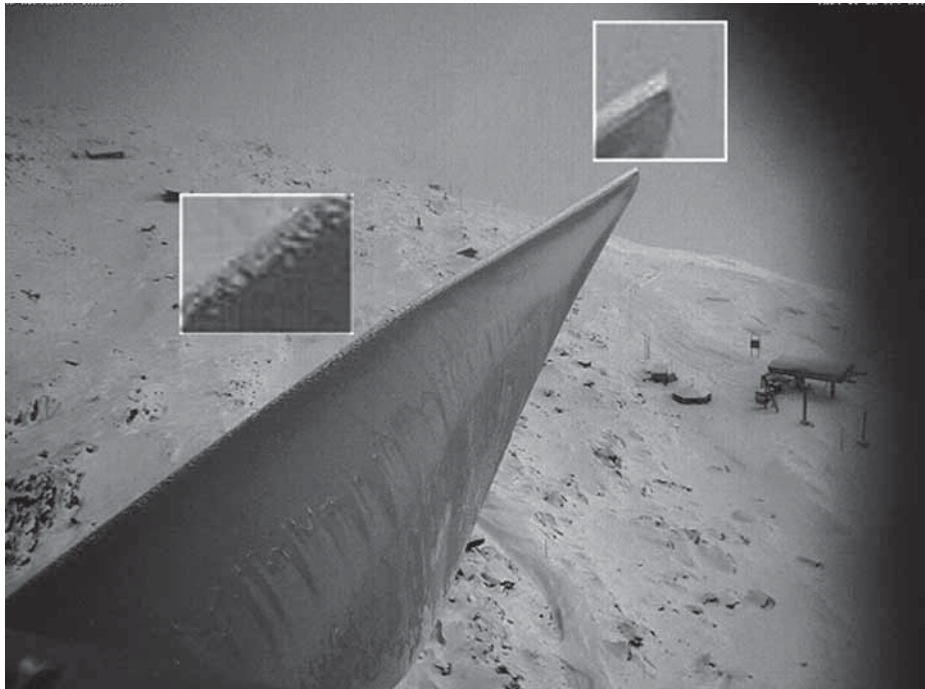


Figure 2 Wind turbine at a walking distance from a ski lift in Güttsch. Turbine is equipped with a de-icing system. Photo: ENCO AG, Switzerland.

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CHAPTER 4 TASK XX

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” (completed 1997) and Task XVIII, “Enhanced Field Rotor Aerodynamics Database” (completed 2001).

These efforts addressed turbine sizes and configurations that 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. This test was designed to provide accurate and reliable experimental measurements, having high spatial and temporal resolution, for a realistic rotating blade geometry, under closely matched Reynolds number conditions, and in the presence of strictly controlled inflows. Completed in 2000, the test included 22 turbine configurations and produced over 2,100 data files containing nearly 100 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 participants 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

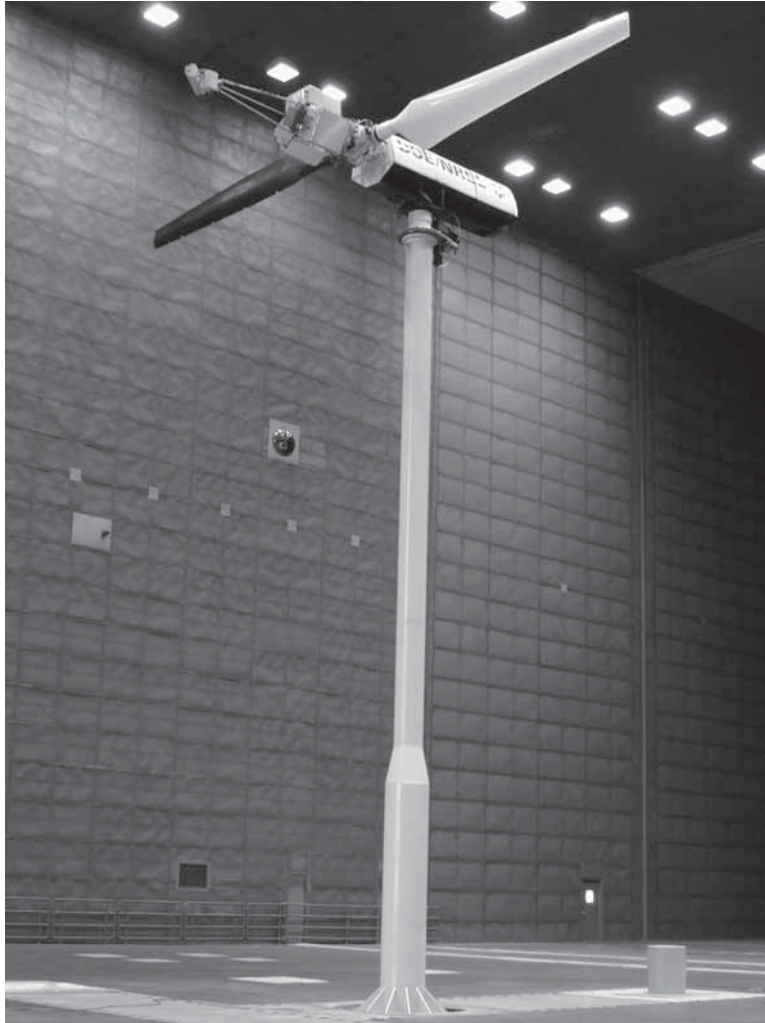


Figure 1 NREL UAE in NASA Ames 80 foot by 120 foot wind tunnel.

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 was clear, and the potential benefits are readily apparent. Research Task XX

was established to capitalize on the 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 new wind turbine aerodynamics models. Improved models will improve wind energy machine design and continue the trend toward lower cost wind energy.

2.0 OBJECTIVES AND STRATEGY

Objectives: Task XX 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.

Participants: In 2005, twelve organizations representing eight IEA Wind member countries participated in Task XX, and are listed below.

- Center for Renewable Energy Systems (CRES), Greece
- Centro Nacional de Energías 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
- National Renewable Energy Laboratory (NREL), United States
- Risø National Laboratory, Denmark
- Swedish Defence Research Agency Aeronautics Division (FFA), Sweden

- Technical University of Delft, The Netherlands
- Royal Institute of Technology, Sweden

3.0 PROGRESS IN 2005

During 2005, participants continued research activities previously proposed and initiated under Task XX. Research results were presented and discussed at the Task XX Annual Progress Meeting, which was held on May 25-26, 2005 at the Centro Nacional de Energías Renovables (CENER), in Pamplona, Spain. As in previous years, the Task XX meeting was held in conjunction with the Task XI Aerodynamics of Wind Turbines meeting.

At the May 2005 annual meeting, researchers representing their respective participating countries reported on work carried out during the preceding year. Brief encapsulations of these status reports are included below.

“The Effect of the Test Set-Up on the Steady State Data” – This purpose of this investigation was to determine in what manner and to what degree the NASA Ames test configuration affected the aerodynamic measurements. Analyses identified deviations in some data and corrections were formulated to compensate for these deviations. Applying the findings of this effort yielded corrected angle of attack, lift, and drag coefficients for use in engineering model development and validation. (R. van Rooij, Delft University of Technology, The Netherlands)

“Using Measured Airfoil Data in BEM Calculations” – DU97-W-300mod airfoil data acquired in the DNW wind tunnel at Cologne were analyzed in preparation for use in BEM model calculations. Using these and other data, it was concluded that realistic consideration of surface roughness is a challenging and crucial problem. (B. Hillmer and A. P. Schaffarczyk, University of Applied Sciences at Kiel, and K. Kaiser, Lübeck, Germany)

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“3D-Correction of Airfoil Data Based on Pressure” – A new model was described for correcting 2D airfoil wind tunnel data to obtain 3D performance characteristics. This model exploited surface pressure distribution differences that exist between the 2D airfoil data and the 3D NREL UAE blade data to generate the data corrections. (C. Bak and J. Johansen, Risø National Laboratory, Denmark)

“The Upstream Flow of a 3-Bladed Wind Turbine Model in Yaw: Comparisons with the Momentum Theory” – High spatial and temporal resolution particle image velocimetry (PIV) was used to acquire detailed flow field surveys upstream of a model turbine in a low turbulence wind tunnel. Axial, radial, and tangential velocity data for both axisymmetric and yawed conditions were analyzed to enable inferences regarding physical mechanisms operating in this flow region. (D. Medici, Royal Institute of Technology, Sweden)

“Aerodynamic Research on Wind Turbine Blade Design via Optimization Technique and Wind Tunnel Experiment” – A new finite vortex wake model was developed and then validated using data from wind tunnel tests carried out by Seoul National University and by NREL at NASA Ames. In addition to wind tunnel experiment data, comparisons with an existing conventional free-wake model also were employed. (S. Lee, Seoul National University, South Korea)

“Aerodynamic Modelling in the Aeroelastic Codes HAWC and HAWC2” – This presentation provided an overview of aerodynamic modeling in HAWC and HAWC2. Described in detail were the methodologies employed for computing wake induction and for computing unsteady blade aerodynamics, including a new near wake model. (H. A. Madsen, Risø National Laboratory, Denmark)

“Aeroelastic Actuator Line Modelling” – An actuator line model was combined with the structural part of the FLEX5 aeroelastic code. The resulting code was tested on a flexible turbine exposed to

harmonic oscillations, using two methods for simulating wake interaction. Both methods captured the wake interaction effects, and thus both were considered feasible in preparation for more detailed assessment. (R. Mikkelsen, Denmark Technical University, Denmark)

“Investigating the Aerodynamics of the NREL Phase VI Rotor Using a Free-Wake Vortex Model” – Blade normal and tangential forces were obtained from NREL UAE blade pressure measurements. These data were iteratively analyzed in conjunction with a free-wake model to yield blade angle of attack, lift, and drag data. (T. Sant, University of Malta, Malta; G. van Kuik and G. van Bussel, Delft Technical University, The Netherlands)

“Hot-Film Anemometry in the Wake of a HAWT” – Hot film anemometry data were acquired in the near wake of a model turbine. A novel data reduction algorithm enabled both speed and direction data to be extracted. Distinct radial and tangential velocity data facilitated physical interpretations of the aerodynamics associated with blade and wake passage. (W. Haans, Delft Technical University, The Netherlands, T. Sant, University of Malta, Malta; G. van Kuik and G. van Bussel, Delft Technical University, The Netherlands)

“Dynamic Inflow Effects in NASA Ames Measurements: Radial Dependency and Comparison with Free Wake Lifting Line Model AWSM” – A simplified vortex computation was employed to construct an engineering model suitable for use in industrial design codes. Model results were compared with NASA Ames fast pitching data, and particular emphasis was placed on the radial dependencies observed in the dynamic inflow responses. (G. Schepers, H. Snel, and A. van Garrel, Energy Research Centre of The Netherlands, The Netherlands)

“Rotational Augmentation in Oblique Flow” – Advancing and retreating components of local inflow were added to a theoretical model for ro-

tational augmentation, to allow prediction of yawed operating conditions. Comparisons with previous models and with measurements were presented and physical explanations were given. (K. Lindenburg, Energy Research Centre of The Netherlands, The Netherlands)

“Stability of the Vortex System Behind a Wind Turbine Rotor” – This work extended the classical Joukowski model of an axisymmetric helical vortex field generated by a rotor. Very good agreement between this extended model and measured data was shown. It was postulated that further refinement of the model will help explain mechanisms responsible for wake meandering. (J. Sørensen and V. Okulov, Technical University of Denmark, Denmark)

“Tip Design Issues” – The KTH Tornado and NASA VLM vortex lattice models were used to investigate blade tip shape and to design a winglet for a 1.5 MW turbine. Model predictions indicated that blade induced drag could be reduced by 8 percent. (A. Knauer, Institute for Energy Technology, Norway)

“Rotor Computations Using ‘Steady State’ Moving Mesh” – A new technique was implemented in the EllipSys3D Navier-Stokes solver for solving steady state rotor computations using a moving mesh technique. Results agreed very well with previous moving frame computations, and showed that the moving mesh technique closely approximates the true physics. (N. Sørensen, Risø National Laboratory, Denmark)

“CFD Flow Field Analysis Around a Wind Turbine Generator” – A numerical simulation model based on actuator disk theory was developed and validated using experimental data. The model then was employed to evaluate intensity and distribution of turbine wake loss over simple terrain. Ultimately, the model will be used to evaluate wake loss over complex topography. (H. Matsumiya, Kyushu University, and T. Takagi, CRC Solutions Corporation, Japan)

“Numerical Computations of Wind Turbine Wakes” – CFD was employed to characterize the wake downstream of a wind turbine. Using detailed circulation analyses, improved understanding of the wake aerodynamics was achieved. This and similar comprehension will be used to construct reliable, physics-based engineering methods for designing future wind turbines. (S. Ivanell, Gotland University and Royal Institute of Technology, Sweden)

“CFD Activities at CENER” – Xfoil and Fluent simulations were used to predict the complex flow physics on rotating turbine blades. Computations were validated via comparisons with the NREL Phase VI rotating blade data for non-yawed conditions. These and subsequent results will provide insight regarding the complex flows underlying 3-D rotational effects. (E. Ferrer, Centro Nacional de Energías Renovables, Spain)

“3D Blade Geometry Stall at Parked and Rotating Conditions on the NREL Phase VI at Zero Yaw Angle” – Flow disparities between 2-D airfoils, 3-D parked blades, and 3-D rotating blades remain a challenge to comprehend. These investigations exploit data from the NREL NASA Ames test and Ohio State University wind tunnel to characterize these flow regimes and to develop better design tools for the wind turbine industry. (X. Munduate, Centro Nacional de Energías Renovables, Spain)

“Post-Stall Airfoil Performance Characteristics Guidelines for Blade-Element Momentum Methods” – This effort analyzed NASA Ames wind tunnel aerodynamic force and power data for unyawed rotors to provide guidelines for developing a stall delay/post stall aerodynamics model compatible with observed flow physics. (J. Tangler, National Renewable Energy Laboratory, and J. D. Kocurek, Computational Methodology Associates, United States)

“Unsteadiness in Rotationally Augmented Flow Field Structures and Aerodynamic Forces” – This project examined NREL UAE Phase VI mean and time varying surface pressure and aerody-

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dynamic coefficient data for axisymmetric operation, to understand the rotationally augmented flow field as a precursor to model formulation. (S. Schreck, National Renewable Energy Laboratory, United States)

4.0 PLANS FOR 2006 AND BEYOND

The 2006 Task XX Annual Progress Meeting will be held during April 2006 at the University of Applied Sciences in Kiel, Germany. As in previous years, the meeting will be held in collaboration with the Task XI Aerodynamics of Wind Turbines Joint Action Symposium Meeting.

The Operating Agent Representative plans to propose a no-cost extension of Task XX at the March 2006 IEA Wind ExCo meeting. If approved, this action would extend the Task XX completion date for one year, from July 2006 to July 2007. Notably, this extension would involve no participant contributions in excess of those already committed for the first three years of operation.

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

CHAPTER 5 TASK XXI

DYNAMIC MODELS OF WIND FARMS FOR POWER SYSTEMS STUDIES

1.0 INTRODUCTION

The worldwide development of wind power installations now includes planning of large-scale wind farms ranging in magnitudes of 100 MW, as well as application of wind power to cover a large fraction of the demand in isolated systems. As part of the planning and design of such systems, it is well established that the stability of the electrical power system needs to be studied. The studies are 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; whereas models for wind turbines or wind farms are not standard features. Hence, users are left to build their own wind farm models. This is not trivial and certainly not efficient. Rather, a coordinated effort is expected to enhance progress, and consequently, Task XXI under the IEA Wind Implementing Agreement was proposed and approved in April 2002 with SINTEF Energy Research of Norway as the Operating Agent.

2.0 OBJECTIVES AND STRATEGY

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

The overall objective is to assist 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 modeling for power system studies
- Develop, describe, and validate wind farm models. (The wind farm models are expected to be developed by individual participants of the task, whereas the description and validation will be 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 PROGRESS IN 2005

The task has participants from nine countries (Denmark, Finland, Ireland, the Netherlands, Norway, Portugal, Sweden, the United Kingdom, and the United States) with research institutes and universities carrying out work to develop and test wind farm models, as well as doing grid studies in cooperation with wind turbine manufacturers

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and electric utilities. In total, participants in the Task are expected to contribute with more than 20 person-years of work effort.

Cooperation within the task is through sharing of measurement data, model descriptions, and discussions at meetings. A total of seven task meetings have been arranged so far with two meetings held in 2005. The first was hosted by INETI in Portugal in June, and in November by ECN in the Netherlands. Model developments are ongoing among participants, including both fixed- and variable-speed technologies and by using various software tools (Matlab/Simulink, PSSE, 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. Benchmark testing of models is ongoing. Such tests include both validation against measurements and model-to-model comparisons, and they con-

sider dynamic operation during normal, fault-free conditions and response to grid fault. See Figure 1 and 2 for examples.

A topic of high interest is the ability of wind turbines to ride through temporary grid faults, hence, contributing to grid stability. Detailed numerical models may be used to assess such abilities, but these models must be validated against measurements to provide confidence. A proposal emerging as a spin-off from Task XXI is to update IEC 61400-21 (Measurements and assessment of power quality characteristics of grid connected wind turbines, ed. 1, 2001) to specify requirements for such testing. This work is now ongoing, expecting a first committee draft of IEC 61400-21, ed. 2, to be out by the beginning of 2006. Hence, in the future, wind turbine manufacturers may refer to standard test certificates for demonstrating performance under grid transients, and also these same test certificates may be used for validating dynamic models of wind farms for power system studies.

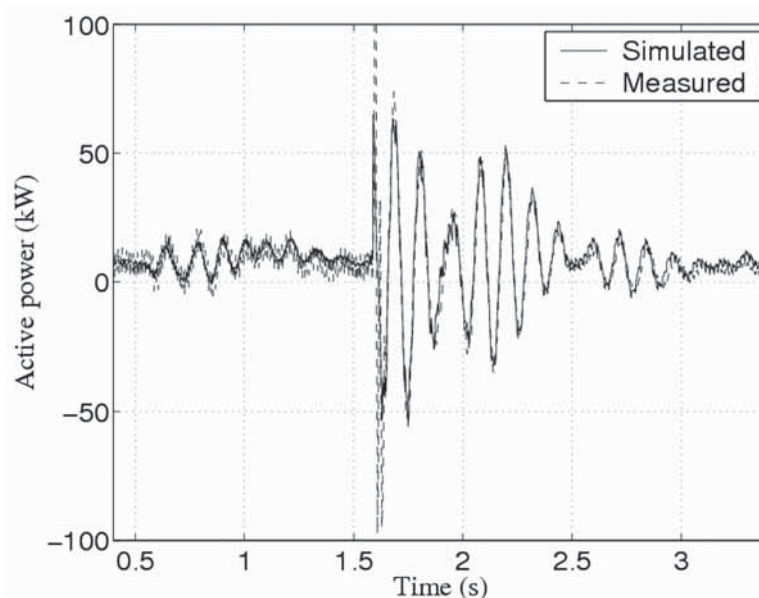


Figure 1 Power spectral density (PSD) of measured and simulated active power output from fixed speed, stall controlled wind turbine during normal operation.

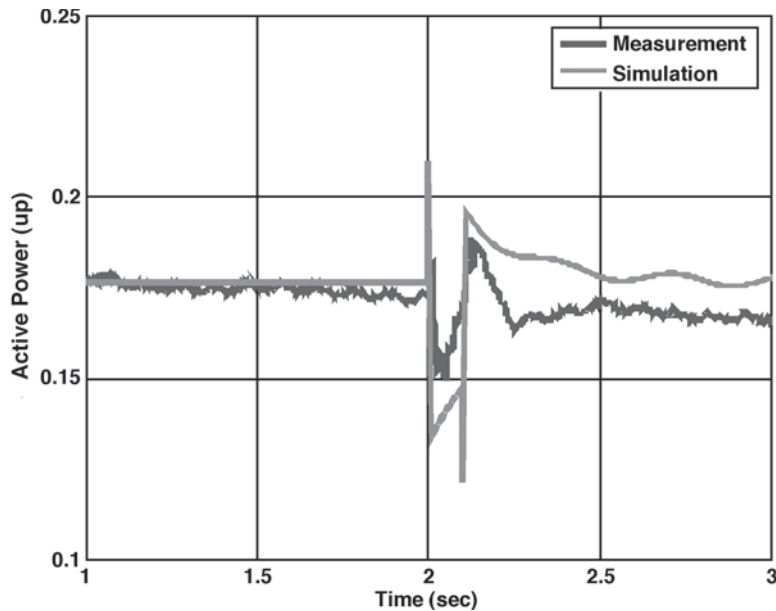


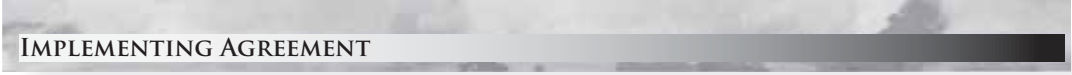
Figure 2 Time-series of measured and simulated active power output from variable speed wind turbine subject to a voltage dip.

4.0 PLANS FOR 2006 AND BEYOND

Task XXI was originally scheduled to close by the end of 2005, but has been extended to mid 2006. Plans for 2006 include organization of a workshop as part of EWEC'06 (European Wind Energy Conference & Exhibition, Athens, Greece 27 February - 2 March 2006). The workshop will include presentations by all participants of the

task and will be an excellent opportunity to disseminate results and getting feedback for final reporting. Additional information about Task XXI can be found on the Internet at <http://www.energy.sintef.no/wind/IEA.asp>.

Author: John Olav Tande, Operating Agent Representative, SINTEF Energy Research, Norway.



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CHAPTER 6 TASK XXIII

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. Especially larger onshore wind farms tend to be in somewhat remote areas, so electricity must be transmitted over long power lines to cities. Offshore wind

farms can be closer to coastal cities simplifying some transmission issues, yet far enough away to reduce visual and noise impacts.

Good wind resource, proximity to load centers, and expansion of development areas are some of the reasons why development of offshore wind energy is moving forward. By the close of 2005, there were 804-MW of offshore wind power operating in Denmark, the Netherlands, Sweden, and United Kingdom. Figure 1 shows how the current capacity is distributed among the European countries. China, Germany, Norway, 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,

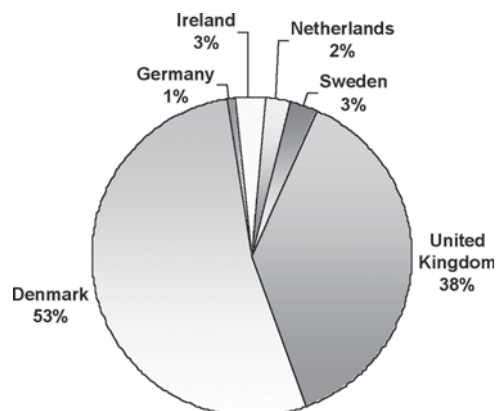


Figure 1 Offshore wind projects installed through 2005, based on a total of 804 MW.

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subsea 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.

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 XI 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. Figure 2 shows that outside the EU, China and the U.S. also have high potential for wind power development in deeper waters, followed by Brazil and Japan.

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

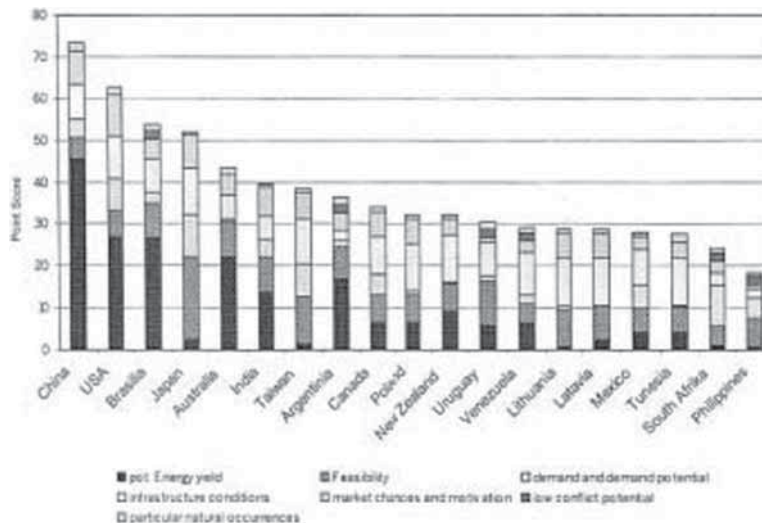


Figure 2 Offshore Potential for Non-EU Countries (some are now EU countries). Source: Siegfriedsen, Lehnhoff, & Prehn aerodyn Engineering, GmbH, Conference Proceedings of Offshore Wind Energy in the Mediterranean and other European Seas, Naples, Italy April 10-12, 2003.

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 XXIII 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.

2.0 OBJECTIVES AND STRATEGY

The overall objectives of Task XXIII 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 Topical Expert Meeting #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 Task 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. Each subtask is divided into Research Areas corresponding to the priorities that were determined at TEM #43 in March 2004. The Task XXIII structure showing the Research Areas with respect to the subtask is shown below in Figure 3.

3.0 PROGRESS IN 2005

3.1 SUBTASK ONE: EXPERIENCE WITH CRITICAL DEPLOYMENT ISSUES

Technical workshops have been planned in the following three research areas under Subtask One: Research Area 1: Ecological Issues and Regulations

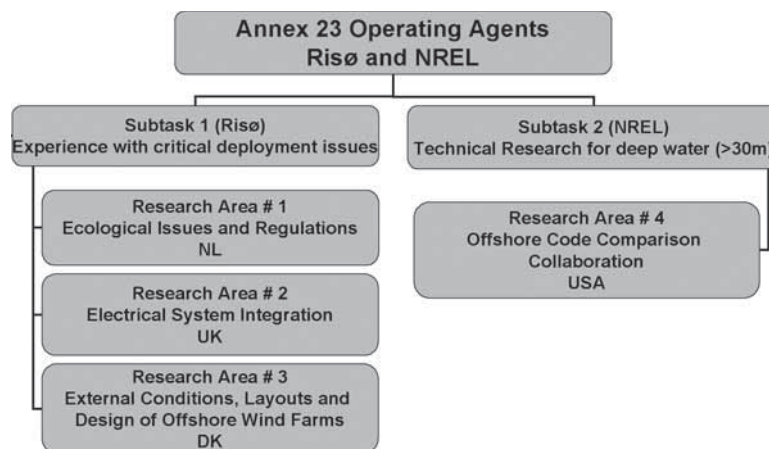


Figure 3 Task XXIII organizational flow chart.

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Research Area 2: Electric System Integration
Research Area 3: External Conditions, Layouts
and Design of Offshore Wind Farms.

The two workshops held in 2005 have been valuable forums for exchange of information.

The first workshop was held on Research Area 2 Electrical System Integration at Manchester University, UK on 12-13 September 2005. At this workshop it was decided to focus the work program on five issues covering the subjects related to Connection of Offshore Wind Farms to Onshore Grids. These are:

- Offshore wind meteorology and impact on power fluctuations and wind forecasting
- Behavior and modeling of high-voltage cable systems
- Grid Code and security standards for offshore versus onshore
- Control and communication systems of large offshore wind farms
- Technical architecture of offshore grid systems and enabling technologies.

The first workshop for Research Area 3 External Conditions, Layouts and Design of Offshore 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 Offshore Wind Farms.

- Wake modeling and benchmarking of models
- Marine boundary layer characteristics.
- Met-ocean data and loads.

The first workshop for Research Area 1 Ecological Issues and Regulations may be hosted by the Netherlands sometime in 2006.

A significant research area dealing with operation and maintenance issues was also considered a high priority topic but the planning of a workshop is pending the results of the Topical Expert Meeting to be held in early May 2006 under Task XI.

3.2 SUBTASK TWO: RESEARCH FOR DEEPER WATER

As a result of several meetings of experts participating in Task XXIII, Subtask Two was set up to address issues pertaining to deployment of wind turbines in water depths greater than 30 m. These issues include support structures that deviate from the present monopile technology. The procedure for identifying specific R&D collaborative tasks for Subtask Two will follow the workshop process similar to that for Subtask One discussed above and this process is already underway.

Under Subtask Two, a committed working group has focused on Coupled Turbine/Substructure Dynamic Modeling. This working group has been named the Offshore Code Comparison Collaboration (OC3) and is led by NREL. There are at least six codes under development or modification for more accurate prediction of support structure load modeling. A detailed plan for this project was distributed to the participants can be found at the following website along with other information for the subtask. (<http://www.ieawind.org/Annex%20XXIII/Subtask2.html>). Parts of this website can only be accessed by 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 comparison is the first step in quantifying and reducing load prediction uncertainties. Thus the OC3 group has identified the following objectives:

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

The scope of this effort within Task XXIII addresses near-term and future needs of the industry. Currently the industry is focused on fixed-bottom shallow water applications, especially in Europe where shallow water sites are plentiful. In Greece, Japan, Korea, Norway, Spain, the United States, and many other countries, deeper water sites are more common; so support structures that are likely to become solutions for these markets must also be included. Therefore, the scope of this collaboration includes technologies ranging from the current shallow-bottom monopiles to deep-water floating platforms using the following boundaries: Water Depth Range: 5 m – greater than 200 meters; Support Structures: monopiles to floating platforms; Wave loading models: linear and non-linear (breaking); Uncoupled and coupled dynamic models: FAST, ADAMS, Bladed, HAWC2, TURBU, FLEX5, others. Not included are aerodynamic models, turbulence models, various turbine types, and controls.

As set up by the participants, OC³ is a multiphase project in which the first phase is strictly analytical with the goal of verifying the capabilities and differences of the codes of the participants. The second and third phases will compare codes with various support structures and foundation models. In Phase I, each code having a unique set of capabilities will run predefined simplifying cases to enable initial transparency among the code comparisons. Making comparisons at the simplest possible turbine and support structure will establish a baseline agreement. Systematically increasing complexity will help isolate sources of model disagreement and the impact of simplifying assumptions. This phase was nearly completed in 2005. Phase II will begin in 2006 after discussion of the final Phase I simulations and resolution of discrepancies. Phase II will compare various support structures under different wind and wave load conditions. Phase III will compare different foundation models.

Since the second meeting in Trondheim, Norway at NTNU on 14-15 June 2005, the committee has

held regular internet meetings. Through this process the baseline turbine model has been finalized, preliminary runs for basic load cases from all the participating codes have been compared, support structures have been agreed on but detailed definitions are expected to be completed in 2006.

The current active OC³ participants include:

DNV, Denmark
 Elsam, Denmark
 Garrad Hassan, United Kingdom
 GL Windenergie, Germany
 NREL, United States
 NTNU, Norway
 RISØ, Denmark
 Siemens Windpower, Denmark
 Stuttgart, Germany
 Vestas, Denmark

4.0 PLANS FOR 2006 AND BEYOND

The task activities are now underway and eight countries are expected to join as shown in Table 1. Because the task rules allow for participation of multiple organizations from each country, the participating organizations are also listed in this table. However, task membership is not limited to those organizations shown.

Each country may have several participating organizations for a single membership fee, with the hope that more organizations will lead to more robust results. It will be the responsibility of each country to determine how this cost of membership is distributed among the individual organizations.

The Task will continue for a period of four years beginning May 2004. The Task may be extended for such additional periods as may be determined by two or more participants, acting in the ExCo.

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

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Table 1 Participating countries and organizations in Task XXIII		
Country	Membership Status/ Contracting Party	Organization
Denmark	Committed/RISØ National Laboratory	<ul style="list-style-type: none"> • RISØ National Laboratory • Vestas • Siemens Windpower • Elsam • Carl Bro • DNV
Finland	TBD	<ul style="list-style-type: none"> • VTT
Germany	Committed/Ministry for Environment, Nature Conservation and Nuclear Safety.	<ul style="list-style-type: none"> • University of Stuttgart • GE Energy • GL Windenergie
Japan	TBD	<ul style="list-style-type: none"> • MITI
Korea	Commitment expected	<ul style="list-style-type: none"> • KEMCO
Netherlands	Commitment expected	<ul style="list-style-type: none"> • ECN
Norway	Committed/Enova SF	<ul style="list-style-type: none"> • NTNU-BAT
Sweden	Commitment expected	<ul style="list-style-type: none"> • Chalmers
United Kingdom	Comitted/Department of Trade and Industry	<ul style="list-style-type: none"> • Garrad Hassan • Ceasa
United States	Committed/US Department of Energy	<ul style="list-style-type: none"> • NREL • MIT • University of Massachusetts • GE Energy

CHAPTER 7 TASK XXIV INTEGRATION OF WIND AND HYDROPOWER SYSTEMS

1.0 INTRODUCTION

Within IEA member countries, there is about 450 GW of hydropower capacity and approximately 52 GW of wind power capacity. Several of the member countries are pursuing the idea of 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 need for conducting research on the integration of wind and hydropower technologies under the auspices of the IEA Wind agreement. In response, a pro-

posal for Annex XXIV Integration of Wind and Hydropower Systems was approved by the ExCo in May 2004. This cooperative research effort (Task), 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. In addition, the IEA Wind Task XXIV works in cooperation with the IEA Hydropower Implementing Agreement, which is investigating integration of hydropower and wind through a complementary set of investigations. Table 1 lists the contracting parties and participants in Annex XXIV.

Table 1 Annex XXIV 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
Norway	Norwegian Water Resources and Energy Directorate	Sintef Energy Research
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

2.0 OBJECTIVES AND STRATEGY

Task XXIV 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 XXIV 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;

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

The objectives and outcomes of the task will be achieved through four types of case studies: 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 task is planning to contribute at least one case study.

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).

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.

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 PROGRESS IN 2005

A kickoff meeting, held on February 22-23, 2005, at Hoover Dam, near Boulder City, Nevada, United States, initiated the collaboration among participating countries and defined the task work plan. Twenty-five people attended the meeting, representing all participating countries. The general work plan is for participating countries to conduct case studies and report on the progress

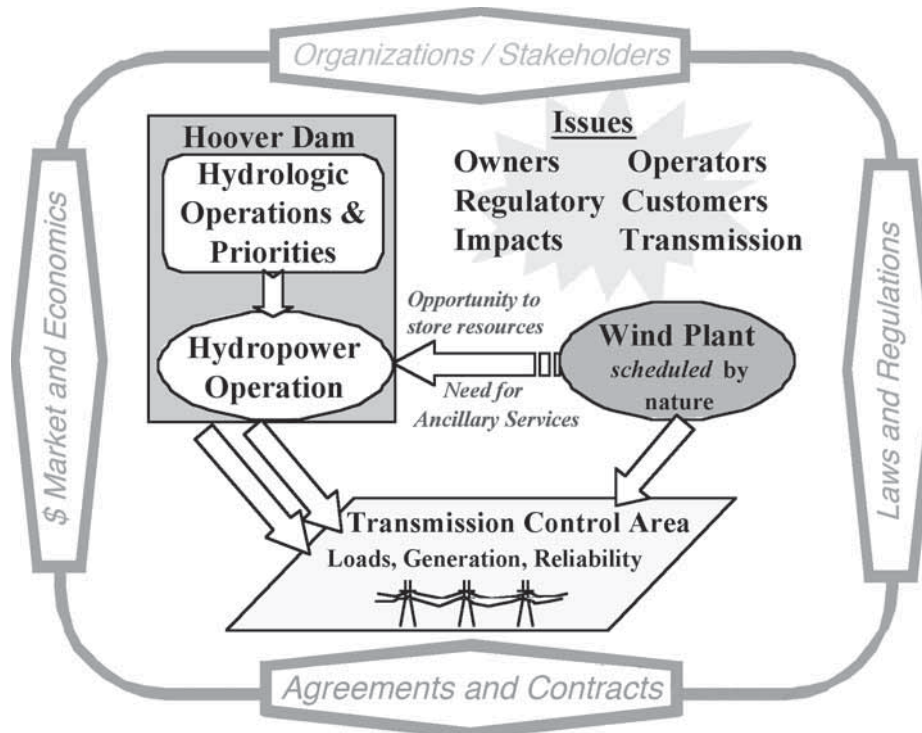


Figure 1. A conceptual view of the relationships between wind power, hydropower, and the transmission control area, and the issues surrounding their integration.

and results of their case studies at task R&D meetings. Due to the differences inherent in an international collaboration, participants decided to formulate a consistent framework for formulating problems and presenting results (a “matrix”) to facilitate the sharing of information. Participants also decided that the work of the task would be completed in close association with a similar task forming as part of the IEA Hydropower Implementing Agreement.

The first task R&D Meeting was held in conjunction with the IEA Wind ExCo Meeting No.56, in Lucerne, Switzerland. The ExCo meeting was held September 27-28, 2005, an excursion to the Andermatt wind turbine and Grimsel hydropower station was conducted on September 29, and the

task meeting was held September 30. Meeting participants presented project progress reports and made excellent progress in formulating the “matrix.”

4.0 PLANS FOR 2006 AND BEYOND

The task will hold a “web meeting” in spring 2006, and the second R&D meeting will be held in September 2006 in Tasmania, Australia. Meanwhile progress will continue in documenting the case studies by each task participant and in simplified modeling of wind-hydro integration potential.

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CHAPTER 8 TASK XXV

DESIGN AND OPERATION OF POWER SYSTEMS WITH LARGE AMOUNTS OF WIND POWER

1.0 INTRODUCTION

Wind power will introduce more uncertainty in 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 first 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 comparisons 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 ultimate 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: Other task work in IEA Wind and IEA Demand Side Management (DSM) Implementing Agreement, International Council on Large Electric Systems CIGRE, Utility

IMPLEMENTING AGREEMENT

Wind Integration Group (UWIG) and European Transmission System Operators (ETSO).

The participants will collect and share information on the experience gained; review the studies made up to and during the task; analyse the data and tools used in the studies; and process guidelines on methodologies used to determine the impact of wind power on power systems. 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: the impact that wind power has on reliability and efficiency of the power system. Costs will be assessed when necessary as a basis for comparison. Also technology that mitigates impacts of wind power and supports enhanced penetration will be addressed by communicating successful concepts such as modification of wind farm controls and operating procedures; dynamic line ratings; storage; DSM, etc.

The task work will start with producing a state-of-the-art report on the knowledge and results so far and 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.

3.0 PROGRESS IN 2005

The Annex was approved at the ExCo meeting in September 2005. The first task was to connect with all possible participants and the system operators through CIGRE and ETSO work. Work for organizing the kickoff meeting (in January in Germany) also started. Table 1 shows the countries that participate in the task. It will be possible for new countries to join the task during 2006.

4.0 PLANS FOR 2006 AND BEYOND

After the kick-off meeting in January 2006, the task work will officially begin, with more detailed


Country	Institution
Denmark	Risø National Laboratories
Finland	VTT Technical Research Centre of Finland
Germany	ISET
Ireland	To be confirmed
Norway	SINTEF and Statkraft
Netherlands	ECN
Portugal	INETI
Spain	University Carlos III, Madrid
Sweden	KTH
UK	Centre for Distributed Generation and Sustainable Electrical Energy
USA	NREL

country contributions, project web pages, and gathering of literature related to system integration. A poster outlining the task objectives and strategy will be presented in EWEC'06 conference, Athens, 27 March 2006.

The national projects working on case studies began in 2005 or early 2006. The work on the state-of-the art report will start in spring 2006, analysing the existing results. This report will be the main subject in the first meeting that will be held in conjunction of Nordic Wind Power Conference 24 May 2006 in Helsinki, Finland. If needed, a second meeting will be organised in conjunction with a UWIG seminar in 26 October 2006 in Oklahoma, in the United States. The first version of the state-of-the art report is due in December 2006.

The second year, 2007, will be working time for national case studies, collecting of more results, and continuing with the analyses. Task meetings will be organised together with other IEA Wind research activities: Task XXIV Integration of Wind and Hydropower Systems and the sub-task working on grid issues from Task XXIII 23 Offshore Wind Energy Technology Development. 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 for. Guidelines and best practices will be formulated.

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IMPLEMENTING AGREEMENT



CHAPTER 9

IEA

ACTIVITIES ON RENEWABLE ENERGY

1.0 RENEWABLE ENERGY RD&D PRIORITIES

The latest IEA study, *Renewable Energy RD&D Priorities, Insights from IEA Technology Programmes*, (1) reveals that the research, development, and demonstration (RD&D) programs of governments will play a vital role in enabling renewable technologies to deliver their potential. The study presents the status of renewables in the energy mix and considers priorities for the RD&D effort, drawing extensively on studies and analysis carried out by all IEA Renewable Energy Implementing Agreements, including IEA Wind.

Across IEA member countries, the range of energy sources used for total primary energy supply is becoming more diverse, and renewable sources play an increasingly important role. In 2003, renewable energy sources constituted 5.5% of the IEA total primary energy supply (Figure 1). The renewable energy sources portion included mainly: biomass and waste (2.91%) and hydropower (2.03%). “Other” renewable energy sources referenced in Figure 1 and their contributions to total primary energy supply in 2003 include: geothermal power (0.392%), solar photovoltaics (0.06%), wind power (0.098%), and tide (0.001%).

The strong growth of emerging renewables over the last few years, particularly wind and solar

electricity generation as well as modern bioenergy plants, is enhancing the importance of renewables in the IEA energy mix. However, the use of these new renewables is concentrated in just a few countries. In 2003, 86% of IEA total installed wind power capacity was in only four countries (Denmark, Germany, Spain, and the United States) and about 84% of the installed solar PV capacity was in just three countries (Germany, Japan, and the United States).

The IEA study reveals that total government energy RD&D budgets in IEA member countries increased sharply after the oil price shocks in the 1970s (Figure 2). In the period 1974–2003, reported renewable energy RD&D budgets of IEA member countries totalled about 27.4 billion USD, some 7.6% of total energy RD&D funding. Expenditures for renewables RD&D grew rapidly in the late 1970s and peaked in 1980 at more than 2.1 billion USD. Expenditures halved in the early 1980s, but they have been relatively stable since. Annual expenditures on renewables RD&D for all IEA member countries averaged about 752 million USD from 1990–2003, or 8.2% of total government energy RD&D budgets.

Charting the shares of renewable energy technology RD&D funded through public resources shows distinct changes in technology priorities over time. In 1974, geothermal, solar heating and cooling, and solar thermal electric accounted for 84% of renewable energy RD&D (Figure 3). In 2003, the predominant technologies were PV, biomass and wind, accounting for 76.3% of renewable energy RD&D.

The IEA study identifies in detail RD&D priorities for all renewable energy technologies, including bioenergy, hydropower, geothermal, wind, photovoltaics, solar heating and cooling, concentrating solar power, and ocean energy systems.

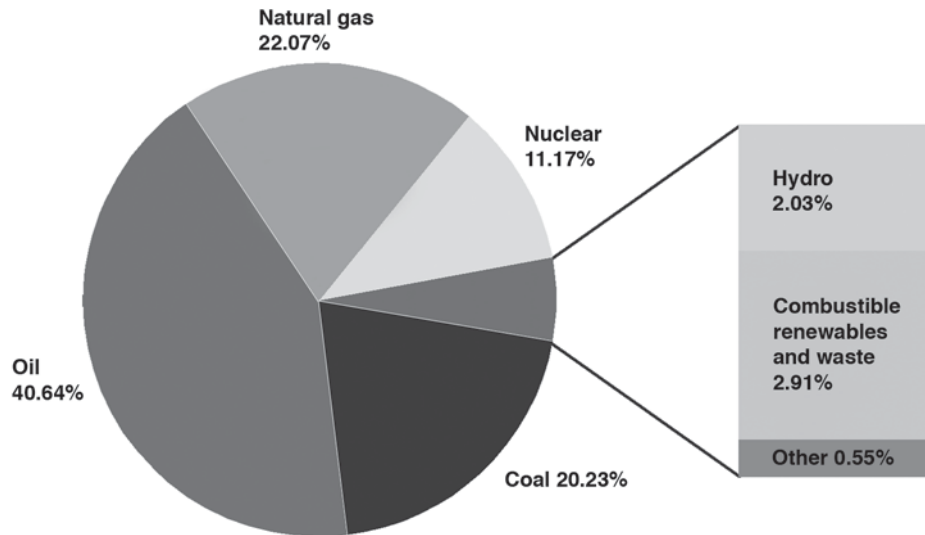


Figure 1 Fuel shares of IEA total primary energy supply, 2003.

These RD&D priorities can be classified in three major groups: social acceptance and environmental impact issues, issues of intermittency and development of materials, and intensified RD&D.

The study concludes that a move towards a greater share of renewable energy technologies in the energy mix depends on three inter-related elements: resource availability, technical maturity, and a policy environment conducive to both technological advancement and commercialisation.

Technology development and market experience are strongly linked and can function as a “virtuous cycle.” The virtuous cycle takes into account the relationship between technology RD&D, improvements in manufacturing, and learning from market experience. A public policy environment that encourages more private sector involvement could enhance and accelerate renewable energy technology development and commercialisation.

The IEA estimates a need for investment of 17 trillion USD for global energy supply infrastructures over the next 25 years. The key to capturing increasingly significant market shares

for renewable energy technologies is a strategy that can concurrently achieve several goals. The key element towards the realisation of the role of renewables in the energy mix is the accelerated technological advancement and cost reduction of all the renewable technologies, combined with novel applications and deployment in the context of distributed generation, global production and trading of fuels, and bulk transmission of renewables-generated electricity.

2.0 NEW IMPLEMENTING AGREEMENT FOR RENEWABLE ENERGY TECHNOLOGY DEPLOYMENT

Over the past several years, following the guidance of the Renewable Energy Working Party (REWP), the renewable energy Implementing Agreements (IA) have undertaken to discuss deployment tasks that would complement and extend their technology-specific work.

At its 45th meeting, in March 2004, the REWP recommended that a new IA be considered to complement the technology R&D work of the existing renewable energy Implementing

Agreements and the IEA Secretariat's policy analysis work by identifying barriers and recommending solutions to commercial deployment of renewable energy technologies as a means to further enhance technology development. Following the meeting, the REWP circulated to its members the concept for a new technology deployment IA. At the International Conference for Renewable Energies in Bonn, in June 2004, six IEA Member countries, Denmark, France, Germany, Ireland, Italy, and Norway, with inputs from the European Commission, announced their intentions to work towards establishment of a Renewable Energy Technology Deployment Implementing Agreement (RETD) and signed a joint declaration.

The interested countries further developed the proposal for a new Implementing Agreement, and in the course of 2004 they determined priorities for the program of work, addressed administrative issues, including budget and structure, and formed an Interim Executive Committee. After

the positive review by the REWP and endorsement by the CERT (IEA Committee for Energy Research and Technology), the IEA Governing Board established the Implementing Agreement for Renewable Energy Technology Deployment on 15 September 2005 and to date the Agreement is participated in by eight Contracting Parties (Canada, Denmark, France, Germany, Italy, the Netherlands, and the United Kingdom).

The following are the three main objectives for RETD:

- To elaborate and present options for “best practice” policy measures and mechanisms for cost reduction, enabling increased use of renewable energy in competitive energy markets through strengthened international collaboration;
- To elaborate and present options for innovative business strategies and projects that will encourage renewable technology deployment to public and private sector stakeholders; and

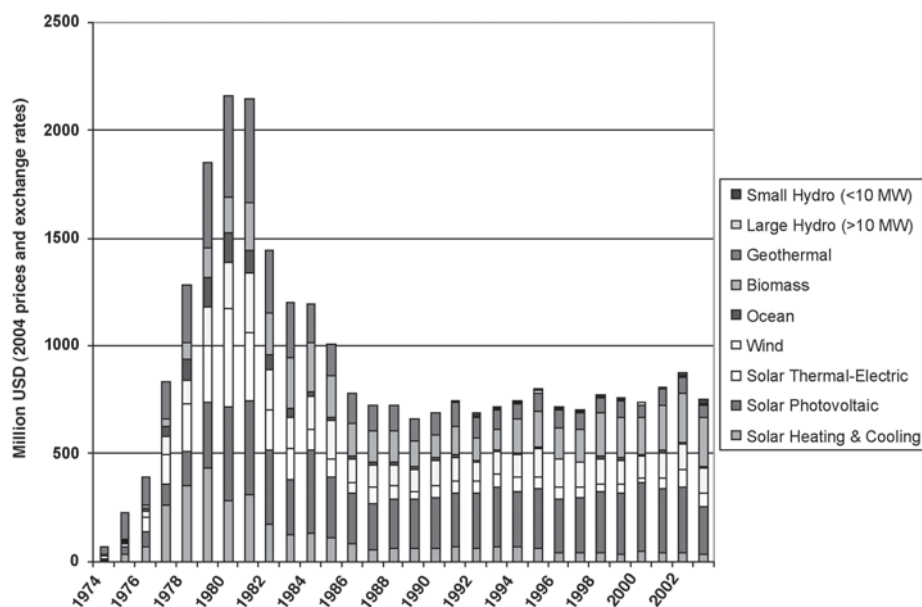


Figure 2 Reported government renewable energy RD&D budgets for IEA member countries, 1974-2003.

NATIONAL ACTIVITIES

- Building from the unique framework of the IEA, to disseminate information and enhance knowledge about renewable technology deployment, complementing other information programs in supporting improved public and private sector decision making.

3.0 IEA REPORT: VARIABILITY OF WIND POWER AND OTHER RENEWABLES

Some IEA member countries have substantially increased their share of renewables in power generation, and others have set themselves ambitious targets for technology deployment. In the view of this, concerns about the integration of renewables into electricity grids have recently received a great deal of public attention, and the intermittency of wind power has been discussed most prominently.

The study, *Variability of Wind Power and Other Renewables - Management Options and Strategies*, draws mainly on experiences in Denmark and Germany. It also draws upon some theoretical analyses, and reviews existing literature from a number of countries putting it into the context of the current debate. It shows how wind intermittency is part of the natural resource variability affecting all renewables and presents the current thinking on the technical and policy implications of variable electricity supply from renewables.

The study concludes that a number of measures are necessary to integrate wind energy and other renewables into modern electricity grids, even though the fundamental technical principles are not new. The geographical aggregation of generators such as wind turbines reduces the volatility of output. Improved forecasting methods will make it more predictable. Both aspects are already widely used in electricity markets. Furthermore,

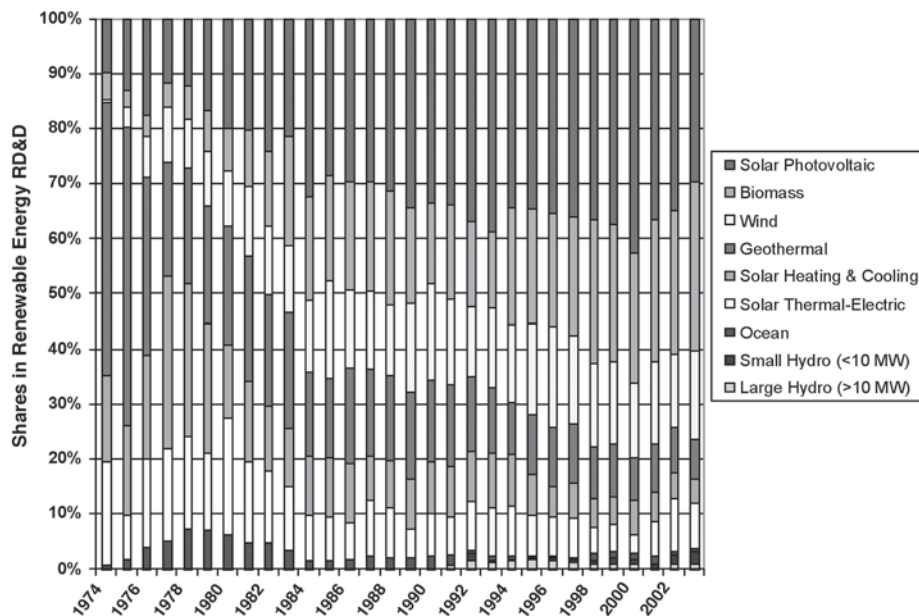


Figure 3 Shares of renewable energy technologies in public renewable energy RD&D spending in IEA member countries, 1974-2003.

careful attention needs to be paid to the timely extension of transmission and distribution grids in order to ensure system stability at all times. In particular, trans-boundary electricity exchange is going to play an increasing role, which will have to be assessed. Although these issues are also central to market liberalisation and security of supply concerns, they will become even more important with increasing market penetration of wind power. Finally, as each renewable energy technology fluctuates over a different time-scale, one can expect gains from the complementarities of these cycles, subject to resource availability.

Apart from the technical issues, the extent to which the intermittency of natural resources constitutes a barrier to the deployment of renewables is mainly a question of economics and market organisation. Grid extensions and the provision of reserves which are attributable to wind power come at costs which have to be taken into account when considering the overall economics of wind power. The precise costs depend on a number of factors, including the level of market penetration of wind power, the availability of the renewable resource, the state of the existing grid and current technology mix. Transparent, inter-connected and well-functioning markets help to minimize these grid integration costs, as will experience with these systems over time.

4.0 IEA REPORT: OFFSHORE WIND EXPERIENCES

The IEA study, *Offshore Wind Experiences*, reviews the experiences of the first series of commercial-scale offshore wind installations. The study concentrates on the pioneering Northern European projects, implemented between 2000 and 2004. It addresses all aspects of the barriers and achievements encountered in these early developments. It has specifically involved five offshore wind farms with interviews of key individuals associated with those projects. The study highlights the importance of thorough planning

and attention to detail. Technology associated costs have tended to be higher than anticipated. There remains a role for RD&D in offshore specific areas as well as collaborative project work.

The report confirms that political support which feeds to a shared agenda across government departments has been instrumental in successful implementation. Stable framework conditions have supported the start-up phase of this new technology and their absence has led to delays in investment. The provision by governments of “one-stop shops”- whereby developers have to communicate with only one official contact point to handle administrative and legal matters - has been a success. Strategic Environmental Assessment is a helpful tool for consenting authorities and for developers as it allows early warning on potential impacts and has reduced individual project consent timescales.

The study reveals that given the large number of projects planned in the North- and Baltic-Sea, there is significant potential for the sharing of transmission lines and costs. Governments need to establish clear rules for the allocation of costs and access to the grid.

5.0 RENEWABLE ENERGY POLICIES AND MEASURES ON A GLOBAL SCALE

The Global Renewable Energy Policies and Measures Database is an initiative led by the International Energy Agency, and is being implemented in collaboration with the European Commission and the Johannesburg Renewable Energy Coalition. The database features over 100 countries and offers renewable energy market and policy information in one format in one location for countries that together represent almost total global renewables supply. The database is freely accessible online at <http://renewables.iea>.

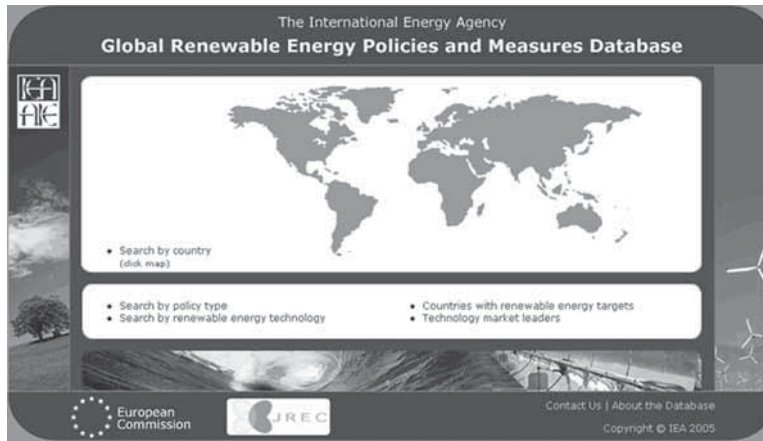


Figure 4 A screen view of the Global Renewable Energy Policies and Measures Database.

org. Visitors can search for information according to country, policy instrument, renewable energy technology, renewable energy target, and other criteria. (Figure 4 pg. 114)

This online database is part of a continued effort by the International Energy Agency to contribute to the global dialogue on renewable energy by providing unbiased information and analysis for the use by decision-makers, policy experts, researchers, and industry, as well the broader public.

REFERENCE

(1) Renewable Energy RD&D Priorities, Insights from IEA Technology Programmes, OECD/IEA 2006.

Author: Piotr Tulej, Head, Renewable Energy Unit, International Energy Agency, France.



CHAPTER 10
AUSTRALIA

1.0 INTRODUCTION

Australia has one of the strongest and most consistent wind resources in the world, with capacity factors almost double those achieved in Europe. Australia possesses large open tracts of land suitable for wind energy projects, and a national electricity grid currently capable of supporting an installed wind energy capacity of approximately 8,000 MW – more than 10 times higher Australia’s current installed capacity of 708 MW (1).

There are close to 6,000 MW of wind energy projects in the pipeline in Australia. These projects are estimated to collectively generate 10 billion AUD in capital investment, 19 million AUD in landholder lease payments, approximately 8,000 jobs, and enough power for more than three million households (2).

With the effects of climate change becoming increasingly apparent in Australia’s rural and regional areas, hosting wind turbines is a desirable rural enterprise for many landholders looking for an alternative drought-proof source of income. In addition to landholder lease payments, there are local government rate payments, and local investment and employment benefits which strengthen the Australian wind energy industry’s position as an attractive business for rural communities.

An important driver for the development of the industry has been the expansion of a strong local manufacturing industry, which now employs close to 350 Australians (3). This local manufacturing capacity supports the Australian industry’s goal of becoming a support hub for the Asia-Pacific region.

Other Asia-Pacific outreach efforts have been achieved through strong advisory alliances and joint ventures with the Chinese and Fijian renewable energy sectors, and new opportunities are being explored with countries participating in the Asia-Pacific Partnership on Clean Development and Climate (AP6) (4).

Total installed wind generation	708 MW
New wind generation installed	328 MW
Total electrical output from wind	2.171 TWh
Wind sector turnover Figure assumes 35% capacity factor and 75 AUD/MWh power price and does not include gains from sales of wind farms.	100 million €
Wind generation as % of national electric demand	<1%
Target:	The MRET target has effectively been met in Australia.

NATIONAL ACTIVITIES

The Australian wind energy industry has expanded considerably under the Federal government's Mandatory Renewable Energy Target (MRET), which requires large energy users and energy wholesalers to purchase 2% of their energy from renewable sources by 2010, or an additional 9,500 GWh (5). Australia's wind energy capacity has grown almost ten-fold under the MRET, from 74 MW in 2001, when the scheme was introduced, to the current capacity of 708 MW (Figure 1).

Due to the success of the MRET scheme, Australia's renewable energy target has been filled almost twice as quickly as expected. In response to the MRET's success, and recognising the potential for the further deployment of wind energy technology, several state governments have introduced their own targets to ensure the continued growth of the renewables sector. The Federal Government has publicly stated its commitment to further develop clean energy technologies such as wind energy, but has not yet established any further legally binding mechanisms to continue the deployment of renewable energy projects beyond the MRET.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

2.1 INDUSTRY GROWTH IN 2005

The Australian wind energy industry experienced significant growth in 2005, almost doubling the industry's 2004 capacity of 380 MW. At the close of 2005, Australia had 708 MW of installed wind energy capacity, estimated to produce 2,170 GWh of electricity every year and meet the household energy needs of over 300,000 Australian homes. By the end of 2006, Australia's installed capacity is expected to reach 788 MW, representing a total capital investment of 1.4 billion AUD.

Australia has approximately 450 turbines operating across the country, with an average rated capacity of 1.75 MW (2). Australia's wind turbines have one of the highest capacity factors in the world, with an average of 35%.

The Australian wind energy industry currently offsets 2.8 million tons of CO₂ per year, the equivalent of taking 650,000 cars off the road (see Figure 2).

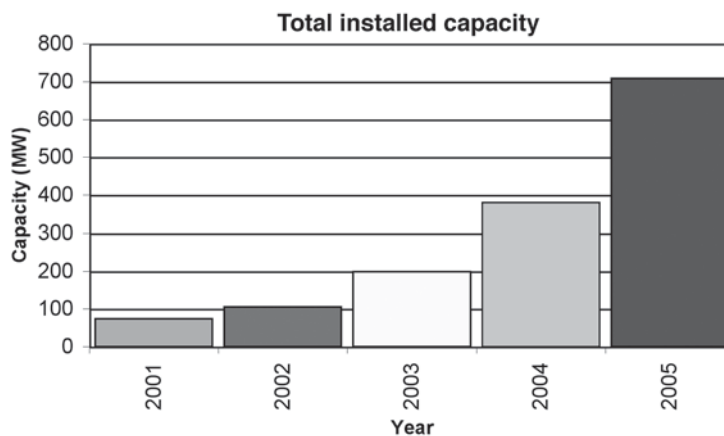


Figure 1 Australian Wind Energy Capacity: Cumulative Growth 2001-2005

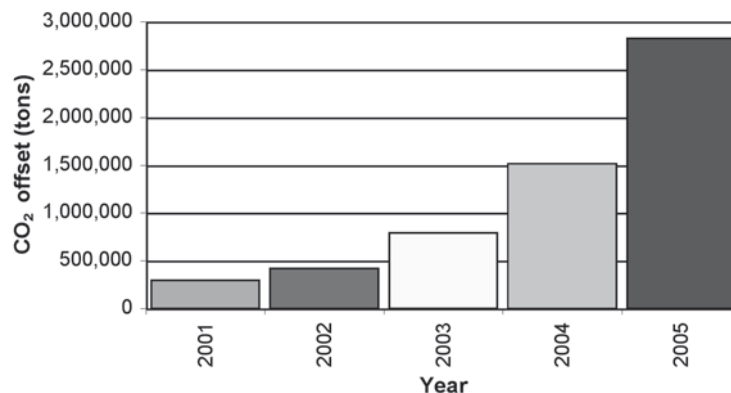


Figure 2 Cumulative tons of CO₂ offset by Australian wind energy production: 2001-2005.

2.2 ASIA-PACIFIC PARTNERSHIP ON CLEAN DEVELOPMENT AND CLIMATE

In August 2005, the federal government announced its commitment to join the Asia-Pacific Partnership on Clean Development and Climate (AP6) along with five of the world's major greenhouse polluters (4). The partnership is designed to bring together key developing and developed countries in the Asia-Pacific region to address the challenges of climate change, energy security, and air pollution in a way that strives to encourage economic development and reduce poverty. The founding countries of this partnership encompass around half of the world's greenhouse gas emissions, population and energy consumption.

The partnership is aimed to work alongside the Kyoto Protocol to reduce the participating nations' greenhouse gas emissions. At the inaugural meeting of AP6 in Sydney, the Australian government committed an additional 25 million AUD over five years for renewable energy projects. No further details have been released on where these funds will be directed or how they will be administered. At this stage, the partnership does not set any binding or regulatory commitments to expand the deployment of wind energy projects in Australia beyond the MRET.

2.3 MARKET DRIVER - MANDATORY RENEWABLE ENERGY TARGET

The majority of renewable energy projects in Australia have been developed under the federal government's Mandatory Renewable Energy Target (MRET) – the mechanism to expand renewable energy production in Australia (5). The MRET was the cornerstone for the Australian renewable energy industry and a world-first in terms of creating a nationally legislated renewable energy market. The target requires large energy users and energy wholesalers to purchase 2% of their energy from renewable sources by 2010 through to 2020. Under the MRET, which covers 23 renewable energy technologies, the Australian wind energy sector has grown by 634 MW – a growth rate of nearly 100% every year since the scheme was introduced in 2001 (Figure 1).

MRET aimed to increase the percentage of Australia's energy from renewable sources to 12.5% by 2010, an increase of 2% based on Australia's 1997 national electricity consumption levels. However, due to higher than expected electricity demand forecasts, this target has been diluted significantly to an increase of less than 0.5% of Australia's total energy consumption.

2.4 STATE-BASED GROWTH AND STRATEGY

A number of state governments indicated their intention to develop a state-based renewable energy target in late 2004. In April 2005, Australia's state and territory leaders reached an in-principle agreement to establish a state and territory-based emissions trading scheme. State energy ministers from NSW, Victoria, SA and Tasmania have so far agreed to:

1. Accelerate the current work being done on emissions trading;
2. Establish an Inter-Jurisdictional Working Group to recommend ways to increase the MRET from the current level and time frame; noting the recommendations of the federal government's MRET review panel as a minimum outcome; and
3. Demand immediate action by the federal government to offer incentives to promote energy efficiency and demand management.

2.4.1 NEW SOUTH WALES

NSW has an excellent wind resource and a robust electricity grid that is ideal for wind energy generation. Modeling conducted by the Australian Greenhouse Office (AGO) demonstrates that NSW's grid has the capacity to support 3,000 MW of wind energy, giving NSW the greatest capacity of any Australian state to incorporate wind energy into the electricity system (1).

The NSW government released an *Energy Directions Green Paper* in December 2004 to map out the future of the state's energy supply (6). The green paper does not include any mechanisms to expand the market for renewable energy in the state. In late 2005, the NSW government also unveiled a new environmental statement which included plans for a three-day national summit on climate change, and a 24 million AUD fund to drive development of clean technologies.

The current installed wind energy capacity of NSW is 17 MW with a further eight wind energy projects, totaling more than 500 MW, already

with planning approval or in the advanced stages of the approval process. There are another 500 MW of wind energy projects on the drawing board in NSW (Figure 3).

2.4.2 VICTORIA

The Victorian government has been extremely supportive of the wind energy industry in its state. The government's Greenhouse Strategy includes a target of 10% renewable energy consumption by 2010, with a non-binding goal of 1,000 MW of installed wind energy by 2006 (7). In 2005, the Victorian government took steps towards introducing a market-based scheme to achieve the state's target (8). Further progress on a market-based scheme is expected to take place in 2006, with an indicative commencement date of January 2007.

In March 2005, the Victorian government launched the Wind Energy Support Package which will provide funding to assist the connection of wind energy projects to the state's electricity network, where these costs would otherwise make the investment marginal. The package aims to increase investment in wind energy facilities in appropriate and environmentally acceptable locations in regional Victoria. Victoria also has an 8.45 million AUD Renewable Energy Support Fund, administered by the Sustainable Energy Authority of Victoria (SEAV), which provides up to 20% of the capital cost of medium-scale renewable energy projects (9).

Victoria currently has 104 MW of projects operating in the state, with a further 30 MW under construction. Approximately 1,700 MW of further projects are undergoing various stages of feasibility, with 300 MW of these projects already receiving planning approval.

2.4.3 QUEENSLAND

Although interest in wind energy generation has not been as strong in Queensland as in other states, the potential for Australia's north-east state is still quite large. Under the Queensland

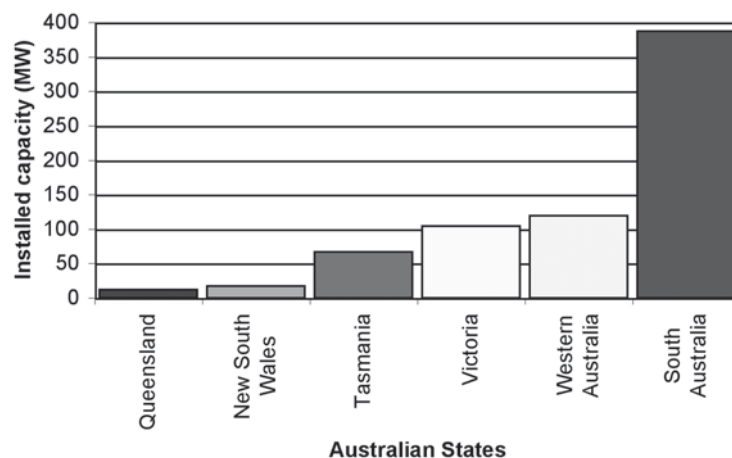


Figure 3 Australian states: installed wind energy capacity 2005.

government's Cleaner Energy Strategy, released in 2000, electricity retailers are required to source 15% of electricity sold in Queensland from gas-fired or renewable energy from January 2005 (10). The government is also spending 50 million AUD over five years on existing and new programs supporting renewable and innovative energy technologies that reduce greenhouse gas emissions.

There is just one 12-MW project operating in Queensland, the Windy Hill Wind Farm located near Cairns. A further 175 MW of projects are in the feasibility stages.

2.4.4 WESTERN AUSTRALIA

The government of Western Australia announced in early 2005 its plans to establish a renewable energy target for WA's main electricity grid and is investing in new renewable energy projects as part of a 59.75 million AUD package (11). The main element of the package is to increase the proportion of renewable energy in the South West Interconnected System from 1% to 6% by 2010. The target represents a 50% increase above what would be expected under the MRET. The government aims to achieve the target by supporting the expansion of the MRET or, if necessary, other mechanisms aimed at delivering renewable energy in a competitive market environment.

The government has also committed to establishing eight new renewable energy projects in remote towns by 2010. Coral Bay on the Ningaloo Coast has already been identified as one of the eight towns to benefit by committing to build a new 5.7 million AUD wind-diesel power system.

There is 119 MW of wind energy capacity currently installed in Western Australia, with over 166 MW in various stages of development and feasibility.

2.4.5 SOUTH AUSTRALIA

South Australia is the country's wind energy leader and has already approved plans which will result in this state having the third highest percentage of installed wind energy capacity in the world. South Australia has 387 MW of installed wind energy capacity, representing more than half of Australia's total installed capacity. There are over 2,000 MW of proposed projects in the state, many of which have already received planning approval.

The South Australian government's Strategic Plan includes a number of targets to encourage renewable energy development in the state (12). These include increasing the use of renewable energy so

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that it comprises 20% of the state's total electricity consumption by 2014, and leading Australia in wind and solar power generation at the end of this period. South Australia's renewable energy target was previously set at 15% by 2014, but was increased in early 2006 due to faster than expected progress towards the target.

2.4.6. TASMANIA

Tasmania is the leader of renewable energy generation in Australia, generating approximately 60% of the nation's supply. Over 90% of the state's electricity needs are currently being met by hydro and wind power.

Wind energy features strongly in the Tasmanian government's energy statement, *Powering Prosperity – Consolidating Tasmania's Energy Advantage* (13). In this document, the Tasmanian Government states its intention to continue pursuing a favorable environment for the establishment of new renewable energy opportunities, such as an extension of the MRET or the development of an emissions trading regime. However, no firm targets for increased renewable energy generation are specified. Tasmania has 67 MW of projects approved, with over 500 MW in various stages of feasibility and planning approval.

2.5 PROGRESS TOWARDS NATIONAL GLOBAL TARGETS

Australia is a party to the United Nations Framework Convention on Climate Change, and took an active role in negotiating the Kyoto Protocol to that Convention which Australia has subsequently signed. The Australian government has not ratified the Kyoto Protocol, although it is on track to meet its agreed target. Australia's Kyoto target is 108% of 1990 emissions over the period 2008-2012. Current projections indicate that Australia's greenhouse emissions will be 586 Mt CO₂-e averaged over 2008-2012, exactly meeting the 108% Kyoto target. This latest projection is lower than the projection of 110% released in 2003, and represents a 12 Mt CO₂-e decrease in emissions from the business-as-usual approach.

This decrease has been largely achieved by reductions in land clearing rather than reductions in emissions in other areas of the economy.

Australia's stationary emissions are predicted to be 146% of 1990 emissions by 2008-2012. This increase is primarily a result of a declining proportion of renewable energy in the total energy mix during the past 20 years. The renewable energy mix has been reduced from approximately 20%, due to Australia's early investment in hydroelectricity, to currently less than 10%.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

The Australian wind energy industry is already making a significant contribution to the Australian economy, particularly in rural and regional locations. Regional areas with wind energy projects experience a significant economic boost through capital investment, local government rates, and landholder lease payments paid to farmers hosting wind turbines on their properties (Table 2). At the close of 2005, almost 1,000 Australians were employed by the wind energy industry, with over three quarters of these jobs located in regional Australia (3).

In 2005, seven new wind energy projects came online, several of which were established by companies with no previous wind energy projects in Australia. Significant market shifts occurred in 2005 as a result of the acquisition of several companies with major wind energy interests by larger investment organisations and energy companies.

The New Zealand company, Meridian Energy, completed the sale of its Australian subsidiary Southern Hydro in 2005, realizing an 600 million AUD profit along the way. Meridian announced the sale of Southern Hydro to Australian energy company Australian Gas Light (AGL) on 31 October 2005, for 1.425 billion AUD. The assets sold included Australia's largest operating wind energy project, the 91-MW Wattle Point Wind

Table 2 Australian wind energy industry 2005: economic, environmental and social benefits*

Installed megawatts	708
Average number of Australian households powered by wind energy	301,490
Number of wind energy projects (2 or more turbines)	28
Annual greenhouse gas emissions displaced	2.8 million tons CO ₂ / yr
Equivalent number of cars taken off the road	651,720/ yr
Landholder lease payments	2.2 million AUD/ yr
Operations and management costs	17.8 million AUD/ yr
Total capital investment	1.2 billion AUD
Manufacturing jobs	345
Construction jobs	374
Operations and management jobs	120
Other jobs (project development, engineering and finance)	157
*All figures are estimates only based on available information obtained by Auswind.	



Figure 4 Wattle Point Wind Farm, South Australia, Photo courtesy of AGL.



Figure 5 Challicum Hills Farm, Victoria. Photo courtesy of Richard Mackie.

Farm commissioned in May 2005 (Figure 4); as well as several other wind energy and hydro projects which are still in the planning stages.

The Australian company Pacific Hydro was acquired by the Australian superannuation group Investment Funds Management (IFM) after a takeover battle between the Spanish company Acciona. IFM won full control with its 5 AUD per share bid after seeing Pacific Hydro's share price below 3 AUD just a year before. Pacific Hydro has several operating wind energy projects in Australia, including the Challicum Hills Wind

Farm in Victoria (Figure 5), as well as renewable energy interests in South America and the Asia-Pacific region.

Babcock and Brown Wind Partners, managed by Babcock and Brown, Australia's second largest investment bank, launched their "cleantech" fund in early 2006. The fund listed on the Australian Stock Exchange in late October 2005 and owns two wind energy projects in Australia: the 80.5-MW installation at Lake Bonney, South Australia, and the 89.1-MW Alinta Wind Farm inland from Geraldton, Western Australia. The



Figure 6 Woolnorth Wind Farm, Tasmania, Photo courtesy of Roaring Forties.

investment bank also expanded its wind and renewable energy portfolio in Europe during 2005.

Australian companies Hydro Tasmania and CLP Power Asia embarked on a joint venture company in 2005 trading as Roaring 40s Renewable Energy Pty Ltd. Roaring 40s now owns all of Hydro Tasmania's wind energy related interests, including the Woolnorth Wind Farm in Tasmania (Figure 6). The company also has a 49% interest in a wind energy development in the Jilin province, China.

Several Australian wind energy developers also launched new initiatives in 2005 to enhance the economic benefits for regional communities hosting wind energy projects. Pacific Hydro launched a Sustainable Communities Fund in 2005 to provide support for organisations that are working to make a positive and lasting contribu-

tion to their communities. The fund is available to organisations which operate in the communities currently hosting wind energy projects owned and managed by Pacific Hydro. Areas of support include providing direct financial assistance to health and welfare, education and training, environment, sporting or recreational activities, and cultural and arts purposes. The Rural City of Ararat in Victoria, which is the location of the Chalicum Hills Wind Farm, is one of the first communities to have access to the fund .

For the first time in the Australian industry's history, a wind energy project was publicly acknowledged for planning excellence during 2005. The New Zealand company TrustPower was commended in the 2005 South Australian Awards for Planning Excellence for their Myponga/ Sellicks Hill Wind Farm proposal in South Australia. The judges commented that "the manner in which

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the public involvement has helped shape the final scheme, and the care which has obviously been taken to make this wind farm an exemplar, is worthy of praise.”

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

International manufacturers state that they are attracted to Australia as a location because it is well situated to export throughout the Asia-Pacific region, and because it possesses political stability, well developed infrastructure, and an array of other positive social, economic and financial factors.

The MRET has underpinned investment in a number of wind energy manufacturing facilities for nacelle, blade, and tower manufacture and assembly. The manufacture of 5-kW to 20-kW turbines for export is a growing Australian industry. Demand for large wind turbine generator components has also developed a vibrant domestic industry for steel tower manufacture. Current Australian content of new wind energy projects is estimated at about 50% of the total requirement, with the balance largely coming from Danish and German manufacturers.

In 2004 and 2005, Australia’s manufacturing industry experienced significant growth and is currently estimated to employ over 345 Australians. Tasmania supports a vibrant manufacturing industry with a nacelle assembly plant (Vestas), nacelle and nose cone manufacturer (AusTech Composites), and a turbine tower manufacturer (Haywards Engineering). In Victoria, there is a manufacturing plant building wind towers and components (Keppel Prince), and a new blade manufacturing plant was opened in Portland in August 2005. The steel industry is also benefiting significantly from the turbine construction business. Air-Ride Technologies in South Australia is a major steel fabrication company supporting the industry.

4.0 NATIONAL INCENTIVE PROGRAMS

4.1 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 greenhouse response (14).

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 significant NGS initiative for the renewable energy sector has been the MRET scheme, discussed above. Other NGS initiatives are outlined below.

4.1.1 RENEWABLE ENERGY ACTION AGENDA

The Renewable Energy Action Agenda (REAA) was developed in 2000 and remains the central guiding point for the renewable energy industry (15). This agenda established a partnership between government and industry to support and advance the domestic renewable energy industry. The intent of the agenda is to foster a competitive energy market, and by providing clear investment signals, to achieve annual renewable energy sales of 4 billion AUD/yr by 2010. Prior to the release of the white paper, and with sales exceeding 1.5 billion AUD, this target was seen as achievable. However, the expected winding back of renewable energy investment over the next twelve months, as the MRET is reached, will make the 4 billion AUD target difficult to achieve.

4.1.2 OTHER NGS INITIATIVES

The NGS also provides direct support to the renewable energy industry through programs that include:

- The 26.5 million AUD Renewable Energy Equity Fund, which provides venture capital to high-growth and emerging companies commercialising 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 greenhouse gas emission reductions.
- The Renewable Energy Showcase, which provides funding and/or promotion of leading edge technologies that are approaching commercialisation.

4.2 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* (16). The existing MRET (9,500 GWh by 2010 through to 2020) was retained, although there was some refining of the processes associated with its administration and operation.

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; and
- 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 long-term abatement potential. However, it is anticipated that this fund will be predominantly focused on the fossil-fuel industry.

4.3 GREEN POWER NATIONAL ACCREDITATION PROGRAM

Renewable energy development is also encouraged by a nationally accredited Green Power program which sets stringent environmental and reporting standards for renewable energy products offered by electricity suppliers to households and businesses across Australia (17).

Since Green Power's inception in 1997, over 138,000 domestic and commercial customers have contributed to reducing greenhouse gas emissions by buying Green Power across Australia, resulting in savings of over 2.5 million tons of greenhouse gas emissions.

4.4 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 (18)

5.0 R&D ACTIVITIES

5.1 NATIONAL R&D EFFORTS

The wind energy industry, in conjunction with federal and state governments, made progress in a number of R&D activities in 2005. Federal

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and state governments are also contributing significant funds towards the R&D of wind energy technology.

5.1.1 WIND INDUSTRY DEVELOPMENT PROJECT

The AGO awarded an 170,000 AUD grant to the Australian Wind Energy Association (Auswind) in 2003 for the Wind Industry Development Project. This project was completed in 2005, resulting in the development of a set of 12 fact sheets for the industry and Bird Impact Assessment Dataset Standards and Protocols as an enhancement of the industry's Best Practice Guidelines (19). The protocols provide a set of agreed and acceptable methods so that statistically meaningful data can be compared between wind energy projects. They also help provide a mechanism for the pooling of experience gained by both developers and regulators in a more cohesive national framework.

The protocols assist industry in implementing effective pre and post-operational monitoring and in addressing the issue effectively; regulators in setting information requirements as part of development approvals and ongoing monitoring; consultants in designing, costing and reporting impact assessment and mortality monitoring work; and community and environment groups in understanding the significance of bird impacts resulting from wind turbines.

5.1.2 WIND FARMS AND LANDSCAPE VALUES PROJECT

Recognizing that the long-term sustainability of the wind energy industry depends on appropriately sited and sensitively developed wind energy projects, Auswind and the Australian Council of National Trusts (ACNT) embarked on a landmark joint project in March 2004 to develop mutually agreed national methodologies for landscape assessment. Stage one of the three-stage Wind Farms and Landscape Values Project was released in June 2005 by Senator Ian Campbell, Australian Minister for Environment and

Heritage (20). The issues paper, produced as part of the first stage of the project, is leading edge not only because it addresses extremely complex matters, but because it has been a truly consultative process which has given all stakeholders the opportunity to assist in formulating an agreed set of national landscape issues for the Australian wind energy industry. Over 50 organisations and many more individuals were consulted in the first stage of the project.

The central finding of the issues paper is that although there is a large body of methodologies and guidelines relating to landscape assessment, none of these assessment methodologies have yet been universally adopted, resulting in confusion and uncertainty about best practice in the community. The work undertaken so far sets the framework for the final two stages of the project, which will result in the culmination of an agreed set of national landscape methodologies to be adopted by the Australian wind energy industry and promoted by the ACNT. The first stage of the project was funded by the AGO in the Department of the Environment and Heritage. Auswind and the ACNT are currently seeking additional funding from federal and state governments for the second stage of the project.

5.1.3 OTHER GOVERNMENT R&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 (Section 4.2). However, it is anticipated that the majority of this funding will go towards 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 organisation, makes its major contribution to wind energy research through its Wind Energy Research Unit (WERU) (21). 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 within the AGO, the CSIRO, and Australian universities.

5.1.4 STATE-BASED R&D

Most states have established authorities to promote and support the uptake of renewable energy technologies and administer R&D programs. In Western Australia, the Sustainable Energy Development Office, formed in 2001, continues to deliver sustainable energy policy in this state. In NSW, sustainable energy development is supported through the Department of Environment, Utilities and Services (DEUS). The Sustainable Energy Authority of Victoria (SEAV) works to accelerate progress toward a sustainable energy future for the state, by facilitating investment in the demonstration of innovative renewable energy technologies. The NSW and Victorian agencies have each produced a state-based wind atlas. These products seek to increase the quality of publicly available information about each state's wind resource.

5.2 COLLABORATIVE RESEARCH

Auswind continues to be the Australian participant for the International Energy Agency's (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), hosting the Australian launch of the new global council at the Auswind 2005 conference and exhibition in Sydney, Australia in 2004. In collaboration with GWEC, Auswind is hosting

the GLOBAL WINDPOWER 2006 conference and exhibition in Adelaide, South Australia from 18-21 September 2006 (22). GLOBAL WINDPOWER 2006 will provide an important forum for the global wind industry to meet, share information, exhibit their products and contribute to GWEC's mission of ensuring that wind power is established as one of the world's leading energy sources.

Auswind also maintains strong ties with industry associations across the world, particularly within the Asia-Pacific region. The industry's cooperative 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

The Auswind Board has identified a number of key priorities to progress for the wind energy industry in Australia. The most urgent priority for the industry 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 a number of 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 the further expansion of the wind energy industry in Australia is an increased market for renewable energy projects. The key market driver for renewable energy, the Federal Government's MRET, is expected to be filled by the end of 2006. While several

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state governments have indicated their commitment to expand renewable energy projects in their states, there is now a sense of urgency to ensure that these policies are implemented in a timely manner. Auswind has established a working group to develop an appropriate industry development mechanism which will recognise the important contribution that wind energy can make towards Australia's future energy supply.

In conjunction with other Australian renewable energy organisations, Auswind has prepared several briefing papers for the federal government and advanced state governments outlining a number of key mechanisms that would encourage further deployment of renewable energy projects. At the federal level, Auswind has been participating in government forums regarding the future of Australia's energy supply and the nation's response to climate change. Most recently, Auswind representatives participated in a business forum held as part of the inaugural AP6 meeting in Sydney to identify future deployment opportunities for the Australian wind energy industry. Participating in such forums as an independent and autonomous industry is a significant step forward for the Australian wind energy sector. Such meetings have previously only been open to Australia's major energy industries and large energy users, with perhaps one or two representatives invited from the entire renewable energy sector. It is anticipated that there will be future opportunities for involvement from the wind energy industry in initiatives arising from the AP6.

At the state and federal levels, Auswind has been in close contact with energy ministers and their advisers to influence government policy on future energy supplies. A priority for the first half of 2006 will be to ensure that the Victorian government's 1,000-MW target by 2006 is enforced through a market-based scheme developed in conjunction with the industry. Auswind will also be continuing close alliances with key government policy makers to ensure that medium to long-term policy recognises the potential contribution of wind energy.

6.1.1.2 GRID INTEGRATION AND MARKET CATEGORISATION

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-fuelled power stations. To enforce these rules without altering the mechanics of the National Electricity Market (NEM) will unnecessarily reduce the amount of energy that can be delivered from clean energy projects.

The Australian wind energy industry is requesting that a new registration category be created for wind and other renewable energy generators which utilise a natural fluctuating energy source (such as tidal and solar energy). This new market registration category would require these renewable energy generators to reduce their output only in circumstances where there is a power system or network limitation that requires energy reduction. Along with a centralized wind energy forecasting system, additional market signals and price mechanisms may be required to ensure that the market has adequate information with which to respond to fluctuations in wind energy. Most of the attention on grid integration and market categorization issues has focused on South Australia, where the small size of the system and the world-class wind resource mean that new grid and electricity market management techniques will need to be implemented in the near future. With sensible infrastructure investment, South Australia could be a profitable exporter of clean, green, and competitively-priced energy to other Australian states that urgently need more power.

A number of reports and recommendations were released in early 2005 relating to the future expansion of wind energy projects in South Australia. The Electricity Supply Industry Planning Council (ESIPC) (23), Wind Energy Policy Working Group (WEPWG) (24) and the Essential Services Commission of SA (ESCOSA) (25) have all released reports that address this issue. Their

central finding is that South Australia needs improved infrastructure and market integration to accommodate a greater supply of clean renewable energy sources like wind energy. Auswind hosted a forum during April 2005 to address these issues and canvass a path forward. Auswind representatives are now participating in the Wind Energy Technical Advisory Group and the Technical Standards Reference Group. The Technical Standards Reference Group is currently reviewing the National Electricity Market Management Company's technical standards for wind farms. The review is designed to progress the integration of wind energy and ensure that the rules associated with the connection and operation of wind energy projects are adequate.

6.1.3. ADDRESSING COMMUNITY CONCERNS WITH WIND ENERGY PROJECTS

Like many other countries around the world, wind energy projects in Australia have attracted considerable media attention and vocal community debate. Auswind completed a number of initiatives in 2005 which 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 towards state government approval for the larger wind energy projects while involving local governments in the consultation process. Victoria, South Australia and NSW have developed extensive planning guidelines for wind energy projects.

The federal government became increasingly interested in the planning approvals process for wind energy projects in Australia during 2005. However, the only formal provision for intervention by the federal government is through the Environment Protection and Biodiversity Conservation (EPBC) Act, which specifically addresses threatened and endangered species which may be impacted upon as a result of wind energy projects (26). Under the assessment and approval provisions of the EPBC Act, actions that are likely to have a significant impact on a matter of national

environmental significance are subject to a rigorous assessment and approval process.

Auswind's comprehensive *Best Practice Guidelines for the Implementation of Wind Energy Projects* in Australia also aids in appropriate installation of wind energy projects (27). The guidelines, originally developed in 2003, were prepared by consulting with diverse stakeholder groups including developers, local councils, consultants, environmental groups, state agencies, network operators and retailers. Auswind is in the process of updating the guidelines and developing an accreditation scheme to demonstrate compliance with the guidelines, with a particular emphasis on the community consultation processes.

Standards Australia is currently developing an Australian Noise Standard for the measurement, prediction and assessment of noise emissions from wind energy projects, although the setting of noise level criteria will remain the responsibility of the relevant regulatory authority. A draft standard has been developed by the committee, and was released for public comment in March 2004. The public comments submitted have been considered by the committee and, where appropriate, included in a new draft standard which was released for a further round of public comment in August 2005. The standard is expected to be completed in early 2006 and adopted by regulatory bodies as the standard methodology for all future noise assessments of wind energy projects.

6.2. AUSTRALIAN DEVELOPMENT POTENTIAL

Auswind estimates that there is almost 6,000 MW of wind energy projects in various stages of feasibility assessment across Australia (Figure 7).

A report commissioned by the Australian Greenhouse Office in 2003 found that the NEM is already able to support an installed wind capacity of over 8,000 MW (Australia's current capacity is 708 MW), provided that the progressive development of wind energy projects is enabled in a dispersed fashion, commercial

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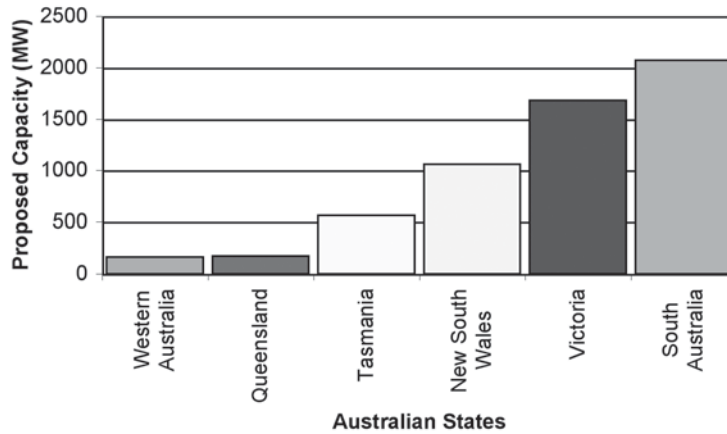


Figure 7 Proposed Australian wind energy projects by state: 2005*
* Includes projects with planning approval but excludes projects undergoing construction.

wind output forecasting is in place and interstate connectivity continues to be enhanced (1). This amount of wind energy would equate to approximately 10% of Australia's electricity needs and is over ten times Australia's current installed capacity. This target 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.

A groundbreaking study released in 2004 by the Clean Energy Future Group, an alliance of industry associations, energy organisations and the Worldwide Fund for Nature, examined a range of scenarios in which greenhouse emissions from Australian stationary energy could be reduced to 50% of their 2001 levels by 2040 (28). The report estimated that wind energy could contribute around 20% of Australia's total electricity generation by 2040, amounting to an installed capacity of 19,000 MW. The study found that there were sufficient sites in Australia capable of generating wind energy at this level of supply without affecting economic growth.

The Australian wind energy industry is emerging from six years of strong growth and is well-placed to accelerate forward from the launching pad

provided by the federal government's MRET scheme. The avenues for development are considerable, even given the existing hurdles currently facing the industry. The sector's highest priority is to achieve the implementation of policy initiatives that will continue the expansion of the wind energy industry. Given the strong policy frameworks being adopted by state governments, and the potential opportunities contained within the new AP6 alliance, Australia has the opportunity to cement its role as the hub of the wind energy generation in the Asia-Pacific region, where market growth is surging ahead.

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CHAPTER 11 CANADA

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 2005, with installed wind energy generating capacity growing to 683 MW. A number of federal and provincial programs, including the recent commitment to quadruple the Wind Power Production Incentive (from 1,000 to 4,000 MW), have helped set the stage for continued growth.

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

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

Though there are no national wind energy deployment targets, the federal government's Wind Power Production Incentive (WPPI) program ensures the provision of economic incentives for up to 1,000 MW of new installed capacity by 2007. Under the new commitment, the program aims to have installed capacity of 4,000 MW by 2010. This program is presently the main driver for wind energy deployment in Canada. Other levels of government support the development and expansion of the wind energy industry to varying degrees, and installed capacity is set to grow quickly.

By December 2005, a total of 683 MW of wind power had been installed in Canada. This is an increase of 239 MW from last year's 444 MW or a 54% increase. Alberta is currently the province with the highest installed capacity totaling 275 MW, however, both the provinces of Quebec and Ontario have awarded contracts for 1,244 MW and 1,310 MW respectively to be built during the next few years and all of the provinces either have wind energy targets or Request for Proposals (RFP) that are in place or being planned.

Total installed wind generation	683 MW
New wind generation installed	239 MW
Total electrical output from wind	1.8 TWh
Wind sector turnover	NDA
Wind generation as % of national electric demand	0.3%
Target:	N/A

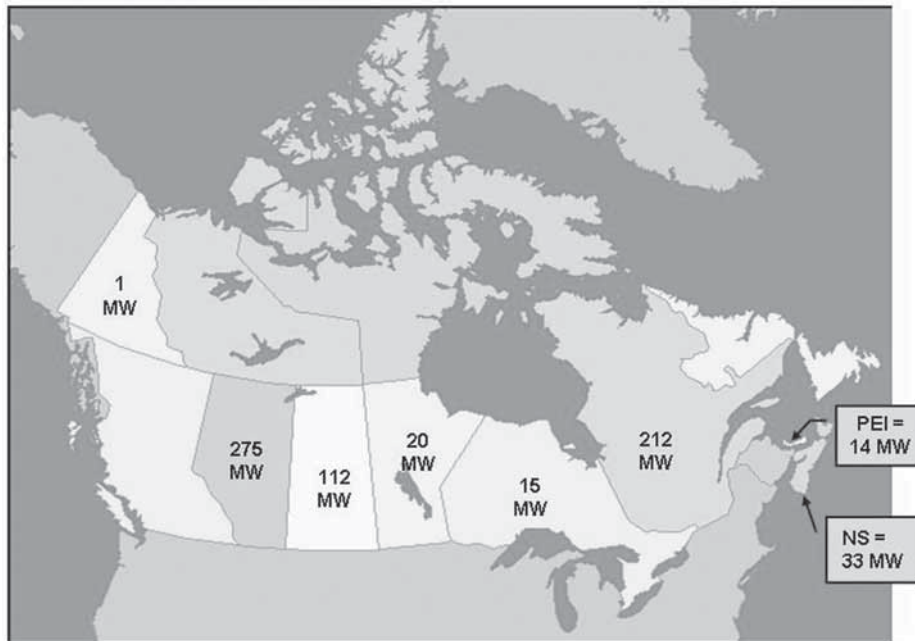


Figure 1 Canada's installed capacity. Source: CANWEA website January 2006.

New installations in 2005 include the first phase of the Centennial Wind Power Facility (90 MW) in Saskatchewan with the second phase of 60 MW to come on line in February 2006 making it the largest wind farm in Canada. In Quebec, the Mount Copper Wind Farm Phase-2 (45 MW) and the Mount Miller Wind Farm (54 MW, Figure 2), both located in the Gaspé area, were commissioned in 2005. In Manitoba, the first phase of the St. Leon Wind Farm (20 MW) was completed with the second phase (80 MW) to be completed in early 2006. Finally, the second phase of the Pubnico Point Wind Farm (27 MW) in Nova Scotia, was completed in early 2005.

2.1 RATES AND TRENDS IN DEPLOYMENT

Installed wind power capacity in Canada has experienced an average annual growth rate of 37% over the past 5 years. Though average growth is high, it has varied widely from year to year. Large capacity additions occurred in 2005 (239 MW) and 2004 (116 MW), but it was only 15 MW in

2002 and 77 MW in 2001. For Canada, 2006 is expected to be a very good year, even though the wind farm developers have to compete for equipment with revived projects in the US as a result of the renewal of the PTC and overall high turbine costs because of lack of North American manufacturers.

2.2 CONTRIBUTION TO NATIONAL ENERGY DEMAND

The national electrical energy generation in Canada in 2005 was estimated at 538 TWh (Energy Statistics Handbook 2005). Total installed generation capacity at the end of 2005, was projected at 123 GW (National Energy Board 2003), which includes hydro power, coal, nuclear, natural gas, oil-fired, wood-fired, tidal and wind plants. The installed wind capacity was 683 MW by the end of 2005, producing an estimated 1,800 GWh of wind energy per year, which represents about 0.3% of total electricity production.



Figure 2 Vestas V80 turbines at the Mount Miller wind farm in Murdochville, Québec.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Domestic turbine manufacturing capabilities are extremely limited and the barriers to entering this market are high. As a result 65-70% of the supply chain's economic benefits leave Canada. However, Canadian expertise and experience does exist in a few areas, for example tower construction, rotor blade manufacturing, nacelle assembly, and electric inverters.

The recent announcements made in Quebec and Ontario should serve to promote domestic capabilities. For example, GE Energy's winning bid in Quebec stipulated that 60% of the components or services for the 660, 1.5-MW turbines will be supplied or assembled in the Gaspé. GE Energy has committed to establish component manufacturing and a nacelle assembly operation in the region. LM Glasfiber has committed to install a

blade-manufacturing unit in Gaspé and Marmen has agreed to manufacture its towers in Matane.

The main constraints for wind energy development in Canada are the lower cost of conventional energy and a surplus of generation capacity in many areas. However, in a few jurisdictions these factors are changing. In some provinces, such as Alberta and Ontario, surplus generation is rapidly declining. In addition, the production incentive allows wind-based electricity generation to be more competitive with conventional forms, particularly in those regions where the provincial governments choose to contribute.

Another constraint is the Canadian 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 to being a concern for safety, icing also increases the loads on the turbine and impacts on fatigue properties of materials. Cold air temperatures also increase

the loading on the turbines by increasing the air density and the power output. Components like gearbox and generators are affected.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

The Canadian industry is composed mainly of companies that manufacture wind related components such as rotor blades, control systems, inverters, nacelles, towers, and meteorological towers as well as wind resource assessment firms and wind farm developers.

Canada has a few small wind turbine manufacturers. Some of them are:

- Vergnet Canada, Wenvor Technology of Guelph, Ontario and Plastiques Gagnon of Quebec are developing small wind turbines in the 10-30 kW size
- Entegrity Wind Systems inc, Vergnet Canada and Atlantic Orient Canada inc. are offering turbines in the 50 to 60 kW size range.

To supply the 1,000 MW tender that was awarded in the fall of 2004 for the technology proposed by GE, several announcements were made in 2005 for industrial activity in the Québec region of Gaspésie. This tender is driven by components having a high regional content.

- LM Glasfiber has opened a blade production facility in Gaspé
- Composite VCI announced plans to open a plant in Matane to build nacelles
- Marmen Inc. has opened a tower plant in Matane.

Other component manufacturers include Mitsubishi Canada, which provides towers to the western market; Marmen Inc. in Trois-Rivières, which provide towers to the Northeastern American market; and Algoma steel, which has made an announcement to build a turbine tower plant in Sault Ste. Marie in Ontario.

3.3 ECONOMIC DETAILS

According to the Canadian Wind Energy Association (CANWEA), the cost of wind energy in Canada currently ranges from 0.055 to 0.12 CAD/kWh. The primary variables associated with this cost range are: the quality of wind resources, transmission connection fees, scale of operation, and size of turbines.

There is growing evidence that wind energy may already be cost-competitive with conventional electricity generation in Canada. Despite this progress, there are a number of economic challenges to both the expansion of wind energy in Canada and the creation of a strong domestic manufacturing base.

3.3.1 TRENDS IN INVESTMENT

Wind project costs have risen dramatically in the last two years from a low of about 1,650 CAD/kW installed in 2004 to more than 2,000 CAD/kW in today's market. Demand is outstripping supply due to the very large demand in the US market and these costs are expected to remain high at least for the next 3 to 5 years. Other factors influencing the increase in cost of installed wind farms are:

- Increase in commodity prices such as fuel and steel
- Increase in costs for interconnection with increasing requirements from most jurisdictions
- Increase in engineering costs
- Increase in installation costs due to skilled trade shortfall
- Increase in environmental assessment costs due to increased presence of wind farms but low understanding of impacts.

Canada has also experienced an increase in size of wind farms, especially in provinces that already had some wind experiences. This is mainly due to the fact that smaller projects (less than 50 MW) can cost from 10 to 30% more because of economies of scale.

3.3.2 TRENDS IN UNIT COSTS OF GENERATION AND BUY-BACK PRICES

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 for 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 based on avoided costs.

4.0 NATIONAL INCENTIVE PROGRAMS

4.1 MAIN SUPPORT INITIATIVES AND MARKET STIMULATION INCENTIVES

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.

In addition, 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.

The federal government has established a Green Power Purchase program. This program allows developers to sell electricity, generated by wind and other forms of renewable energy, to the government at premiums negotiated through a competitive process. As a byproduct of the federal program, wind power producers have built additional wind plants and green energy is being sold to private, provincial and municipal consumers.

The most influential market stimulation instrument so far is 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 10 years of production and helps to provide a long-term stable revenue source. The program is intended to help address climate change and improve air quality. Originally slated for 1,000 MW to be built by 2007, the program has been expanded to 4,000 MW to be built by 2010.

Interest in WPPI has been high. By December 2005, the program had registered Letters of Interest totaling 253 projects and 16,600 MW of capacity. On the basis of the quantity of projects that have actually applied to the WPPI program, it is expected that 2006 will be better than 2005 for wind power development in Canada. Provincial and territorial governments have shown a strong desire to provide additional support, and most provinces have begun to develop their own complementary programs.

Table 2 compiled by CANWEA shows the level of commitment in each province.

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

NATIONAL ACTIVITIES

The Wind Energy Atlas is a massive database of high-resolution wind statistics for all of Canada. This makes Canada one of the large-area countries in the world to have a comprehensive Wind Energy Atlas across its entire territory. The Wind Atlas 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, a “wind atlas,” 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 Wind Atlas can be found on the internet at: <http://www.windatlas.ca>

In October 2005, MSC launched WindScope as a complement to its Wind Atlas. Wind Scope is an integrated wind-energy mapping solution for the Microsoft Windows environment that 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 modeling of all scales down to the wind farm level and integrates over 50 years of global historical meteorological data. WindScope’s ability to assess an area of one kilometer down to an area as small as 100 meters, allows wind location studies to be made much more rapidly, with greater confidence and certainty, and at a lower cost than what was possible up until now.

NRCan recently funded CANWEA to examine the interconnection requirements for wind technologies in Canada. The report by Garrad Hassan proposes a Base Code which incorporates the existing codes developed in Alberta, Ontario, Québec, and through the American Wind Energy Association. It adopts a structure allowing variability in requirements to accommodate both provincial differences and site specific differences.

The report will be studied by the different provincial bodies responsible for grid interconnection.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

The Fiscal Year 2006/07 budget for the Wind Energy R&D (WERD) program of 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 program 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. The program also supports a national test site: The Atlantic Wind Test Site (AWTS) at North Cape, PEI for testing electricity generating wind turbines and wind/diesel systems.

The program supports new technology development activities related to:

- components for wind turbines in the 600 kW to 2 MW range
- small to medium size wind turbines (10 kW to 275 kW) for use in agro-business, and to supplement diesel-electricity generation in remote communities
- wind/diesel control systems for wind/diesel hybrids in remote communities
- Net metering for turbine whose power output is less than 50 kW (some provinces allow for higher output).

Table 2 Federal and provincial objectives for wind energy

Jurisdiction	Initiative	Status
Federal	Expanded the Wind Power Production Incentive (WPPI) in the 2005 Federal Budget	The expanded WPPI program will support the development of 4,000 MW of wind energy in Canada by 2010
British Columbia	50% of new generation to come from clean energy sources	Issuing a call for proposals in 2006 that will be open to wind energy developers
Alberta	Voluntary commitment to see 3.5% of total electricity coming from new renewable energy sources by 2008	This target is likely to be met and would result in a total of 500 MW of wind in Alberta by 2008
Saskatchewan	150 MW wind farm under construction, RFPs issued for smaller projects	Current initiatives will result in wind energy meeting 5% of electricity demand in Saskatchewan (close to 200 MW)
Manitoba	Manitoba government seeking 1,000 MW of wind energy by 2009-2014	First 103-MW project under construction, a request for expressions of interest in meeting the 1,000 MW target has been issued
Ontario	Renewable Portfolio Standard (5% by 2007; 10% by 2010) – potentially three-quarters of this will be wind energy – 2,000 MW. The Ontario Power Authority recently called for 5,000 MW of wind energy by 2025.	350 MW of wind energy contracts awarded in 2004, 955 MW of wind energy contracts awarded in 2005, request for proposals for 200 additional MW of renewable energy has been issued
Quebec	Quebec government seeking 3,500 MW of wind energy by 2013	1,190 MW of wind energy contracts awarded, 2,000 MW wind energy request for proposals has been issued
New Brunswick	NB Power seeking 400 MW of wind energy by 2016	20 MW wind energy contract awarded, planning underway for future requests for proposals
Nova Scotia	Renewable Portfolio Standard (5% by 2011 – 3.75% of which is “new”) – wind energy likely to provide between 100-200 MW – proposed a target of 380 MW by 2014	31 MW facility completed, contracts signed for an additional 70 MW
Prince Edward Island	Government seeking 200 MW of wind energy (100% of power needs) by 2010	Currently seeking bids to construct a 30 MW wind farm
Newfoundland	Target of 150 MW of wind energy development	A 25 MW request for proposals has been issued

NATIONAL ACTIVITIES

The government is studying the impacts and regulation of offshore wind farms in the context of large projects off the West coast in the Pacific, East coast in the Atlantic, and in the Great Lakes off Ontario.

5.2 COLLABORATIVE RESEARCH

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

- Annex XI - Base Technology Information Exchange
- Annex XIX - Wind Energy in Cold Climates
- Annex XX - HAWT Aerodynamics and Models from Wind Tunnel Measurements
- Annex XXIV - Integration of Wind and Hydropower Power Systems.

In addition, Canada participates in the IEC TC-88 technical committee with a full participant status.

The exchange of information benefits Canada and the Canadian wind industry as it makes Canadians aware of the developments in other

countries and the challenges facing the industry worldwide. It also brings to the attention of the international community the advances and developments taking place in Canada facilitating possible cooperation between foreign and Canadian companies.

6.0 THE NEXT TERM

Canada will continue its R&D activities in the following areas: wind energy-hydropower integration, atmospheric icing and its prevention on wind turbine rotor blades, small turbine single-phase net metering and the development of a universal small wind turbine. A production incentive is required to sustain the actual growth rate of commercial turbine installations. The provincial initiatives in terms of regional manufacturing content have contributed to the inception of a large wind turbine industrial base in Canada.

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CHAPTER 12 DENMARK

1.0 INTRODUCTION

1.1 OVERVIEW

The present Danish Energy Policy is based on broad political agreements. The agreements have been implemented by the Danish Energy Authority through a number of strategies and action plans for production, distribution, and consumption of energy taking into account issues like security of supply, cost-efficiency, and international commitments. Cross-cutting analyses are performed in order to establish ways in which given objectives can be fulfilled in the most flexible and cost-efficient manner.

The history of the Danish energy policy goes back to the first oil crisis in the 1970s, when energy policy started to occupy a relatively significant position in the political debate. At first the focus was on the problem of security of supply, but gradually the focus shifted to domestic energy production

(North Sea oil and gas, renewable energy etc.), to more efficient energy supply and distribution (the natural gas grid, CHP etc.) and to energy savings (insulation, labelling schemes etc.).

Since 1980, the yearly gross energy consumption has been kept nearly constant at around 800 PJ. In 1980, 67% of the Danish energy came from imported oil and 30% from imported coal. Less than 5% came from national resources. Today, more than 15% come from renewable energy (around 20% of the electricity comes from wind), 23% from natural gas, 20% from coal. The dependence on oil is reduced to 42%. In total, the degree of self-sufficiency has grown to more than 150%, and Denmark is now a net exporter of oil and natural gas from its resources in the North Sea.

But also the international sustainability targets not least of which is the reduction of CO₂ emissions and economic considerations have had a significant role to play in recent years. For example, there have been subsidies for energy savings and green energy taxes, liberalization of the electricity and gas markets, and introduction of CO₂ quotas.

The development in the area of wind energy has been a commercial success. Since the first wind turbines were industrially constructed around

Table 1 Key Statistics 2005: Denmark

Total installed wind generation	3,128 MW
New wind generation installed*	4 MW
Total electrical output from wind	6.614 TWh
Wind sector turnover	4,400 million €
Wind generation as % of national electric demand**	18.5 %
Target:	N/A
* 24 MW installed; 20 MW removed	
** Actual for 2005 (with correction for wind index 2005 (0.86): 21%)	

NATIONAL ACTIVITIES

1980, there has been tremendous growth in technological development and turnover. Modern Danish wind turbines produce about 100 times as much electricity as the first industrial wind turbines from 1980, and over the last decade the global annual sales of Danish wind turbine manufacturers have grown from about 200 MW/yr to more than 3,000 MW/yr. The global market share of the Danish wind turbine industry over the last couple of years has been around 40%.

2.0 PROGRESS TOWARDS NATIONAL OBJECTIVES

The national objectives are based on the political agreement from 2004 which include the construction of new offshore wind farms and a second repowering scheme for the replacement of wind turbines in unfavorable locations 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 on the agreement was reported in the IEA Wind Annual Report from 2004 and can also be downloaded from the Danish Energy Authority's web site www.ens.dk.

According to the above mentioned energy policy agreement, it was decided to develop a governmental long-term strategy on energy policy. The goal was to secure a greater degree of security of supply, to establish well-functioning competitive markets, and to accommodate a larger amount of renewable energy. The strategy plan "Energy Strategy 2025" was published in June 2005.

Energy Strategy 2025 consists of analyses of challenges and perspectives on to 2025 and an action plan for a new infrastructure for electricity and natural gas to be established in 2010. For the first time, the energy consumption in the transport sector is included in the analysis. The strategy focuses also on the significant Danish business potentials regarding new and more effective energy technologies.

Already today more than 25% of the electricity and district heating consumed are produced from renewable energy and nearly 24% is used for electricity supply. The Danish Energy Authority (DEA) has prepared projections to 2025 on the production of electricity and district heating. According to the basic projection with oil prices at 30 USD/barrel and moderate rises in oil prices and in CO₂ allowance prices, the contribution of renewable energies to electricity supply will amount to more than 36% in 2025. Wind energy will account for a major part of that increase.

If the price of oil remains high (over 50 USD/barrel) and if ambitious international climate objectives result in higher CO₂ allowance prices, both wind energy and biomass will become so advantageous that the amount of renewable energy produced will increase significantly. It could amount to as much as 80% in 2025 and wind power is expected to be able to cover more than 50% of the Danish electricity consumption. And with high oil and CO₂ prices, such a development would be achieved with reduced production subsidies or perhaps without any production subsidies at all.

Regarding wind power, it is the government's intention that new wind energy capacity, both onshore and offshore, should continue to be established on an economically healthy basis. In this context, the basis for assessing possibilities for the physical location of new offshore wind farms and the various considerations relative to nature, the environment, and the landscape, as well as the related challenges, will all be updated. In December 2005, the Danish Energy Authority started work on a new plan for siting the next generation of offshore wind farms in the period from 2010 to 2025.

2.1 INSTALLED CAPACITY AND PRODUCTION IN 2005

The total capacity of wind power in Denmark only increased by 4 MW in 2005, bringing it up to 3,128 MW by the end of the year. The total

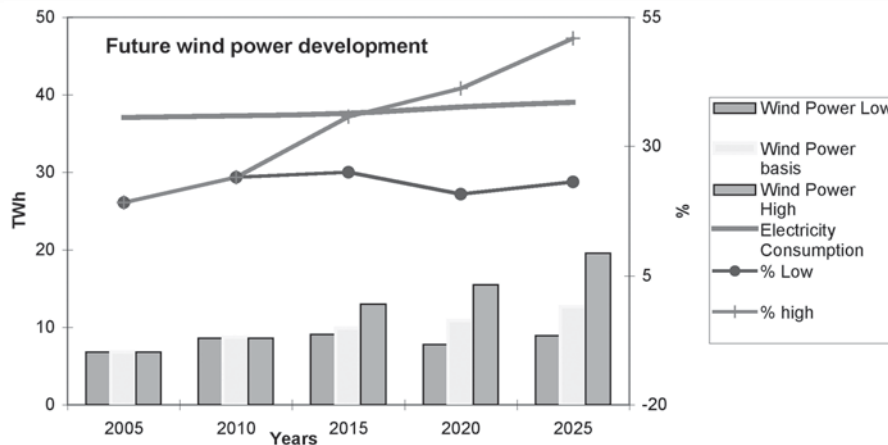


Figure 1 High and low scenarios showing possible wind power developments in Denmark.

number of turbines was reduced to 5,293. During 2005, the number of new wind turbines installed was only 18 and 129 turbines were dismantled. The average capacity of those installed in 2005 was slightly higher than in 2004, 1.23 MW compared with 1.08 MW. The deployment rate in Denmark in numbers and accumulated capacity are shown in Figure 2.

Also in 2005, electricity from wind energy has covered 18.5% of the total electricity consumption in Denmark due to a lower wind index as compared with 2004. The development in the wind energy index is shown in Figure 3 (0.90 in 2004 and 0.86 in 2005). The total electricity production from wind energy in 2005 was 6,614 TWh, which was nearly the same as in 2004.

The Danish Energy Authority calculates the annual CO₂ emissions, which takes annual temperature variations and foreign trade in electricity into account. In 2004, observed CO₂ emissions decreased by 9.4 percent relative to 2003. This fall is primarily due to the fact that electricity production fell significantly in 2004 and there was a smaller net export. Warmer weather in 2004, than the year before, also contributed to the lowering of emissions. In 2005, the primary data show a further fall in production of more than 10% com-

pared to 2004 and a net import. In 2004, adjusted CO₂ emissions were 1.5% lower than the year before. Relative to 1990, this means a fall of 15.9%. A figure for 2005 has not been calculated yet.

Gross energy consumption has been more or less constant over the last 10 years; however, the fuels used have changed considerably. The shift from coal to natural gas and renewable energy etc. has meant that, year by year, less CO₂ is linked to each unit of fuel consumed. Thus, in 2004 each GJ of adjusted gross energy consumption was linked to 61.2 kg CO₂, against 74.2 kg in 1990. This corresponds to a 17.5% reduction. One kWh of electricity produced in Denmark caused 526 grams of CO₂ emissions in 2004. In 1990, CO₂ emissions were 937 grams per kWh of electricity produced. This corresponds to a reduction of almost 44%. This large reduction is attributable to fuel conversions in electricity production and the growing significance of CHP production and wind power.

Danish wind turbines are operating offshore and on land. The largest turbines installed on land are five turbines of 3.0 MW and five turbines 2.75 MW installed in 2002 at special sites. At the Risø test site at Høvsøre one 3.6-MW turbine and one 4.2-MW turbine have been tested. The

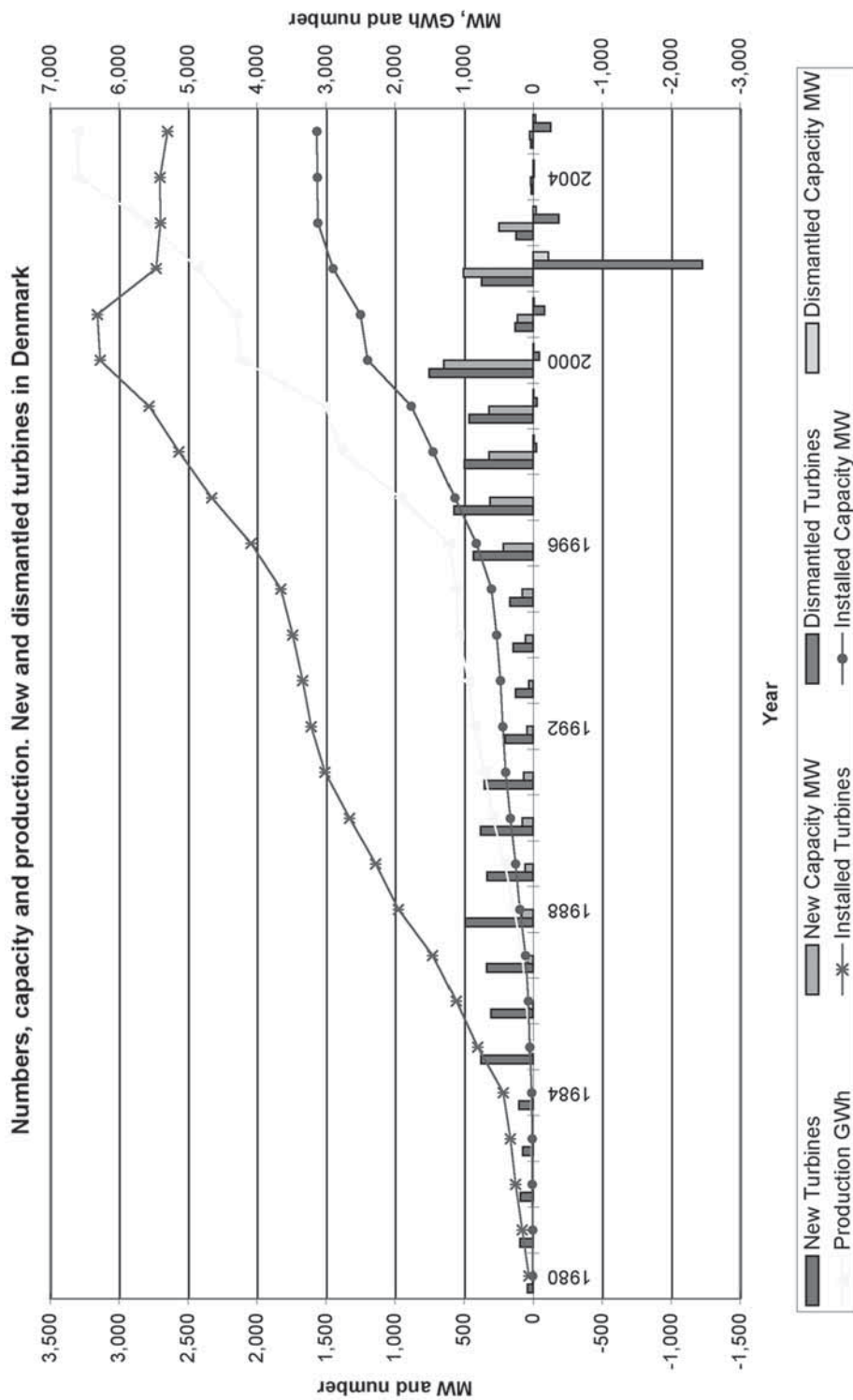


Figure 2 Deployment rate in numbers and capacity, new and dismantled turbines in Denmark.

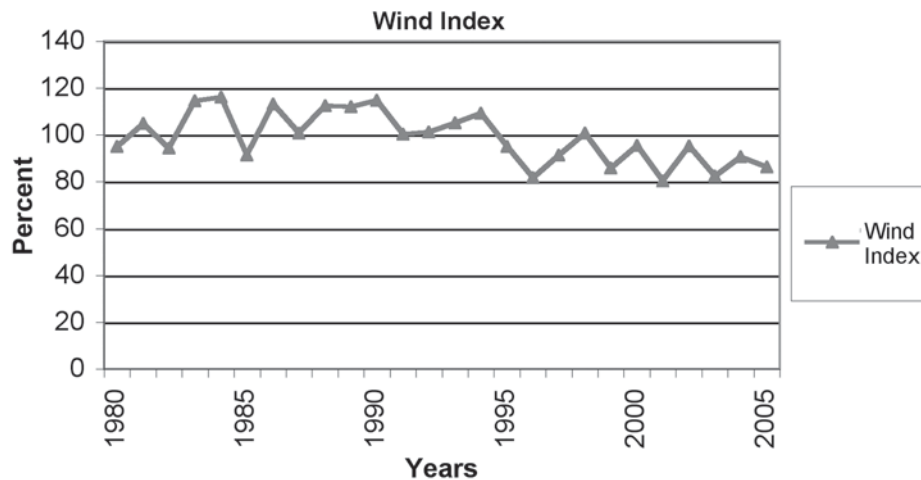


Figure 3 Annual energy in the wind in Denmark, illustrated by the wind energy index.

two largest offshore wind farms are still the 160-MW offshore wind farms at Horns Rev consisting of 80 Vestas 2-MW wind turbines placed in the North Sea, 14-20 km offshore Blaavands Huk and the Nysted wind farm south of Lolland in inland waters consisting of 72 Bonus 2.3-MW wind turbines (see Figures 4 and 5 for maps).

According to the political agreement from 2004, two more offshore wind farms of 200 MW each are to be established. The contract notices were published in 2004 for two sites, one for an area at Horns Rev and one for an area at Rødsand. Areas from a screening in 2003 are shown in Figure 4.

2.2 HORNS REV II

The deadline for submitting tender bids for the offshore wind farm concession for Horns Rev II expired on 4 January 2005. Three applicants submitted bids for the tender, Energi E2, Elsam Kraft A/S, and Horns Rev II A/S. In March 2005, the Danish Energy Authority decided that Horns Rev II A/S had not documented the necessary financial and economic capacity to establish an offshore wind farm of 200 MW within the area tendered.

The energy company, Energi E2, has submitted the successful tender for the Horns Rev farm with the lowest price. The price to be paid is 0.518 DKK /kWh for the first 50,000 full-load hours corresponding to about 12 years of electricity production. It is estimated that the offshore wind farm at Horns Rev will be able to supply about 200,000 households with electricity annually, corresponding to about 2% of the Danish electricity consumption.

The offshore wind farm is to be located about 10 km west of the existing wind farm at Horns Rev. The wind farm will cover a total area of about 35 km². It has been agreed that the wind farm will be commissioned during 2009. Energinet.dk is responsible for extending the electricity grid to the wind farm. Energi E2 is now conducting feasibility studies and preparing an EIA-report where environmental and natural conditions etc. will be clarified. The EIA-report will be distributed for a public hearing.

2.3 RØDSAND II

Before the deadline on 13 December 2005, the Danish Energy Authority received three tender

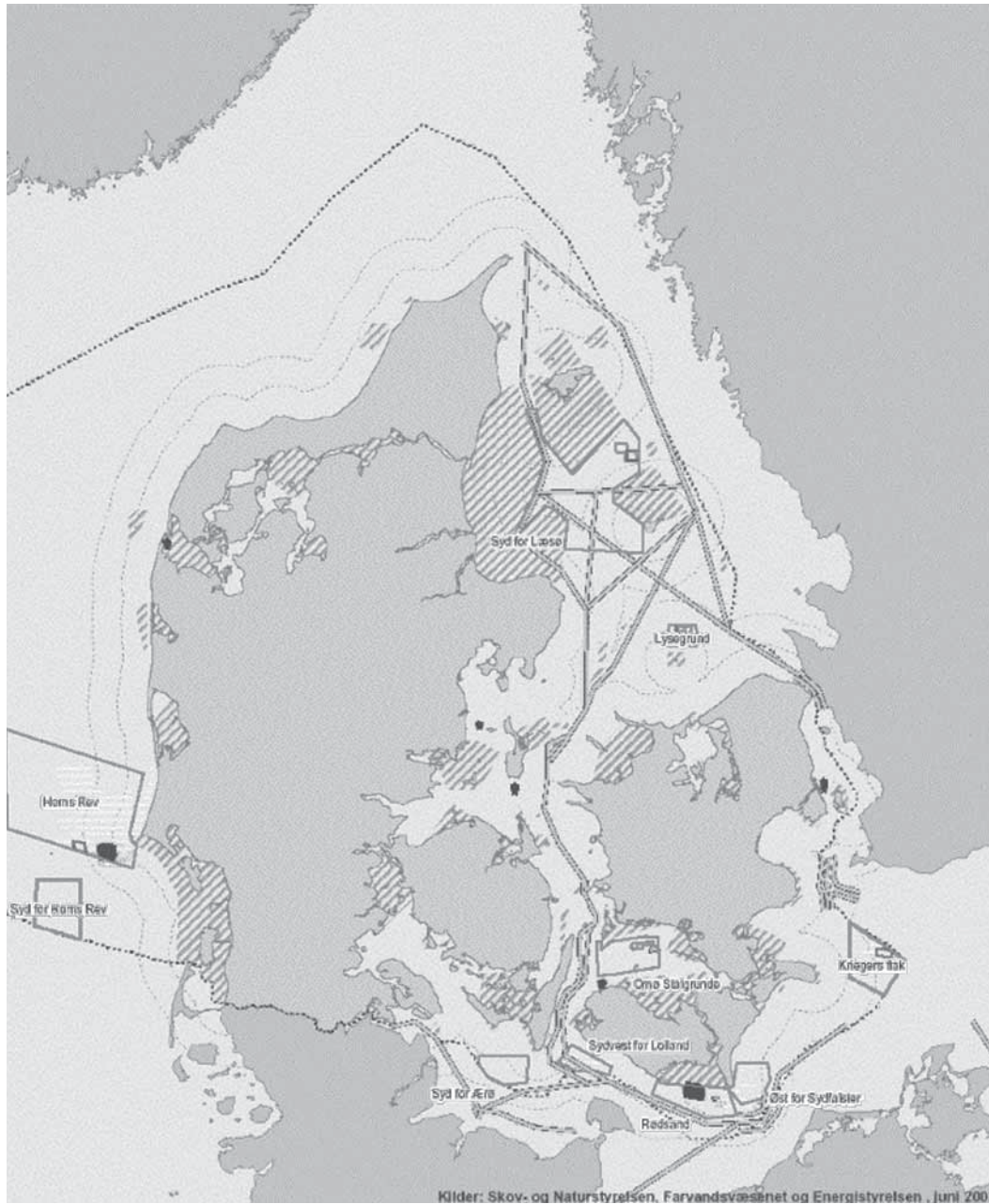


Figure 4 Map showing screening of offshore areas in 2003. Potential locations for future Danish wind farms are shown. Black spots indicate existing Danish offshore wind farms. Restricted areas are hatched and shipping routes are indicated.

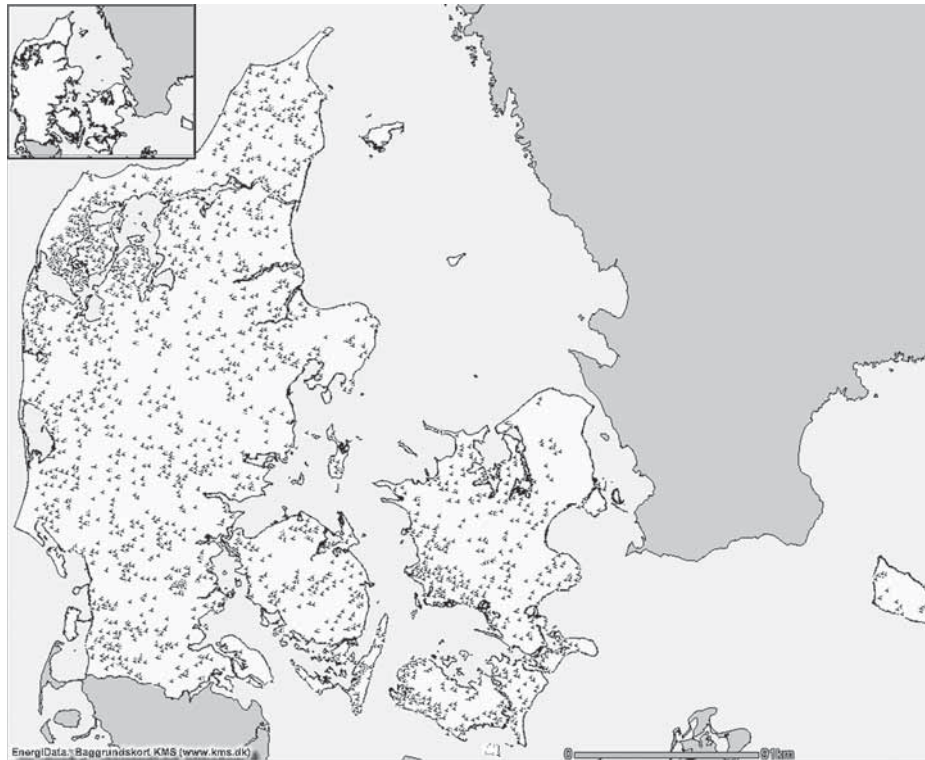


Figure 5 Map showing Danish onshore wind turbines. All turbines are registered in a data base. Using the link shown, the map can be focused to show the actual position of any turbine, placed separately or within a wind farm.

bids for an offshore wind farm concession at Rødsand of 200 MW. The tenders are: A group consisting of two Dutch companies: Ballast Nedam Infra B.V. and Evelop BV, Rødsand II A/S (with Vattenfall as the main shareholder) and a group consisting of: DONG Vind A/S, Sydkraft AB, now E.ON Sverige, and Energi E2 A/S. The Danish Energy Authority is now evaluating the information submitted in order to decide whether the tender bids fulfil the conditions. Negotiations are expected to be conducted from the start of 2006.

More information on the deployment of offshore wind is available on the Danish Energy Authorities publication "Offshore Wind Power – Danish Experiences and Solutions" which was

published for the Copenhagen Offshore Wind Conference, October 2005. (<http://www.ens.dk/graphics/>).

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

The sales by the Danish wind turbine manufacturers (Vestas and Siemens Wind Power) were 3,290 MW in 2004 (2005 not available), which was a little higher than the figure for 2003 (3,189 MW). The Danish home market in 2005 amounted to 22 MW, about the same as in the previous years. Therefore nearly all turbines manufactured are exported contributing to the national



Figure 6 Offshore wind farm at Horns Rev, 160 MW. Published with the permission of ELSAM.

economy with more than 20 billion DKK a year. Again in 2004 the two large manufacturers Vestas Wind Systems and Siemens Wind Power together had a world market share of more than 40%. More than 20,000 people are employed in the Danish wind sector.

Between 1995 and 2002 the Danish market was of a significant size and was relatively constant. It was expected that the market would slow down due to limitations in land and future lower purchasing prices. But after 2002, when the first repowering program was fulfilled and the two large offshore farms were built the investments in new wind turbines on land has come to a nearly complete stop. The reason for that is the introduction of a purchasing price based on the market based price with a cap of 0.36 DKK/kWh. Future inland market development will therefore mainly be tied to repowering of smaller 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 market-based procedures according to the Act on

Electricity Supply and the updating of the Action Plan for Offshore Wind Power from 1997 as a follow up to the Energy Strategy 2025.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

3.2.1 MANUFACTURING

Today the major Danish based manufacturers of large commercial wind turbines up to the 3 MW size are: Siemens Wind Power (former 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 number of industrial enterprises have developed important businesses as suppliers of major components for wind turbines. As examples LM Glasfiber A/S is a world-leading producer of composite blades for wind turbines, Mita Teknik A/S produces controller and communication systems, and Svendborg Brakes A/S is a leading vendor of mechanical braking systems.

Industrial development in 2005 continued to focus on new generations of 3 to 5- MW turbines and adapting to the emerging offshore wind farms. The largest prototype is the 4.2-MW wind turbine from Vestas (NEG-Micon), which was erected in late 2003 at the Høvsøre test site. In 2005, especially Vestas has, based on experiences at Horns Rev, spent a lot of effort improving the quality of offshore wind turbines.

The power production companies Elsam, Energi E2 and DONG merged in 2005, and it is expected that the new company will continue their business both as developers and as owners and operators of wind farms in Denmark and internationally.

The two major organisations that represent the owners and the manufacturers are: "The Danish Wind Turbine Owners' Association," www.dkvind.dk and the "Danish Wind Industry Association," www.windpower.org.

3.2.2 OPERATIONAL EXPERIENCE

Technical availability of new wind turbines on land in Denmark is usually in the range of 98% - 100%. Offshore the availability of the small near-shore farms are also high, but in 2004 the availability on Horns Rev was low due to a comprehensive repair of the gears and transformers on all the Vestas turbines. However during 2005 all turbines have been operating nearly 100% with an availability of 95%, whereas the Siemens (Bonus) turbines at Nysted reached 97%.

3.3 ECONOMIC DETAILS

Operation and maintenance costs including service, consumables, repair, insurance, administration, lease of site, etc. for new large turbines have been scarcely reported. The growing commercialisation in the wind energy market makes it more difficult to have data on both hardware cost and O&M costs. Based on a study carried out by



Figure 7 Offshore wind farm at Nysted, 158 MW. Published with the permission of Energi E2.

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the Danish Wind Turbine Owners' Association, some results on the operational experience of turbines between 600 kW and 1,300 kW were reported in the last IEA Wind Annual Report.

3.4 CERTIFICATION OF WIND POWER INSTALLATIONS

Wind turbines installed in Denmark have to fulfil the Danish Certification Scheme. In December 2004, a new scheme has been introduced instead of the former Type Approval Scheme. The new scheme is based on the IEC WT01 System for Conformity Testing and Certification of Wind Turbines. The implementation of the IEC system means a higher degree of mutual recognition of certificates between countries and therefore an easier access for all manufacturers to sell their products internationally. The certification bodies providing services according to the new scheme now can operate based on an accreditation given by any international recognised accreditation body. However due to the very slow Danish market, very few practical experiences have been obtained with the scheme.

The Danish Energy Authority is responsible for the administration of the scheme. Risø National Laboratory acts as secretariat and information center for the scheme. 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, which 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 have been postponed and the certificates are 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 20 years. In 2005, the market price plus premium varied between 0.27 and 0.36 DKK, which is the cap. Since May 2005, the market price has been between 0.26 and 0.33 DKK actually reducing the premium to as little as 0.03 DKK/kWh. The details about the purchasing prices were listed in the IEA Wind Annual Report from 2004.

5.0 RD&D ACTIVITIES

No major change in funding of Wind RD&D has been introduced in 2005. Prior to the political agreements of 9 May 2003 and 29 March 2004, the public funds, including funds financed by the consumers, reserved for energy research, development, and demonstration in 2005 amounted to approximately 273 million DKK (app. 242 million DKK in 2004). Plans for 2006 show an increase in the total to 326 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.

5.1 THE ENERGY RESEARCH PROGRAMME

The Danish Energy Authority, in 2004 part of the Ministry of Economic and Business Affairs, is responsible for the administration of the Energy Research Programme (EFP), which covers research in both conventional energy and renewable energy. The EFP is intended to contribute to establishing the technological opportunities required for the practical implementation of Danish energy policy. The EFP is also intended to contribute to strengthening exports of Danish energy technology and know how. Recently, the Danish Energy Authority released a report showing that Danish energy technology and know how export in 2004 amounted to 32.3 billion DKK, 7.1% of all Danish export. Wind turbines are accounting for 70% of the energy export.

Description of the program and the projects supported (in Danish) are available on the Danish Energy Authority's Web pages (refer to www.ens.dk). The budget for the EFP program in 2005 has

Table 2 Programs and available funds for RE R&D projects including wind energy

	2003	2004	2005	2006
	Million DKK	Million DKK	Million DKK	Million DKK
Energy Research Program (EFP)	41	72	73	74.0
PSO-electricity production	100	130	130	130.0
PSO-electricity utilisation	25	25	25	25.0
Renewable energy R&D – Danish Research Agency	35	45	45	108.3
Total	201	242	273	337.3

been maintained at the level reached in 2004 due to the political agreement of 9 May 2003. In 2005, three wind energy projects were supported. These and other important wind energy projects supported in 2005 are shown in Table 3. In addition, EFP supported international R&D cooperation through IEA.

A funding of 2 million DKK for quality assurance of wind turbines is allocated to the Secretariat for Danish Wind Turbine Certification Scheme to manage the scheme. The actual certification of

turbines and installations are carried out by private certification companies like DNV and GL. Denmark has also been active in international standardisation in IEC and CEN/CENELEC for several years, and standardisation work has a high priority and is supported through R&D funds.

5.2 THE PSO PROGRAMME OF THE TRANSMISSION SYSTEM OPERATORS

In addition to the government R&D programs, the transmission system operators, which from

Table 3 Important wind energy projects funded by Danish R&D programs in 2005*

Title	Applicant	Support (million DKK)
Program for Research in Applied Aeroelasticity	Risø	3.5
Improved Design Basis of Large Fiber Composite Rotors (3 Part)	Risø	3.7
Soil-Structure Interaction of Foundation for Offshore Wind Turbines	AAU	2.3
Sustainable Resource Utilisation of Marine Habitats for Wind Farms	National Environmental Research Institute	5.0
Probabilistic Design of Wind Turbines	AAU	2.0
12 MW Wind Turbines – the Scientific Basis for their Operation at 70 to 270 m Height Offshore	Risø	2.5
Wind Profiles and Forests	Risø	2.5
Medium Voltage Grid Investigations in Modern Wind Farms	Delta	3.7
Experiences from Offshore Demonstration Projects. Offshore Turbine Parameters (2 Part)	Risø	8.2
* In addition to these nine projects another four projects were funded with a total amount of 5.8 million DKK.		

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2005 are merged into one government owned company Energy DK, have PSO subsidised R&D programs for non-commercial projects concerning new and environmentally friendly energy technologies. The programs focus on development of RE 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 emphasises the interaction between turbines and the power system, including the wind power plants' abilities to contribute to regulation and stability. Furthermore, the PSO program supports the utilisation of measurements and experiences from ongoing offshore wind farm projects. The most important wind energy projects funded in 2005 are included in Table 3.

For the environmental offshore demonstration program, a total of 84 million DKK has been allocated as PSO funding during the period 2001 - 2006. Baseline studies have been undertaken in the projected areas to be able to compare the existing environmental conditions to the situation after introducing a wind farm. Topics such as the

effect on birds, mammals, fish, benthic invertebrates & plants, hydrology, and geomorphology as well as noise will be considered. In order to concentrate the investigations, it has been decided to conduct a monitoring program for prioritised subjects and to make effect studies in areas where the presence of species to investigate can be expected to be high.

Out of the total annual R&D budget of 100 million DKK in 2005, approximately 15% has been used on wind energy. Prioritised issues are efficiency, costs, and reliability of the wind turbines, grid integration, erosion protection, and monitoring the offshore demonstration program. In 2005, it was agreed also to allocate 30 million DKK for demonstration projects, but the tender for projects has been delayed and the start up will take place in 2006.

5.3 THE DANISH RESEARCH AGENCY – THE NATIONAL RESEARCH COUNCILS

According to an agreement reached in 2002 between the government and the opposition, an amount of 110 million DKK (20 million DKK in



Figure 8 A SODAR installation at the test site for MW-sized wind turbines at Høvsøre. The wind field is measured up to a height of 150 m.

2003 and 45 million DKK in 2004 and 2005) will be devoted to strategic renewable energy research projects. The funds will be administered by the Danish Research Agency, The Danish Council for Strategic Research. The most important wind energy projects funded in 2005 are included in Table 3. For 2006, the annual budget will increase to 108 million DKK of which 11 million DKK will be disposed for systematised renewable energy, an important subject for wind energy.

5.4 RISØ NATIONAL LABORATORY

In order to strengthen its competence to cover all sides of offshore development and in order to strengthen the education of PhDs and engineering candidates, Risø, in May 2002, formed a consortium together with the Technical University of Denmark (TUD) in Lyngby, Aalborg University (AaU) and Danish Hydraulic Institute (DHI). This builds on the existing close cooperation with TUD on Aeroelastic Design and with AaU on Electrical Design. The cross disciplinary consortium is intended to improve the network and coordination between research, education, and industry. The research is planned and implemented around the following themes: a) climatic conditions, b) wind turbine design, c) electrical systems, control and integration, and finally d) society, markets and energy systems. Many of the R&D projects listed in Table 3 are carried out by partners in the consortium.

In addition to project cooperation between the consortium partners, a grant has been given by the Danish Research Training Committee to a national research school during 2002 - 2006, the Danish Academy in Wind Energy, with the purpose to strengthen the education of PhDs and to attract visiting students, researchers, and professors.

During the last few years, large efforts have been spent on establishing a new test site for multi-MW wind turbines. The test site has been selected at Høvsøre, a site at the northwest coast of Jutland in order to have a reasonable number of high wind situations during a limited test period. The annual

average wind speed at 78 meters height is 9.1 m/s at the site. The test site consists of five test stands allowing turbines with heights up to 165 m and a capacity of 5 MW each. West of each test stand a meteorological mast has been erected, and two 165 m masts with light markings have been installed. Three manufacturers have leased test stands, Vestas, Siemens Windpower and Nordex. The first wind turbine at the test site, a 3-MW turbine with rotor diameter of 90 m and hub height of 80 m, was put in operation on 7 November 2002. At present five wind turbines are installed. The test site is shown in Figure 8.

5.5 COLLABORATIVE RESEARCH

A possible constraint to the future deployment of wind energy into the Danish energy system is maintaining the power balance or dealing with the electricity surplus. Due to the high share (~50%) of electricity from combined heat and power (CHP) and the high share (~25%) from renewable electricity (mainly wind power), a substantial part of Danish electricity production is influenced by weather conditions (outdoor temperature and wind speed), thus limiting 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 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 the fluctuating electricity production.

Electricity surplus is generally exported. If it is not physically possible to export the entire surplus, a critical situation arises which can require the wind capacity to be reduced. This happens already today in the western part of Denmark with increasing frequency. The economical benefit of utilising the surplus (rather than export it) depends on the price on the power market and on the environmental value of electricity export from Denmark. In general, more flexibility in the power production and demand will be appropriate to be able to respond to market conditions. Wind generated surplus

electricity is advantageous, lowering consumer prices. Tax releases on future production of heat from surplus electricity will open up new market possibilities for wind energy electricity.

At the level of EU, a contract has been signed about a large project called UpWind with the aim to design a wind turbine of 8 to 10 MW which shall be able to operate onshore and off-shore in wind farms of several 100 MW. With Risø National Laboratory as the coordinator, 38 partners will participate in the project to start early in 2006.

Denmark participates in IEA Wind Tasks XI, XX, XXI, XXV, and in Task XXIII as one of the subtask operators.

- Annex XI – Base Technology Information Exchange. The participation is important for Denmark having a large export of wind turbine technology and know how.
- Annex XX – HAWT Aerodynamics and Models from Wind Tunnel Measurements. The participation is important for Danish research not having access to large national wind tunnel installations.
- Annex XXI – Dynamic Models of Wind Farms for Power System Studies. Modelling Danish power systems occasionally dominated by wind power is necessary to develop the concept of a wind power station, wind turbines not to be considered only as decentralised production units.
- Annex XXIII – Offshore Wind Energy Technology Deployment. Cost reductions and environmental considerations are principal matters for deployment strategies. The participation will be beneficial to the partners of the above mentioned EU project UpWind.
- Annex XXV – Power System Operation with Large Amounts of Wind Power. The Danish participation is important since 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 2005 being nearly zero and the new, large offshore projects being only in the planning process, new information on investment costs is not available. 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 larger and the amount wind energy harvested is therefore better, the total economy of the megawatt-scale projects will be better.

Availability of capital for wind power projects is not a problem. Financial institutions compete efficiently on this market, and different financial packages have been developed. Typical projects are financed over 10 years. Additional costs depend on local circumstances, such as condition of the soil, road conditions, proximity to electrical grid substations, etc. Additional costs on typical sites can be estimated to approx. 20% of total project costs. Only the cost of land has increased during recent years.

The production cost for wind generated electricity per kilowatt hour has decreased rapidly over the last two decades, and the trend is that the production from large-size turbines in a few years will be able to compete on equal terms with electricity production from conventional power stations. Consequently, the consumer price for wind generated electricity approaches the level of other electricity prices. As mentioned in an earlier section of this report, the difference during long periods of time has been as little as 0.03 DKK/ kWh.

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CHAPTER 13

EUROPEAN COMMISSION

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1.0 INTRODUCTION

Wind power is a success story in Europe. The White Paper (1) target of 40 GW of installed capacity by 2010 has already been reached in 2005 (2) and 74% of the worldwide generating capacity and 90% of the generating equipment are European. Wind power supplies more than 2% of gross electricity consumption in Europe. In a recent survey entitled "Attitudes towards Energy" (3), 31% of EU citizens consider that governments should focus on wind power to reduce the dependency on imported energy resources.

Since 2001, the EU has put in place a new regulatory framework, with a view to accelerating the growth of EU markets for renewable electricity. In this context, the most important instrument is the Directive (4) on electricity production from renewable energy sources and its monitoring process, which is underpinned by a number of data gathering activities, notably also for the new Member States and Candidate States. In view of

these policy commitments, the future development of wind power is supported through the EU Framework Programmes, for both research and demonstration activities and through the Intelligent Energy - Europe Programme for non-technological actions aimed at overcoming market barriers.

Currently, more than 30 R&D projects are in progress under the Fifth and Sixth Framework Programmes (FP5 and FP6). A brochure "European Wind Energy at the dawn of the 21st century (5)" was published in August 2005 to synthesize the results of FP5 wind projects and provide some reference data about them. The Directorate-General for Research (DG Research) of the European Commission manages research projects with medium- to long-term impact, while demonstration projects with short- to medium-term impact on the market are dealt with by the Directorate-General for Transport and Energy (DG TREN).

2.0 DG RESEARCH ACTIVITIES

The projects running in 2005 can be divided into the following categories:

- A. Wind turbines
- B. Blades and rotors
- C. Wind resources forecasting and mapping
- D. Wind farm development and management
- E. Integration of wind power

In the descriptions below, the projects are named through their acronym. Further references and project data are given in Table 1.

A. WIND TURBINES

The MEGAWIND project sets out to formulate procedures to overcome the barriers to the trans-

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portation and erection of MW-sized machines in complex terrain, high wind speed areas with limited infrastructure and to reduce costs through design optimization and tailoring, with the results applied to the design and construction of a 1.3-MW prototype.

Within the EXPLOREWIND project, efficiency, cost reduction, and environmental issues related with new wind turbine concepts for small non-grid connected power systems are investigated.

B. BLADES AND ROTORS

The KNOW-BLADE project aims to reduce 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 2D and 3D 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 aims to provide just 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 developed with which silent airfoils can be designed. The airfoils will be applied to existing turbines and subjected to extensive measurement campaigns.

To improve knowledge in the field of the aero-elastic stability and control of large wind turbines, the STABCON project has been funded. 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, for use by the industry. Besides this database, design guidelines ready to be implemented into the design standards will be formulated.

At the intersection of material development and aero-elastic stability, research is being carried out on the development of damped composite blades. The DAMPBLADE project is focusing on using the benefits that can be gained from taking advantage of material damping properties in the design of large composite blades. As an additional result, the project will provide the wind industry with an analytical tool to incorporate the explicit modeling of composite structural damping in stability and fatigue analyses.

C. WIND RESOURCES FORECASTING AND MAPPING

The ANEMOS project aims 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, 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, as well as the expected risk based on ensemble weather forecasts.

Given that substantial improvement in wind power forecasting can be achieved by more accurate weather forecasting, the HONEYMOON project has developed an approach that focuses on identifying weather prediction errors and developing methods to reduce them.

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 POWWOW 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.

D. 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, not only with condition monitoring techniques but also with the more “traditional” measurement systems. The main objective is to improve monitoring systems and to develop data processing techniques to create an early warning system for component failure.

E. INTEGRATION OF WIND POWER

Using techniques such as forecasting, interconnections and electricity storage, as well as reinforcement of the grid network itself, and in-

creased geographical dispersion of wind power, it is feasible to have a very high level of wind penetration in the European electricity systems without affecting the quality of supply. The WILMAR project contributes to this through investigating a range of possibilities such as dedicated storage facilities and regional power exchanges.

As part of the desire to increase the expertise in the former eastern European area, FP5, through the RO-SWEET project, is encouraging knowledge exchange on solar and wind energy systems between Romania and centers of excellence in the West.

The Wind Energy R&D Network organizes industry wide discussion on R&D needs with a view to establishing a strategy for wind research, assigning individual research tasks among public and private sectors. The network seeks to ensure that research tasks falling into nine categories are undertaken across the wind community, the objective being to achieve more optimal efficiency and a more aggressive development in the wind industry.

3.0 DG TREN (ENERGY AND TRANSPORT) ACTIVITIES

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

A consortium around Nordex is developing a new crane concept - the power crane - for the N80 2,5 WTG WEC. With the availability of such a power crane, expensive mobile cranes are only needed during the initial installation process. During wind energy converter (WEC) operation the power crane, which is part of the turbine, allows the replacement of major components, thus reducing the down time (with related income loss) and the external crane costs significantly. This concept shall be demonstrated and tested in the framework of the Estonia 20-MW Wind park project to be installed at Paldiski, the first wind park in Estonia.

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A consortium around Enercon developed a 5-MW off-shore WEC for pilot operation in the framework of the 5-MW off-shore project. This will be the first off-shore WEC to be installed in Germany. The rotor of this WEC has a diameter of 112 m.

INNOWT5000 is the name of a project aiming at designing, manufacturing, and installing a 5-MW wind turbine. This first REpower 5-M WEC prototype with a rotor diameter of 126 m is designed for on-shore and off-shore application. LM Glasfiber developed the blade, which uses carbon fiber reinforced plastic. Non-locating bearings for the drive train are supplied by SKF.

One of the largest off-shore wind farms in the world and one of the first wind farms to be connected to a full-scale HVDC light system will be realized in the framework of CLOWEBS at Klasården. This 42-MW wind park will be sited some 2 km from the west coast of the Näs peninsula on the island of Gotland in the Baltic sea and shall be operational by 2006.

The objective of the DOWNVIND project is to pioneer cost-effective deepwater windfarms in water depths of up to 50 m and approximately 25 km away from the shore. This FP6 project consists of a targeted research program and a demonstrator adjacent to the Beatrice Alpha platform in Scotland/UK, which will pioneer the reuse of oil infrastructure in the wind industry. It is planned to use 5-MW WEC for this off-shore application.

Maintenance of off-shore WEC is a challenge, especially when considering the harsh weather conditions encountered out on the sea. The economic viability of off-shore WEC can be improved with clever operation monitoring systems, which help to detect future problems before such problems lead to critical operation conditions. Within the project Offshore maintenance and repair (M&R) advanced maintenance and repair tools are to be developed for off-shore wind farms. These tools will use fault prediction and condition

monitoring techniques as well as technically and economically optimized M&R strategies for wind energy converters in off-shore wind farms. The expected result is to reduce the response time and the costs for WEC maintenance and repair.

The Concerted Action for the Deployment of Offshore Wind Energy - COD - project was initiated in 2002, with the objective of speeding up the environmentally responsible implementation of offshore wind energy in the European Union by the early identification and possible removal of non-technical barriers: legal, administrative, policy, environmental and grid infrastructure planning issues. COD's ultimate aim was to produce European guidelines on the deployment of offshore wind that would draw on best practice established in the course of the project. Work leading up to the guidelines included collation from COD member countries of the existing knowledge base on environmental, grid and legal/administrative issues. This included guidelines, reports, assessments and data. The resulting COD resources comprise a database of documents reporting on the environmental effects of offshore wind farms, a review of the situation with regard to grid integration in COD member countries, and a database of administrative/legal procedures in place.

4.0 FUTURE PROJECTS

Several new wind projects are expected to start in 2006.

The Integrated Project (IP) UPWIND will commence at the beginning of 2006. It aims at developing design tools for future very large wind turbines (8-10 MW) standing in wind farms of several hundreds of MW, both on- and off-shore. Coordinated by the Risø National Laboratory (Denmark), this large long-term research effort will involve 39 partners and run for 5 years.

Three Specific Targeted Research Projects (STREPs), part of the demonstration activities

funded by DG Energy and Transport, namely NEWGEN3MW, SIWT, and WINDEX, are close to finishing their negotiations and should become operational by mid-2006. More details will be available after the signature of the contracts.

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- (2) EWEA – press release 8/2/2006
- (3) Attitudes towards Energy – Eurobarometer 247 – January 2006
- (4) Directive 2001/77/EC on promotion of electricity produced from renewable energy sources in the internal electricity market
- (5) European Wind Energy at the dawn of the 21st century - EUR 21351 - 2005

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Table 1 List of Wind R&D Projects running in 2005 (DG Research and DG TREN)

DG Research	
A – Turbines	
A1. Development of a MW scale wind turbine for high wind complex terrain sites	
Reference: ENK5-CT-2000-00328	Project Acronym: <i>MEGAWIND</i>
Starting date: 1/1/2001 Duration: 54 months	
A2. Exploring new concepts for small and medium-sized wind mills with improved performance.	
Reference: ENK5-CT-2002-30034	Project Acronym: <i>EXPLOREWIND</i>
Starting date: 1/1/2003 Duration: 24 months	
B – Blades and rotors	
B1. Wind turbine rotor blades for enhanced aeroelastic stability and fatigue life using passively damped composites	
Reference: ENK6-CT-2000-00320	Project Acronym: <i>DAMPBLADE</i>
Starting date: 1/1/2001 Duration: 48 months	
B2. Wind Turbine Blade Aerodynamics and Aeroelasticity: Closing Knowledge Gaps	
Reference: ENK6-CT-2001-00503	Project Acronym: <i>KNOW-BLADE</i>
Starting date: 1/12/2001 Duration: 36 months	
B3. Model rotor experiments under controlled conditions	
Reference: ENK5-CT-2000-00309	Project Acronym: <i>MEXICO</i>
Starting date: 1/1/2001 Duration: 60 months	

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B4. Reliable Optimal Use of Materials for Wind Turbine Rotor Blades	
Reference: ENK6-CT-2001-00552	Project Acronym: <i>OPTIMAT BLADES</i>
Starting date: 1/1/2002 Duration: 52 months	
B5. Silent rotors by acoustic optimisation	
Reference: ENK5-CT-2002-00702	Project Acronym: <i>SIROCCO</i>
Starting date: 1/1/2003 Duration: 36 months	
B6. Aerolastic stability and control of large wind turbines	
Reference: ENK5-CT-2002-00627	Project Acronym: <i>STABCON</i>
Starting date: 1/11/2002 Duration: 48 months	
C – Wind resources forecasting and mapping	
C1. Development of a next generation wind resource forecasting system for the large-scale integration of onshore and offshore wind farms	
Reference: ENK5-CT-2002-00665	Project Acronym: <i>ANEMOS</i>
Starting date: 1/10/2002 Duration: 48 months	
C2. A high resolution numerical wind energy model for on- and offshore forecasting using ensemble predictions	
Reference: ENK5-CT-2002-00606	Project Acronym: <i>HONEYMOON</i>
Starting date: 1/1/2001 Duration: 24 months	
C3. Prediction Of Waves, Wakes and Offshore Wind	
Reference: SES6-CT-2005-019898	Project Acronym: <i>POW'WOW</i>
Starting date: 1/10/2005 Duration: 36 months	
D – Wind farms	
D1. Condition Monitoring For Offshore Wind Farms	
Reference: ENK5-CT-2002-00659	Project Acronym: <i>CONMOW</i>
Starting date: 1/11/2002 Duration: 48 months	
E – Integration of wind power	
E1. Wind Energy Network	
Reference: ENK6-CT-2001-20401	Project Acronym: <i>WIND ENERGY NETWORK</i>
Starting date: 1/12/2001 Duration: 42 months	
E2. Wind power integration in a liberalised electricity market	
Reference: ENK5-CT-2002-00663	Project Acronym: <i>WILMAR</i>
Starting date: 1/11/2002 Duration: 36 months	
E3. Solar and Wind Technology Excellence, Knowledge Exchange And Twinning Actions Romanian Centre	
Reference: ENK5-CT-2002-80667	Project Acronym: <i>RO-SWEET</i>
Starting date: 1/11/2002 Duration: 36 months	

DG TREN - Demonstration Projects	
F1. Klasorden 42 Mw; A Demonstration Of Cost-Optimised Large Scale, Offshore Wind Energy In The Baltic Area	
Reference: NNE5/703/1999	Project Acronym: <i>CLOWEBS-2000</i>
Starting date: 1/7/2000 Duration: 54 months	
F2. 5MW Wind Energy Converter for Off-shore Application	
Reference: NNE5/412/2000	Project Acronym: <i>5MW-OFFSHORE-WEC</i>
Starting date: 1/6/2001 Duration: 48 months	
F3. 8 X 2.5 MW Wind Turbines with Crane-free Erection to be Implemented in Estonia	
Reference: NNE5/142/2000	Project Acronym: <i>ESTONIA 20 MW WIND</i>
Starting date: 1/10/2001 Duration: 48 months	
F4. Concerted Action for Offshore Wind-energy Deployment	
Reference: NNE5/633/2001	Project Acronym: <i>COD</i>
Starting date: 1/1/2003 Duration: 36 months	
F5. Advanced Maintenance and Repair for Offshore Wind Farms Using Fault Prediction And Condition Monitoring Techniques	
Reference: NNE5/710/2001	Project Acronym: <i>OFFSHORE M&R</i>
Starting date: 1/1/2003 Duration: 36 months	
F6. 5MW Innovative Wind Turbine Suitable for On Land and Offshore Installations	
Reference: NNE5/977/2001	Project Acronym: <i>INNOWT5000</i>
Starting date: 1/1/2003 Duration: 36 months	
F7. Distant Offshore WindFarms with no Visual Impact in Deepwater	
Reference: Wind/503202/2003	Project Acronym: <i>DOWNWIND</i>
Starting date: 04/09/2004 Duration: 60 months	



NATIONAL ACTIVITIES



CHAPTER 14

FINLAND

1.0 INTRODUCTION

The energy production of Finland has a high share of renewables, mainly hydro power and biomass. The gross electricity demand is about 86 TWh and is characterised by energy intensive industry. About half of the electricity is consumed by the paper and metal industry. Finland's generating capacity is diverse: 26% nuclear, 16% hydro power, and 31% from combined heat and power (coal, gas, biomass, and peat).

Most of Finland's hydro-power resource has already been utilised; 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 where most of the increase in renewables is foreseen by biomass.

Wind energy potential is located mostly on coastal areas. There is a huge technical potential offshore,

with ample shallow sites available. The short-term potential on the coastal areas of Finland, taking into account both economical and land use restrictions, 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

Targets for wind power deployment in Finland are set in the National Climate Strategy (2001). It recognises the EU RES-E-Directive on national objectives concerning electricity produced from renewable energy sources, which for Finland is 31% of the total electricity consumption in 2010. The electricity production with renewable energies would increase by 8.3 TWh from the level in 1995. The major part, 75%, would be generated from bio-fuels. The target for wind energy deployment was set to 500 MW in 2010 and a vision of 2,000 MW in 2025 was foreseen (5% of gross demand).

In 2004, the progress towards the goals was assessed. It was recognised that the progress has been slow compared to the goals, especially for wind and solar energy. Also the funds available for investment subsidy are not adequate to achieve the goals set by 2010. The factors behind the slow

Table 1 Key Statistics 2005: Finland

Total installed wind generation	82 MW
New wind generation installed	0 MW*
Total electrical output from wind	0.170 TWh
Wind sector turnover	Est. 250 million €
Wind generation as % of national electric demand	0.2%
Target:	500 MW by 2008-2012
* 4 MW installed; 4 MW removed	

progress in wind energy have been the low cost of electric energy in the market together with the on average lower than earlier investment subsidy, the long lead time for planning of wind projects, and the differing practices in grid connection policies for distributed generation. It was proposed that alternative subsidy systems for wind energy will be looked for. With the existing support, the realised wind power capacity of 300 MW is foreseen for 2010.

The national energy and climate strategy was updated in 2005 and will be approved by the parliament in spring 2006. The only target suggested is for 31% of the total electricity consumption in 2010 to be provided by renewables. No major changes in measures to achieve the targets are suggested. Thus the investment subsidy will probably remain the primary support mechanism although new support mechanisms are to be investigated.

The development in wind power capacity and production is presented in Figure 1. The installed capacity in Finland did not grow in 2005. Four new turbines totalling 4 MW were installed. However, two of the three 2-MW turbines of the 6-MW wind farm in Inkoo were dismantled and shipped back to Germany due to local opposition. This left the total 82 MW of capacity at the end of 2005 the same as end of 2004. The total wind energy production in 2005 showed growth due to good wind resource and whole year operation of the 2004 installed capacity: 170 GWh corresponds to 0.2% of the annual gross electricity consumption of Finland.

There were 94 wind turbines in operation in Finland at the end of 2005. Average wind turbine size is 870 kW. About 62% of the installed capacity originates from Denmark, 20% from Finland, and 18% from Germany. The size of the installed capacity ranged from 75 kW to 3 MW.

There are currently more than 100 MW of total projects in various planning phases in Finland. The three largest projects are in Pori (onshore 12 MW in 2006 and offshore demonstration in plan-

ning phase 45 MW) and Kemi (partly offshore 30 MW).

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 was 7% in 2005).

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

A group of the wind technology manufacturing industry under Technology Industries in Finland released a road map for wind power technology in November 2005. The group concluded that combining existing know how with special requirements for new market segments for wind power (e.g. offshore, cold climates) could bring in new export possibilities for Finnish wind power technology. According to the calculations, investing a total of 220 million € for wind energy in 2006 to 2020 by creating demonstrations (50 million, 80 - 130 MW), building a home market for wind power (investment subsidy 95 million, 500-600 MW), and providing 4-5 million €/year for R&D and road-map studies could result in the following:

- Raising the yearly wind technology exports from 200 to 1,400 million € per year in 2020, creating 18,000 new jobs
- Total investment for wind power in Finland of 100 million € per year on average during 2006-2020 (1,500 MW)
- CO₂ reduction in Finland by 7 million tons during 2006 to 2020 (10 TWh in total)

Most of the turbines in Finland are owned by power companies and local energy works. Green electricity is offered by most electric utilities; however, the marketing is not very active. Supply for used turbines from the first demonstration

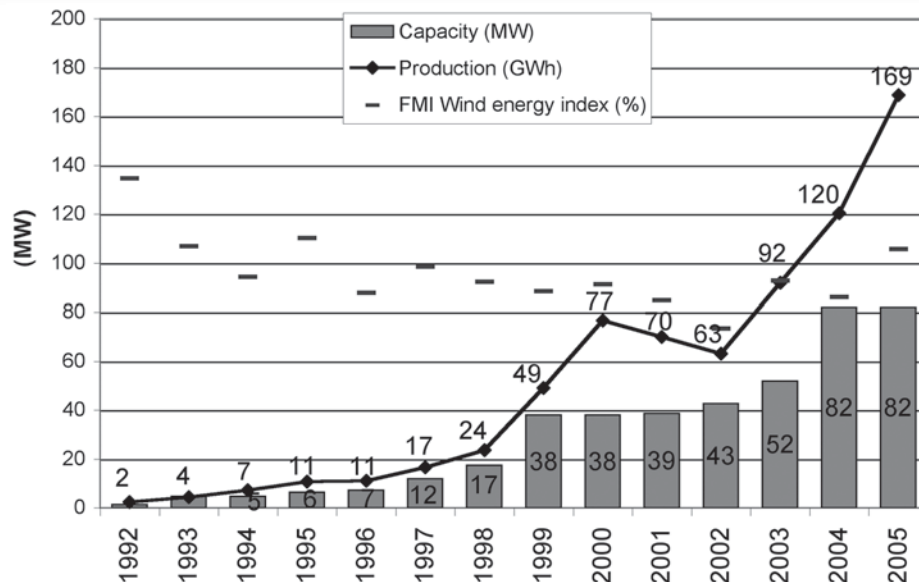


Figure 1 Development of installed wind power capacity (MW at end of year), yearly wind power production (GWh), and wind production index (calculated from Finnish Meteorological Institute wind speed measurements converted to wind power production, 100% is average production for years 1987-2001).

projects in Finland and from the Netherlands has encouraged some farmers to acquire a second-hand turbine – they are located in-land where the wind resource is limited. Good sites for larger wind farms on the coastal areas are scarce. This is one reason that offshore is starting to interest the power companies: the two first demonstration projects in Pori and Kemi are now in planning phase.

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 one-stage planetary gearbox and a permanent-magnet generator. WinWinD has manufactured about 20% of all turbines in Finland (16 MW) (Figure 3). WinWinD started their export activi-

ties in 2004, with turbines sold to Portugal and Sweden. In 2005, new projects in Estonia (24 MW) and Sweden (5 MW and 2 MW) were announced, and a joint venture in China was founded with the first demonstration turbine erected.

For some time, the Finnish industry has produced main components such as gearboxes and induction generators as well as materials like cast-iron products, tower materials, and glass-fibre products for the main wind turbine manufacturers. The total turnover exceeded 200 million € in 2004.

A blade heating system for wind turbines operating under icing conditions was released as a commercial product in 1998. It has been developed mainly for the domestic market but also for export. The first delivery to Sweden was made in 1998. It has been also been tested at sites in southern Finland where public safety is a concern (due to occasional icing) since 1999. The wind potential at arctic fell areas in Finland still needs a next generation blade heating to materialise.

Finland year 2005:
82 MW, 94 turbines

- Wind farm 4... 11.5 MW
- Wind farm 0.6... 3 MW
- Single turbine 1...3 MW
- Single turbine < 1 MW
- ▨ area for offshore wind farm in regional plan

Wind farms labeled from 4 MW up

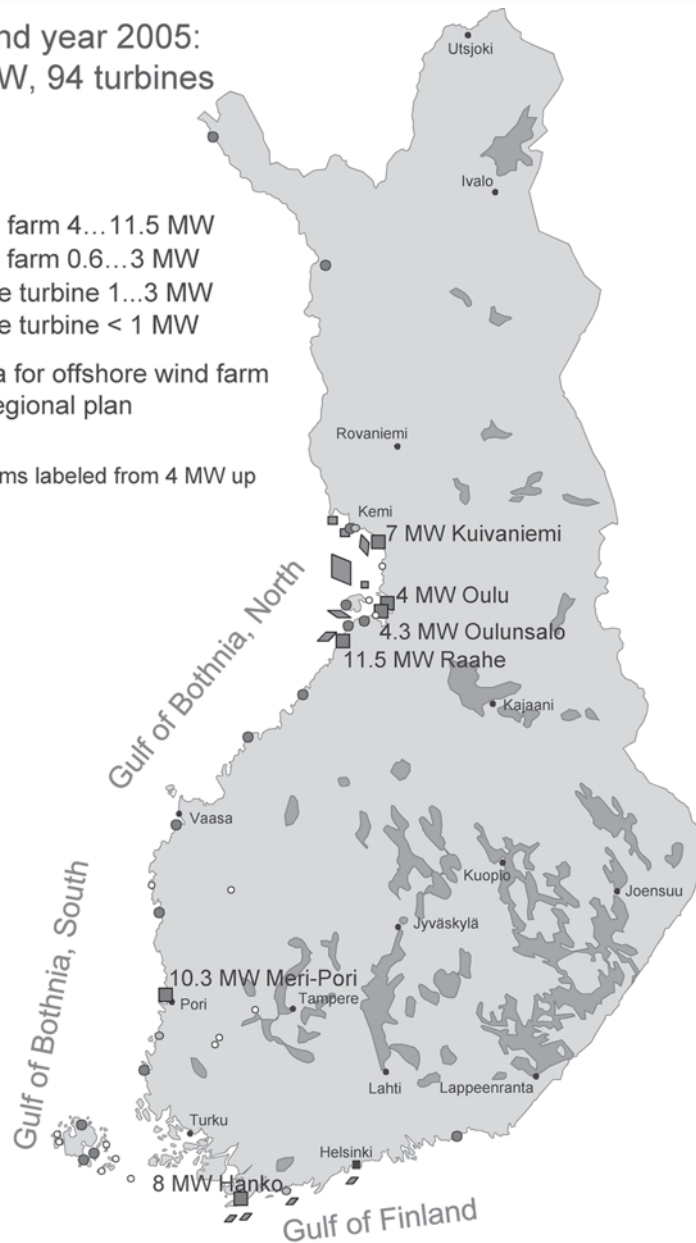


Figure 2 Locations of wind turbines in Finland at the end of 2005. Also, larger offshore sites in regional plans are marked on the map.

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

3.2.2 OPERATIONAL EXPERIENCE

According to the production statistics, an improved performance of wind power production can be seen in Figure 4. The average capacity factor

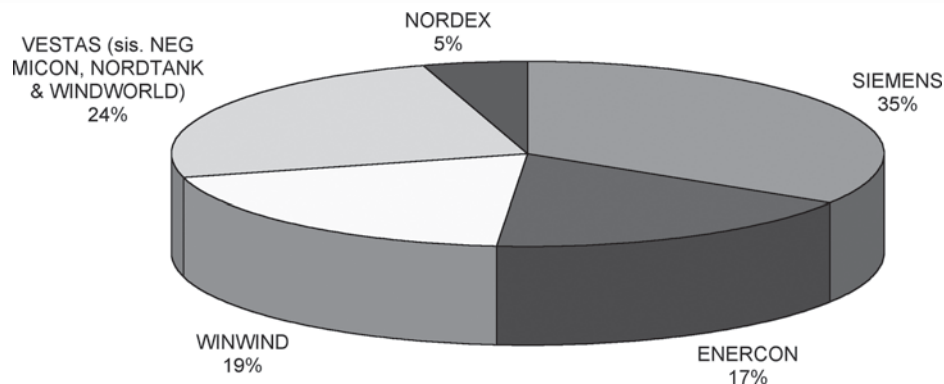


Figure 3 Market shares of turbine manufacturers in Finland as a percentage of the total capacity at the end of 2005 (82 MW).

has been higher in 2000 to 2005 than it was in the 1990s even though the production index has been lower in recent years. This is mainly due to more megawatt-scale machines reaching a higher wind resource.

Overall availability of the wind turbines operating in Finland was 94% in 2005 (95% in 2004). One of the 78 reporting turbines had an availability of less than 30% due to a slow repair of first a broken main unit and then a transformer failure. The second most frequent causes for downtime were hydraulics and blade tips. A gearbox failure and a slow rebuilding of one 1.3-MW turbine destroyed by fire in 2004 reduced the availability of two turbines.

3.3 ECONOMIC DETAILS

At a good site on coastal Finland, the cost of wind energy production could be about 30 to 40 €/MWh, including an investment subsidy (15 years, 7% internal rate of return). The average spot price in the electricity market Nordpool has been 27 to 31 €/MWh in 2004-2005. 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.

All wind energy installations are commercial power plants and have to find their customers on a free power market. In most cases, an agreement

with a local utility is made, giving market access and financial stability. Several companies offer “green” or specifically “wind” electricity, certified by the association for nature conservation, at a price higher than the average for households. The market success for these initiatives has, however, been modest. Only a few percent of the household consumers have changed electricity supplier at all since the liberalisation.

If the impacts of emission trading continue to raise electricity market prices, this will affect the cost competitiveness of wind power and make also sites with less favorable wind resource realisable. In this way the wind power market in Finland may increase.

4.0 NATIONAL INCENTIVE PROGRAMS

For wind energy installation an investment subsidy of up to 40% can be awarded, depending on the level of novelty in the project. Projects that have applied for subsidy in 2001-2005 have received an investment subsidy of 35% on average. In addition to the investment subsidy, a tax refund of 6.9 €/MWh is awarded. This corresponds to the tax on electricity that is paid by household consumers.

The national energy and climate strategy was updated in 2005 and will be under discussion in the parliament during spring 2006. No major changes

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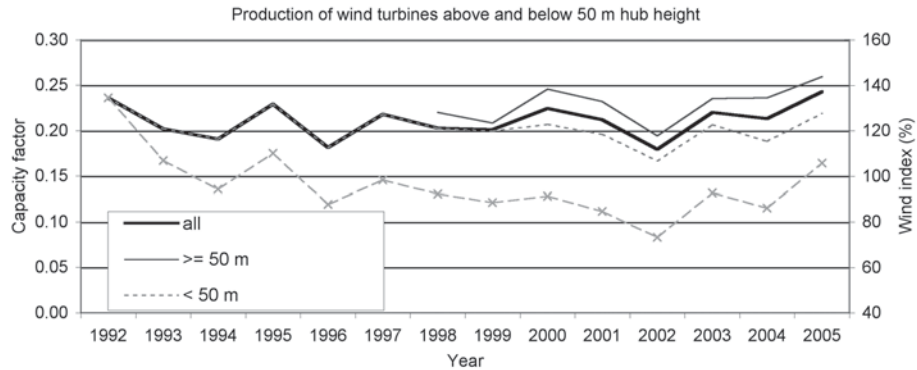


Figure 4 Average capacity factor of wind turbines in Finland: for all turbines and for higher and lower hub height turbines. The production index calculated from FMI wind speed measurements is also shown (100% corresponds to average production in 1987-2001).

in measures are suggested. The emission trading is expected to have an impact on electricity market price and thus improve the cost-competitiveness of wind power.

A working group established by the Ministry of Environment has set up a framework for planning and building permission procedures. Wind energy deployment is slow but there is still a continuous discussion on the environmental impact of wind turbines. Land-use restrictions and visual pollu-

tion, especially in relation to summer residents and vacation activities, might yet prove a significant obstacle to development. In order to overcome these problems, the Ministry of Environment published guidelines for planning and building permission procedures of 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 been added already for the Gulf of Bothnia, North (about 4,000 MW) and the Gulf of Finland, West

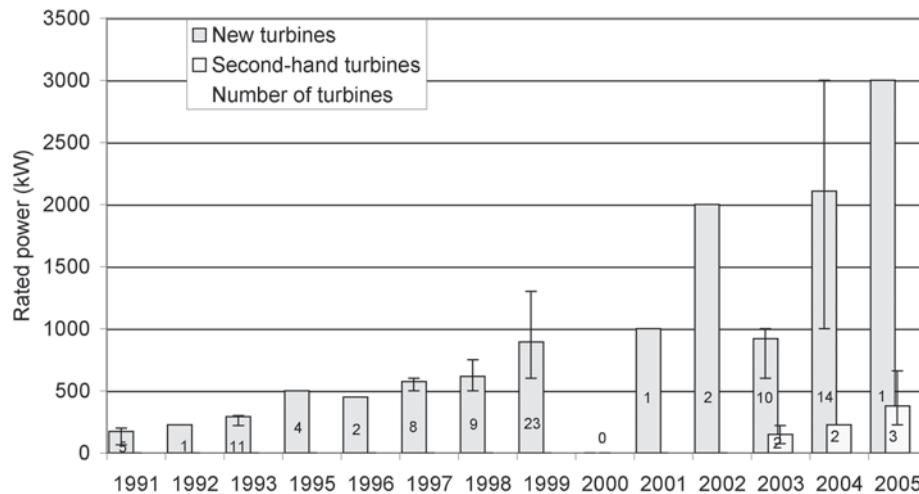


Figure 5 The average size of installed capacity (rated power in kW) is indicated by the bar (for new and second-hand turbines). The number of installed turbines is marked in the bars. The vertical line represents minimum and maximum capacity of turbines installed.

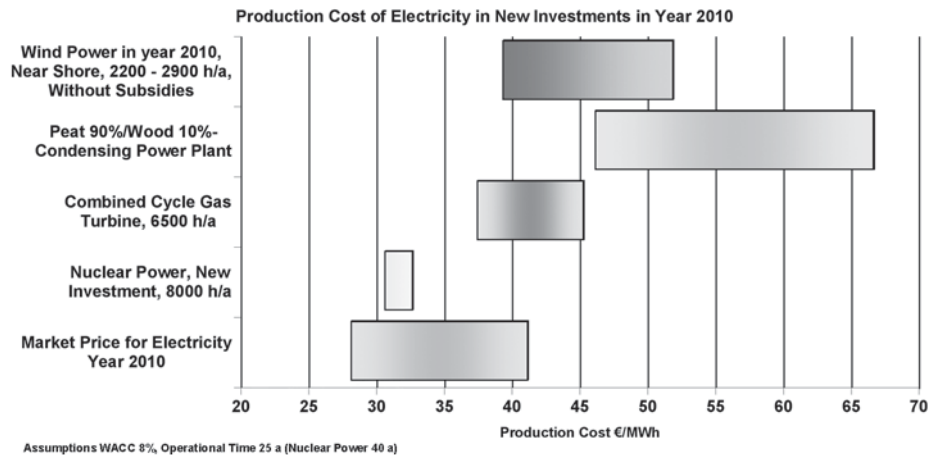


Figure 6 Comparison of costs from wind and other sources. Source: Road map for wind energy in Finland, Technology Industries, 2005.

(about 500 MW). The planning process is ongoing for the Gulf of Bothnia, South and the Gulf of Finland, East.

The Ministry of Trade and Industry is investigating the transmission and distribution charges for distributed generation including wind. The charges vary across the country and in some areas hinder local generation.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

Since 1999, there has not been 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. 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 DENSITY (Distributed Energy Systems), launched in 2003, contains the following wind-related research projects.

- Grid connection of distributed energy systems, including wind (protection, voltage regulation)

- Energy storage of distributed energy systems, including wind
- Technology development, enterprise projects (WinWinD technology; ABB, Rotatek, Vacon and Verteco generator and converter technology; Kylmätek small wind turbine)
- National projects for wind energy IEA collaboration in research Annexes

The technology program CLIMBUS (Business Opportunities in Mitigating Climate Change) was launched in 2004. The 5-year technology program aims to develop technology and business concepts related to reduction of greenhouse gas emissions: clean energy production and fuels; business services; and technologies for energy efficiency and non-CO₂ greenhouse gases. There is one project on short-term forecasting services for wind power producers. The road map for wind power technology by Technology Industries in Finland has been co-funded in this program. Also in the project "Demand for Finnish energy technology and business opportunities in global markets," wind power is assessed.

As part of its strategic research program on Smart machines (2002-2006) VTT has developed technologies, components, and solutions for large wind

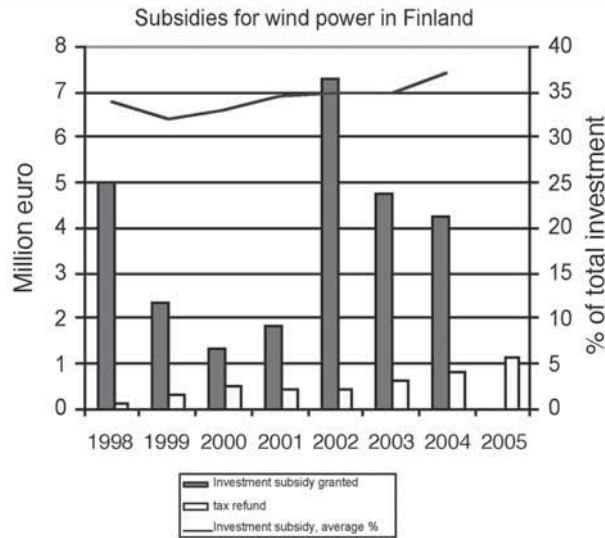


Figure 7 Investment subsidies granted for wind power and the total amount of tax refunds for wind electricity in Finland. The average investment subsidy as a percent of total investment costs is also shown.

turbines. As an example, technologies to control the shape of composite structures have been developed in laboratory scale.

5.2 COLLABORATIVE RESEARCH

VTT Technical Research Centre of Finland has been active in several international collaborative projects in the EU, Nordic, and IEA framework.

EU project WILMAR Wind energy in liberalised energy markets was a collaboration between the Nordic countries and Germany, and it concluded in 2005. It produced a planning model of the Nordic and German markets in an hourly time resolution. This can be used as a tool to estimate the impact of wind energy variations and unpredictability to both day-ahead and regulation markets. For more information see (<http://www.wilmar.risoe.dk/>).

Ongoing EU projects include OPTIMATBLADES where material tests for wind turbine blades are being conducted at VTT. Also a demonstration project HISP is going on where three 2-MW direct-drive turbines (Harakosan Europe) are connected to a

weak network. VTT will be involved in the large UPWIND project starting 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,” where VTT is participating. The final report of the FMI coordinated EU project NEWICETOOLS was published in 2005. In the project, a new icing map over Europe was produced, as well as tools and recommendations concerning e.g. ice-free wind sensors and ice detection.

Nordic Energy Research has two ongoing projects related to wind energy. VTT is participating in a grid integration project. VTT and FMI have contributed to research on climate change impacts on wind energy (Climate and Energy).

VTT is acting as Operating agent in two IEA Wind Annexes and taking part in the following research tasks.

- Annex XI Base technology information exchange

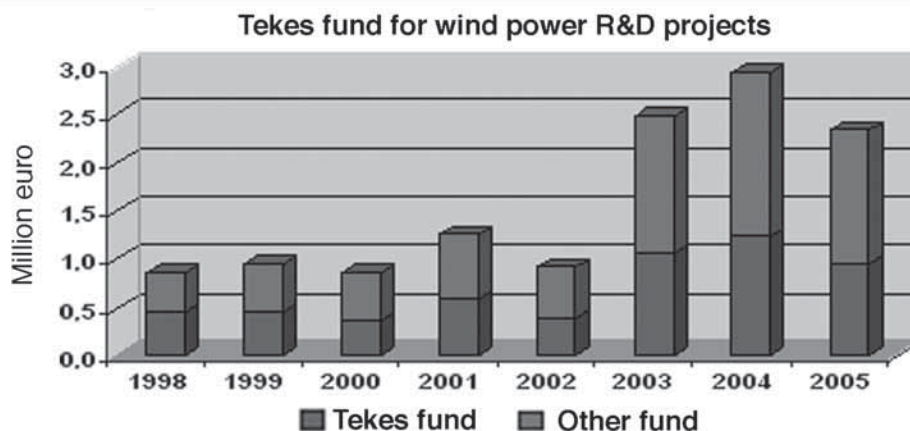


Figure 8 Development of R&D funding for wind power in Finland: Tekes funding and total funding

Annex XIX Wind energy in cold climates,
Operating Agent
Annex XXI Dynamic models of wind farms
for power system studies
Annex XXIV Integration of wind and hydro-
power systems
Annex XXV Design and operation of power
systems with large amounts of wind power,
Operating Agent

Annex 21, 24, and 25 work is closely related to the national technology program DENSYS in Finland. Annex 19 work has connection 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 currently projects totalling more than 100 MW in various planning phases in Finland. About 200 MW of the huge offshore potential could be realised before 2010. The expected impact of emission trading on electricity market prices will enhance the cost competitiveness of wind power. The effects of the

new energy and climate strategy remain a question mark because wind power is not mentioned explicitly.

The road map for wind power technology released by Technology Industries in Finland brings up needs for technology development and a working home market for demonstrations and establishing a track record. The success in implementation of this road map is crucial for realising the potential technology exports for Finnish manufacturers.

The need to update the wind resource mapping in Finland has been brought up. The current wind atlas is from 1992, and a lot of uncertainty remains when estimating the production for taller MW machines in the forested coastal areas of Finland.

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

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NATIONAL ACTIVITIES



CHAPTER 15

GERMANY

1.0 INTRODUCTION

As predicted, the increase of newly installed wind power in Germany in 2005 was considerable but the increase was somewhat less than in 2004. This is due to the shortage of good wind areas onshore, lacking offshore construction activities, and re-powering methods. At this stage, wind energy is potentially able to produce 6.7% of the German annual net electrical energy consumption. Wind is the leading renewable energy in Germany and a growing factor in the national electrical energy market. Most of the data presented in this paper was collected by the German Wind Energy Institute (DEWI GmbH) and by the German Wind Energy Association (BWE e.V.).

The leading federal state in Germany in wind energy deployment is Lower Saxony with 4,508 turbines and potentially 9.3 TWh produced in 2005.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

The German government acknowledged in autumn 2005 the importance of renewable energies and among them wind energy, and the national policy was generally continued. Renewable energies accounted for 10.2% of the electrical energy consumption in comparison to 9.4% in 2004. By 2010, 12.5% shall be covered by renewable energy sources. Wind energy is financed according to the Renewable Energy Recourses Act (EEG) (1).

The national offshore strategy focuses on having 2,000 MW by 2010 (1). At the end of 2005, 11 pilot wind farms in the German Exclusive Economic Zone (EEZ) were approved by the federal authorities with 777 turbines and 3,331 MW (2). Most of them still require permission for the transmission cable. Licensing of the cable is a matter of the federal authorities in the EEZ as well as of the German state governments in the territorial waters and onshore.

Main constraints for more onshore development – even though German deployment of wind en-

Table 1 Key Statistics 2005: Germany

Total installed wind generation	18,428 MW
New wind generation installed	1,808 MW
Total electrical output from wind	26.5 TWh
Wind sector turnover	7.3 billion €
Wind generation as % of national electric demand	4.3%
Target:	Share from renewables in 2010 12.5%

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Table 2 Additional figures of wind energy deployment in Germany at the end of 2005 (3, 4)

Number of turbines	17,574
Number of new turbines in 2005	1,031
Potential energy production	33.8 TWh
Potential part of German net electrical energy consumption	6.7% *
Total German net electrical energy consumption	484 TWh
CO ₂ reduction in 2005	24.6 Million t.
Part of German CO ₂ reduction commitment	12.7%
* Comment: This figure is based on a net energy consumption of 509 TWh per year (3).	

ergy is still leading the international scale - are as follows.

- The rather slow beginning of the repowering process (the replacement of older, lower-capacity turbines with multi-megawatt-scale turbines) due to complex reasons among which investment decisions play only a subordinate part.
- The limited number of remaining areas for onshore wind energy deployment because of meteorological reasons and landscape protection reasons. For example, in the state of North Rhine-Westphalia a new construction act for wind turbines stipulates a minimum distance of 1,500 m between new turbines and houses.

Main constraints for offshore development:

- Approval of the cable connections by state authorities
- Financing of projects
- General constraints caused by high sea and deep water conditions.

Grid connection and grid capacity at appropriate points near the coast are not expected to be a problem for the first offshore wind farms. However, further needs of grid expansion are being investigated in the second phase of a survey

by the German Energy Agency (Dena). Results of the first phase of these studies were presented at an international conference in Berlin in March 2005 (1, 5).

3.0 BENEFITS TO NATIONAL ECONOMY

The world turnover due to wind energy in 2005 reached more than 10 billion €. About half of that was earned by the German industry. The German domestic market turnover declined slightly in 2005. But this decline was compensated for by an increase of the export turnover. The total German wind sector turnover in 2005 amounted to about 7.3 billion €. The value of domestic manufacturing, taking into account turbine and component suppliers, was more than 4.8 billion € (3). About 64,000 people were employed in the wind sector and 157,000 in the sector of renewable energies in total; more growth is expected.

The current costs of wind energy installations are around 1,170 €/kW. Current turbine-only costs are about 900 €/kW. Three German manufacturers developed turbines in the 4.5 to 6-MW class. More than 10 prototypes have been erected at near coastal or near shore locations. The three leading manufacturers on the market for turbines installed in 2005 were as follows (3).

Enercon	41.7%
Vestas (incl. NEG Micon)	26.8%
GE Energy	8.1%

The German industry has initiated an Offshore Wind Energy Foundation to promote offshore development and support technological and deployment projects. The first project is the installation of an offshore test site in the North Sea adjacent to the FINO 1 research platform (1). The main objective of the test site is proving the capabilities of 5-MW class turbines and their foundations under high sea conditions. The test site project is supported by the Federal government by 5 million €.

4.0 NATIONAL INCENTIVE PROGRAMS

The main stimulation/incentives for the German wind market are provided by the Renewable Energy Sources Act (EEG). Grid operators have to pay 0.085 €/kWh to the turbine owner for turbines installed in 2005. If the energy output reaches a reference amount, the payment reduces gradually. For turbines installed in 2006 or in the following years, the payment will be reduced by 2% each year. Stimulated by this cost reduction the price for wind energy gradually approaches the market price for electrical energy. On the national scale, a four-person household has to pay less than one Euro for wind energy in the monthly bill for its electrical energy consumption. The EEG will be audited in 2007 to adapt the prices for renewables to new market conditions and technological developments.

5.0 RD&D ACTIVITIES

The government agreed in 2005 that the proportion of the total research budget of the Federal government for renewable energies research shall grow to 2.67% from about 1% at present. The responsibility for renewable energies research is with the Federal Ministry for the Environment, Nature

Conservation and Nuclear Safety (BMU). In 2005, BMU started 100 new projects with 83 million € in the field of renewable energies. Among these projects, 24 were wind energy related projects for 16.5 million € (6).

5.1 TURBINE PROTOTYPES

The Enercon company has installed at least eight E 112 turbines since 2002. Three of them with a rated power of 6 MW each were installed in 2005 at near-coast sites. The development of the first prototype was supported by BMU. Special features are the gearless generator and the wide range of usable wind velocities from 2.5 m/s to more than 28 m/s.

A 5-MW prototype was erected by REpower in February 2005 in Northern Germany. Additional turbines of this type will be installed in 2006 in Scottish North Sea waters in the framework of a European project. An agreement was concluded with Chinese partners to construct an offshore wind farm with five REpower 5-M turbines in China in 2008. Development of the prototype was supported by the European Commission and the state Schleswig-Holstein.

The world's third type of the 5-MW class wind turbine, the M 5000, from Multibrid, started its operation in spring 2005 in Bremerhaven. The development was supported by BMU. A special feature of this machine is the relatively low mass of the housing: about 300 t. The first French offshore wind farm in the Canal, planned for 2007/2008, will be equipped with 21 of these M 5000 turbines.

Other research projects are dealing with new gear concepts or gearless concepts for multi-megawatt turbines. These ideas should reduce the mass and improves the maintenance characteristics of new machines.

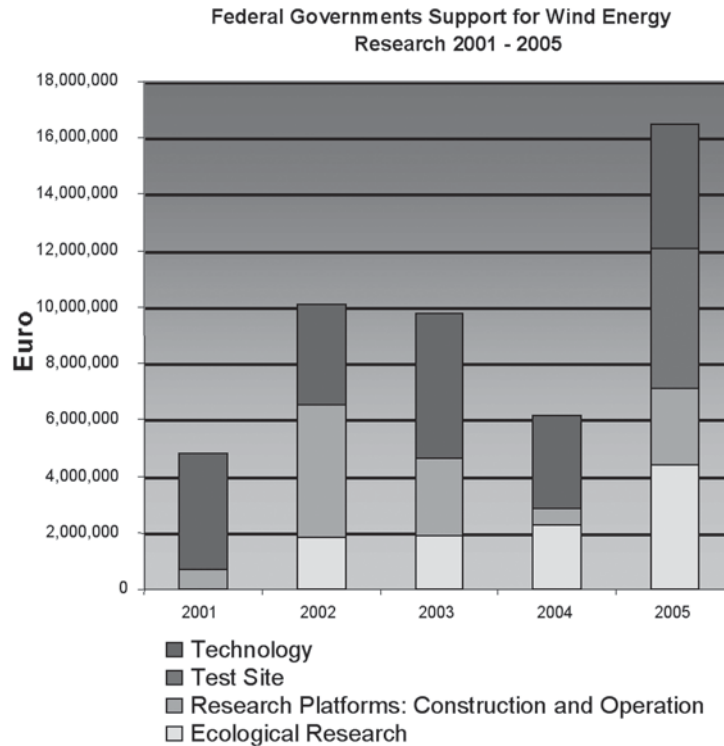


Figure 1 Governmental funds for wind energy research.

5.2 SCIENTIFIC MEASURING PROGRAMS

Since 1989, the Scientific Measuring and Evaluation Programme (WMEP) has been supported by the Federal government, and in 2005 it was prolonged for another year. In the frame of WMEP, energy output data of 1,500 wind turbines together with wind data at 60 locations have been gathered. Further data on damage caused by lightning, storms, ice, and grid failures have been collected. One of the results is development of a wind prognosis system which is used in power generation planning by the transmission system operators (TSO). It allows the prediction of wind energy yield 48 hours in advance with accuracy of 7%. The day-to-day prognosis accuracy is 5.7% (7).

The research platform FINO 1 (www.fino-offshore.de) in the North Sea has been in operation for more than two years with very high availability for the scientific measuring systems.

Meteorological data has been requested by more than 40 users from scientific institutes as well as from industry. One example of research conducted on the basis of FINO 1 data is the analysis of wind turbulence characteristics and resulting mechanical loads for new technical standards of offshore turbines.

The wind data of FINO 1 also allow the following conclusions for a potential wind turbine in the North Sea:

Medium yearly wind velocity
9.8 m/s

Time with more than 4 m/s wind velocity
8,000 h/yr

This means that a wind turbine at this location could produce electricity during about 90% of the yearly operation time, and the electricity output would be about double that of a good onshore site.

Concerning hydrographic measurements, the maximum registered wave height was 10.67 m in January 2004. This illustrates the mechanical requirements which offshore foundations have to meet.

Concerning the ecological investigations, data on the succession of benthic organisms in the surrounding of the platform as well as important data and findings about bird migration were gathered with radar and optical methods. The intensity of bird migration and the flight altitude varies by different factors. In general, there is more bird migration close to the coastline than further offshore and intensive bird migration was observed particularly under conditions of offshore going wind. More than one-third of the registered birds were recorded in the lowest 100 m. And almost half of the radar echoes up to 1,500 m came from the lowest 200 m. This is particularly evident in the daytime and to a lower extent also in the morning and evening periods. At night, many birds also migrate at altitudes below 200 m in a seasonally varying proportion, with a minimum of 20% of all echoes in summer 2004 and at least 64% in winter 2003/04. The flight altitudes of the birds recorded on FINO 1 also varied according to weather parameters. For instance, on rainy nights the percentage of birds migrating under 200 m was distinctly higher than during nights without rain. In both spring and autumn, tailwinds and light headwinds were associated with higher flight altitudes. In autumn, the five nights of heaviest migration were associated with easterly winds and in spring with southerly winds at the location (8). These findings will be used in the planning process of wind farms in the North Sea and to develop mitigation methods which could help prevent bird collisions or avoid a barrier effect of wind farms for birds.

The planning of two more research platforms was started in 2005.

FINO 2 (www.fino2.de) is located in the Baltic Sea, at the borders of the German, Swedish, and Danish EEZ. The measuring regime for wind will be the same as for FINO 1. This way comparable

wind data will be available from all three research platforms. Additional, mainly bird and benthos investigations will be made. The FINO 2 platform will be open for cooperation with Swedish and Danish scientists. It is expected that commissioning will be at the end of 2006.

FINO 3 in the northern part of the German EEZ of the North Sea about 70 km west of the Island Sylt will be commissioned in autumn 2007. Wind measuring is orientated again strongly to the FINO 1 measuring regime. A special focus of FINO 3 will be geophysical investigations concerning interactions between sediment and monopile and lightning at open sea and its possible impact on turbine components.

FINO 2 and FINO 3 will be constructed as monopiles.

6.0 NEXT TERM ACTIVITIES

In spring 2006, a German energy summit is planned. Renewable energies, bio fuels, and wind energy deployment in the German seas are the most important topics to be discussed at the summit among other technologies.

In May 2006, a wind energy expert panel will discuss new needs and developments of research for the next years. The results shall be used as a basis for an update of the BMU wind energy research program.

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CHAPTER 16

GREECE

1.0 INTRODUCTION

Greece is making profound institutional, regulatory, engineering, and funding efforts in order to meet the indicative target set by Directive 2001/77/EC. Among the aims of the Greek government is to substitute expensive imported fuel, currently used for electricity production in a large part of the Greek territory, by exploiting the country's abundant wind potential. A clear and impressive acceleration of the RES market's development is presented for the year 2005.

According to the most recent estimates, the gross consumption of electric power in 2010, will reach the level of 68 TWh. The main fuel source is domestically extracted low-calorific-value lignite, which accounts in 2005 for 55.9 percent of the total needs for energy. Oil, mainly used by the power plants on the islands not connected to the mainland's system, is estimated to have a share of 13.5%. Natural gas imported from Russia and Algeria in the form of LNG will cover 12.9%. In the same year large-scale hydroelectric plants are

estimated to produce 6.3%. Lastly, wind energy, small hydro, biomass and photovoltaics combined muster 3.1%, whereas, the net of imports-exports make up the remaining 5.5%. (1)

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 sources (RES) 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 the expected electricity consumption in 2010, a production of electric power from RES in the order of 13.7 TWh (including large-scale hydro-electric plants) is set as the goal for 2010. In order 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 of the order of 7 TWh.

In 2005, the installed capacity of the wind turbines reached 605 MW, showing an impressive acceleration over the previous year of 25%. In 12 separate projects, a total of 99 wind energy conversion systems, with an installed capacity of

Table 1 Key Statistics 2005: Greece

Total installed wind generation	605 MW
New wind generation installed	121 MW
Total electrical output from wind	1.27 TWh
Wind sector turnover	NDA
Wind generation as % of national electric demand	2.5 %
Target:	3,370 MW by 2010

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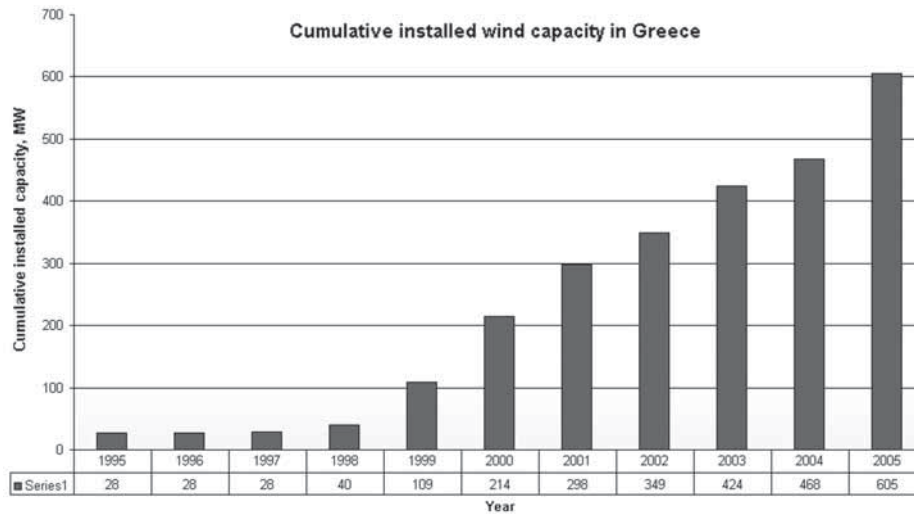


Figure 1 Cumulative installed wind capacity in Greece.

approximately 121 MW, were connected to the electricity supply network. The current estimation of wind energy production in 2010, ranges between 2,100 MW (conservative scenario) and 3,270 MW (optimistic scenario) (1). The development of wind energy within the last 10 years is shown in Figure 1, which depicts the total installed capacity per year.

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

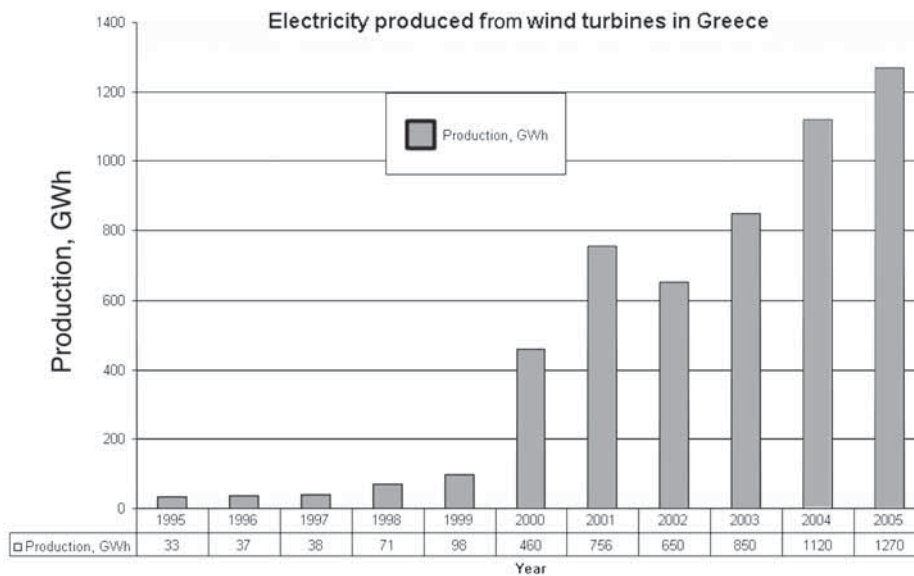


Figure 2 Electricity produced from wind turbines in Greece.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

There is an increasing interest among, mainly, construction companies and individual investors for wind energy related projects. Wind energy deployment has become a challenging area for development all over the country, especially in areas of poor infrastructure, where some of the most promising sites for wind energy development can be found. Although manufacturing of wind turbines has not been established in Greece, there is considerable domestic added value, especially with regard to the infrastructure works, e.g. grid strengthening, tower manufacturing, road and foundation construction, civil engineering works, etc. In addition, new jobs are created, related to the maintenance and operation of the wind farms in mainly underdeveloped areas. Eventually, an expanding network of highly experienced engineering firms has been created, which is currently working on all phases of the development of new wind energy projects. Thus, wind energy is gradually becoming a considerable player contributing in the development of the country. The distribution of installed wind farms all over the country is graphically depicted in Figure 3.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

No significant manufacturing developments occurred in 2005 apart from the continuing involvement of the Greek steel industry in wind turbine tower manufacturing.

The average capacity of the wind turbines installed in 2005 was 1,188 kW, while the average capacity of all the wind turbines operating in the country was 651 kW (Figure 4). The market share per manufacturer is depicted in Figures 5 and 6.

Due to the relative short operation periods of most wind energy projects limited malfunctions have been reported since their commissioning, mainly

related to gearbox failure and lightning strike events. 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 970 and 1,170 €/kW and is mainly influenced by the international market prices and the interconnection costs. The generated wind power cost could be assumed to be between 0.026 and 0.047 €/kWh, depending on the site and project cost. The typical interest rate for financing wind energy projects is 7% to 8%.

The power generation system in Greece is divided into two categories: the so-called interconnected system of the mainland and the autonomous power plants of the islands. In the liberalized electricity market, as well as before, a single price exists in both systems, depending on the identity of the consumer and the voltage class. This price list presented in Tables 2 and 3 concerns the tariffs of electricity purchased since September 2005 by the Hellenic Transmission System Operator according to the Law 2244/94; the decision of the Minister of Industry, Energy and Technology numbered Δ6Φ1/OIK.8295/19.4.95 (ΦΕΚ 385/10.5.95); and Law 2773/99. This electricity either is produced by independent producers or is the surplus of auto-producers and comes from either RES or cogeneration of heat and power (CHP). There is no capacity charge on purchases from producers in non-interconnected islands.

4.0 NATIONAL INCENTIVE PROGRAMS

Financial support for wind energy projects is provided by the state in the framework of the Operational Program “Competitiveness” (OPC) and the new Law for Development.

The OPC raises resources from the 3rd Community Support Framework. OPC provides public aid to RES and energy saving, substitution,



Figure 3 Installed wind farms distribution in Greece.

and other energy-related actions. The public aid accounts for 30% of the eligible cost of the projects and goes up to 50% in the case of transmission lines that will be constructed for the connection of RES plants with the grids. The Center for Renewable Energy Sources (CRES) acts as an intermediate agent in charge of the administration and management of projects included in Measure 2.1, Action 2.1.3 of the OPC. More specifically, CRES is the thematic Intermediate agent responsible for the administration and management of all wind energy projects in the mainland and those with nominal capacity greater than 5 MW on the islands of Greece. An installation permit is necessary in order to finance a project. The eligible cost for financing a wind farm is up to 900 €/kW, without including the cost for the electrical grid

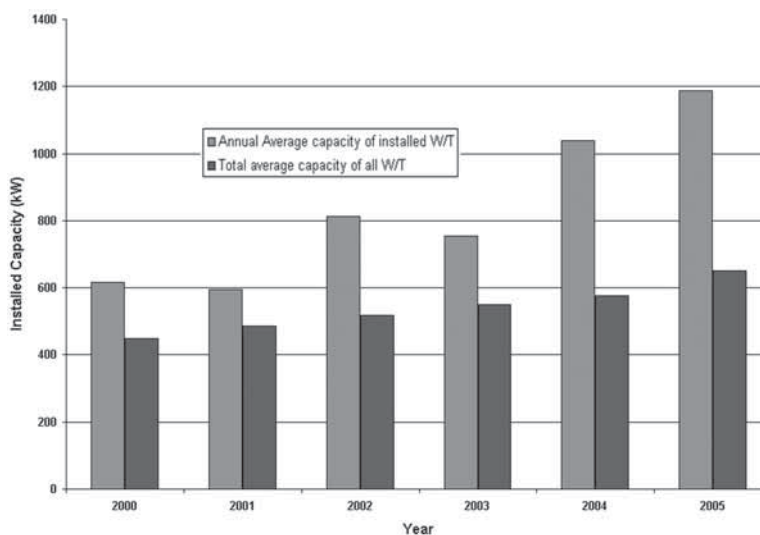
connection. In addition, co-financing of the connection of wind farms to the grid is provided in the framework of Measure 6.5 of the OPC, providing public funding up to 45-50%. Eventually, financial support for wind energy investments is foreseen through the new Law for Development 3299/2004, which provides grants of up to 50% of the total investment.

5.0 RD&D ACTIVITIES

The Ministry for Development promotes all R&D activities in the country, including applied and basic R&D as well as demonstration projects. Key areas of R&D in the field of wind energy in the country are: wind assessment and characterization, standards and certification, wind turbine devel-

Table 2 Interconnected system and interconnected islands. Prices in €/kW per month for capacity

Connection voltage	Magnitude with tariffs	Independent production a) from RES b) from CHP through RES	Auto-producers surplus	
			a) from RES	b) from CHP through RES
High	Energy	0.06842	Peak	0.03475
			Interim load	0.02407
			Low load	0.01786
	Capacity	1.75645		-
Medium	Energy	0.06842		0.05321
	Capacity	1.75645		-
Low	Energy	-		0.06579
	Capacity	-		-

**Figure 4 Average capacity of the wind turbines installed in 2005 and operating in the country.****Table 3 Non-interconnected islands. Prices in €/kWh**

Connection voltage	Magnitude with tariffs	Independent production a) from RES b) from CHP through RES	Auto-producers surplus	
			a) from RES	b) from CHP through RES
ALL	Energy	0.08172		0.0636

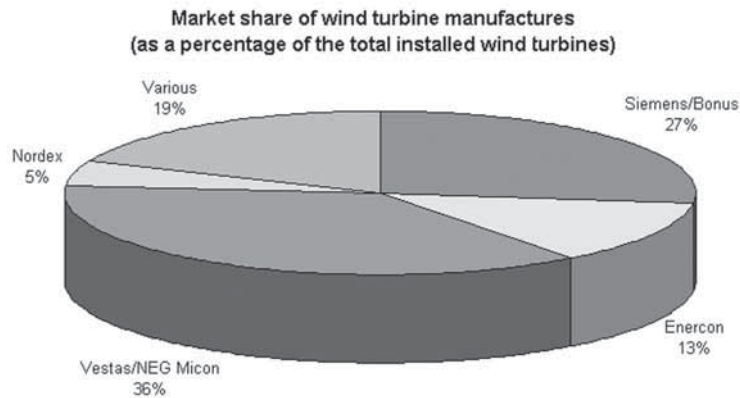


Figure 5 Market-share of wind turbine manufacturers (as a percentage of total installed wind turbines).

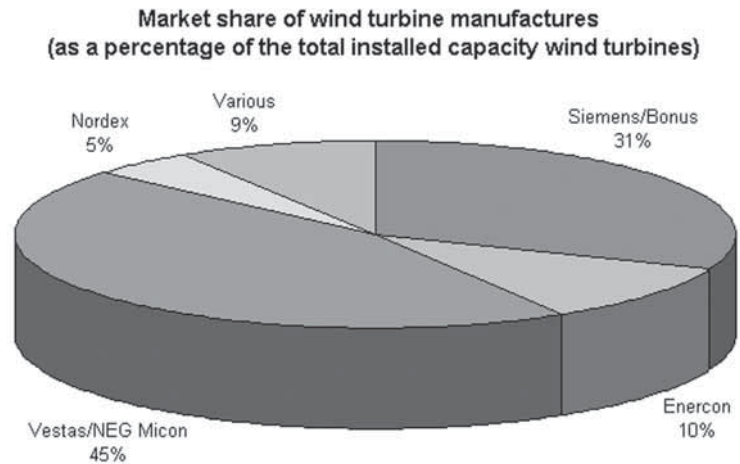


Figure 6 Market-share of wind turbine manufacturers (as a percentage of total installed capacity of wind turbines).

opment, 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 the renewable energy in Greece mainly involved in applied R&D in the fields of aero-

dynamics, structural loads, noise, power quality, variable speed, wind-desalination, standards and certification, wind assessment, and integration. CRES has developed and operates its Laboratory for Wind Turbine Testing, which has been accredited under the terms of ISO/IEC 17025:2000.

Several research projects were running at CRES during 2005, co-funded by the European Commission and the Greek Secretariat for Research and Technology. These research projects had the following goals:

- Characterizing the main features of complex or mountainous sites and identifying the crucial parameters affecting both the power performance and the loading of different types of wind turbines operating in such environments
- Developing wind turbines for installation in hostile environments
- Improving the damping characteristics of wind turbine blades
- Developing new techniques for power quality measurement and assessment
- Increasing understanding of wind turbine standardization procedures
- Developing blade material testing techniques within the in-house experimental facility
- Understanding generic aerodynamic performance of wind turbine blades through computational fluid dynamics (CFD) techniques
- Developing cost-effective, micro-siting techniques for complex terrain topographies.

In 2005, MEGAWIND, a research project coordinated by CRES and co-funded by the EC under the 5th Framework Program was completed. In MEGAWIND, procedures to circumvent the barriers set to the transportation and erection of megawatt-size machines in areas of limited infrastructure were formulated and applied to the design of a 1.3-MW wind turbine for installation on a high wind speed complex terrain site. The conventional wind turbine design procedure was revised and adapted in the following four aspects:

Blade design: The geometry of the blade was optimised for maximum energy capture under high wind speed conditions, while the split-blade concept was introduced in its structural design.

Tower design and construction: New structural solutions were introduced for the tower by using advanced composite materials technology, featuring manufacturing and installation concepts adaptable to on-site assembly.

Gearbox design: The novel gearbox concept pro-

posed aimed at achieving high reliability, easy maintenance and low noise levels.

Overall design assessment: Systematic full-scale testing of the developed components was carried out for evaluating the innovative features introduced (more details can be found in www.cres.gr/megawind).

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 wind energy integration into the electrical grid. The fluids section of the Mechanical Engineering Department of NTUA is active in wind modeling, rotor aerodynamics, load calculation, fatigue analysis, noise issues, and wind farm design. Highlighting the work conducted during 2005, a systematic analysis of stability issues on wind turbines has been conducted with respect to: (a) possible passive ways to increase damping, (b) assessment of non-linear effects in predicting the stability characteristics. The results of this work are scheduled to be presented during the EWEC Conference in 2006.

The kernel of NTUA's aerodynamic free-wake model has been upgraded to also include a section-by-section solution of the viscous flow based on strong viscous-inviscid coupling. Results were presented during the PhD Seminar of the EAWE, Athens September 2005.

Two members of the family of airfoils, which were designed in 2005 for use on pitch regulated wind turbines, have been measured in the wind tunnel. Measurements were successfully compared with CFD predictions.

In 2005, the Electric Power Division of NTUA continued its research activities on issues related to the technical constraints and problems in the integration of wind power into the electrical grids, the management and control of isolated power systems with increased wind power penetration, power

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quality of wind turbines and wind parks, and the design of electrical components for wind turbines. Specific research areas include the following:

- The technical constraints and problems in the integration of wind power into the electrical grids are investigated, both to develop suitable guidelines and evaluation methodologies, as well as in relation to specific regions in Greece, where the transmission system is weak and there is high interest in wind projects because of favorable wind conditions.
- Island interconnections to the mainland system, besides improving the quality of service for the isolated grids, are also a prerequisite for achieving high exploitation levels of the significant wind potential available. The interconnection of specific isolated island grids to the mainland system has been studied, including both the technical requirements and the financial feasibility issues.
- Research in distributed renewable generation has continued, gaining increased attention. Particular emphasis has been placed on microgrids, developing analysis tools and distributed control methodologies. Further, the prototype microgrid, originally developed in 2003, was expanded with the addition of a 1-kW wind turbine. A second, similar microgrid pole was also developed, which can operate autonomously, connected to the grid, or in parallel to the first pole, forming a larger microgrid.
- Design of electrical generators and converters for wind turbine applications is in progress, including permanent magnet synchronous generators with state-of-the-art electronic converters, suitable for small wind turbines. Research was also focused on power converters, suitable for other types of distributed generation sources, including fuel cells.

- Research on the integration of wind turbines in small standalone systems has continued, with specific application in water desalination for remote areas. The electrical system and the control of a completely autonomous, wind-driven desalination system have been designed.

- Increasing wind power penetration in isolated island systems, with proper application of pumped storage via reversible hydro-power stations, has been studied regarding its steady state and transient stability performance, as well as with respect to their technical-economic feasibility. This is crucial for the exploitation of the wind potential in many non-interconnected Greek islands.

- The development of advanced control functions for the management and central control of power systems with increased penetration of wind power is an on-going research area. Algorithms and techniques are elaborated for on-line dynamic security assessment of the system. These algorithms provide rules for optimal spinning reserve by the conventional units and other operating rules in order to achieve optimal economic scheduling with increased security.

- Advanced short-term wind power forecasting functions for operational planning have been developed using numerical weather predictions and applying advanced artificial intelligence techniques.

The Applied Mechanics Section of the Department of Mechanical Engineering and Aeronautics, University of Patras (UP), has, since 1990, focused on educational and R&D activities involving composite materials and structures. Emphasis is given to anisotropic material property characterization, structural design, and dynamics of composite rotor blades of wind turbines. Experience has been acquired by participating in several National and EC-funded research projects.

During 2005, in the frame of the European research project MEGAWIND, UP has successfully accomplished the structural design verification of a modular (split) 30-m blade, full-scale tested under ultimate extreme static and cyclic loads. The prototype was manufactured by Geobiologiki SA. In the EC-funded research project OPTIMAT BLADES, UP is Task Group leader in investigating blade material behavior under complex stress states in which the effect of multi-axial static and cyclic loading on strength and life of composite laminates is assessed. Amongst others, results are available in the form of design guidelines for rotor blade manufacturers. A wealth of experimental data gathered in the course of this project by the various partners of the consortium, OPTIDAT database, will be soon available for the public (http://www.kc-wmc.nl/optimat_blades).

Other research activities of the Applied Mechanics Section are: (a) development of finite element formulations and dedicated code accounting for selective non-linear lamina behavior, e.g. in shear, in the laminate, modeling of property degradation due to damage accumulation so as to predict life of large rotor blades under spectrum loading; (b) probabilistic methods in the design of composite structures; (c) residual strength and fatigue damage characterization of composite materials using wave propagation techniques; (d) smart composites and structures; and (e) structural damping, passive, and active vibration control.

5.3 PARTICIPATION IN IEA WIND ANNEXES

Greece participates in Annexes XI and XX. The participation in Annex XI, "Base Technology Information Exchange" is promoting wind turbine technology understanding through cooperative activities and information exchange on R&D topics of common interest with the other member countries. Extra emphasis has been given through

the years, especially at NTUA and CRES, in the development of aerodynamic models of wind turbines, an activity, which is supported by the involvement in the activities of Annex XX, "HAWT aerodynamics and models from Wind Tunnel Measurements."

6.0 THE NEXT TERM

In 2005, the existing legal framework was reviewed. A new law for the promotion of renewable energy sources and especially wind energy is under preparation and is expected to take effect by mid 2006. The new law aims to accelerate the licensing procedures as well as to alleviate major bureaucratic bottlenecks. A critical point for the achievement of the targets is the completion of the extensive projects destined to boost transmission capacity of the grids in the areas of great interest for wind energy deployment (Eastern Macedonia-Thrace, South-eastern Peloponnese and Euboea). The promotion of national land planning currently underway is expected to further facilitate investments in renewable energy systems. However, reaching the targets set for 2010 is still uncertain, unless additional measures and policies are undertaken, both institutional and technological. The institutional measures are expected to be implemented in the new legal framework, while technological actions such as the interconnection of the Northeastern Cyclades islands complex with the interconnected system are still to be decided and implemented.

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CHAPTER 17

IRELAND

1.0 INTRODUCTION

A total of 493 MW wind energy generating capacity was operational in Ireland at the end of 2005. Of this total, 468 MW was operating onshore and 25 MW offshore. This represents an increase of almost 240 MW over the 2004 level and is a new annual installation record. The previous annual installation record was 70 MW in 2004. Capacity therefore almost doubled during 2004 and there are good indications that the increased installation rate will persist in 2006 as there is a total of 225 MW of new capacity in grid connection agreements contracted to be realised in 2006.

In the longer term, at the close of 2005 there was a total of 676 MW of new capacity in contracted grid connection agreements up to 2011; this ad-

ditional capacity is sufficient to meet the projected increase in wind power required to meet Ireland's 2010 renewable energy target and more agreements may yet be signed to connect wind capacity during this period. By the end of 2005, there were wind farm connection applications totalling 2,994 MW capacity waiting processing in the grid operators connection application queues. The cumulative total of connected contracted, and applications in February 2006 was 4,152 MW.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

Ireland has a target of achieving a renewable energy contribution of 13.2% to national electricity demand by 2010. While no specific target has been set for wind energy deployment, the government has agreed with the main affected parties that the required contribution from wind power to this target would be 1,100 MW of installed capacity. Wind energy is the country's most plentiful renewable energy source and most of the new capacity will come from onshore wind projects. Other technologies supported include biomass, landfill gas, anaerobic digestion plants and hydro. As of the end of 2005, 493 MW of wind energy

Table 1 Key Statistics 2005: Ireland

Total installed wind generation	493 MW
New wind generation installed	233 MW
Total electrical output from wind	1.100 TWh*
Wind sector turnover	70 million €*
Wind generation as % of national electric demand	4.25%*
Target:	13.2% of National Electricity Demand from Renewable Sources by 2010. Officially interpreted as 1,100 MW Installed Wind Capacity by 2010
* Estimated figures	

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generating capacity, or 45% of this target had been constructed, connected, and commissioned.

In April 2005, the Minister for Communications Marine and Natural Resources, Noel Dempsey, T.D., announced that the next market support mechanism for renewable energy will be based on a fixed feed-in tariff system. This support system will be designed specifically to encourage new capacity development and will only apply to newly built projects. On 27 September 2005 Minister Dempsey announced details of the new system (see Section 4).

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

The primary benefit to the national economy from wind energy deployment in 2005 was the generation of electricity valued at approximately 70 million € from an indigenous resource thus offsetting the need for imported fossil fuels. The total value of the new wind energy generating capacity constructed during 2005 is estimated at 264 million €.

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.

4.0 NATIONAL INCENTIVE PROGRAMS

The primary market support mechanism for renewable electricity in Ireland has been the Alternative Energy Requirement (AER) scheme through which price support contracts with a 15-year term are awarded to renewable electricity generators in regular competitive tender rounds.

The scheme has been in place since 1996 and the results of the last round, AER VI, in which contracts for 334 MW of wind projects were awarded, were announced in July 2003. Support for an additional 235 MW of wind projects under AER VI was announced in December 2004, after EU state aid approval for support for this additional capacity was received.

In 2005, the Minister for Communications Marine and Natural Resources announced that the next market support mechanism for renewable energy will be based on a fixed feed-in tariff system. This support system will be designed specifically to encourage new capacity development and will only apply to newly built projects. The program provides support of 119 million € to renewable energy projects over a fifteen year period.

The new fixed price tariffs now confirmed are: Large wind energy (over 5 MW) 0.057 € per KWh and Small wind energy (under 5 MW) 0.059 € per KWh.

The main fiscal incentives, from which investors in wind farm projects can benefit, are the Business Expansion Scheme (BES) and tax relief under Section 486b of the 1998 Finance Act, on capital directly invested in wind farm assets. Under the BES, those investing in approved qualifying businesses can claim a tax refund on income invested. Electricity generation is a qualifying business activity. The scheme has an investment cap of 750,000 € and is thus of limited value to larger wind energy projects.

Under Section 486b of the 1998 Finance Act, corporate investors in renewable energy projects can claim tax relief on equity investment in capital assets. However, the corporate tax rate has been reduced to 12.5%, so this fiscal incentive will have limited future attraction. A 2002 amendment to the Finance Act also restricted eligibility for tax relief on capital assets to active participants in projects, and this measure effectively eliminated a commonly used investment vehicle for private investment in wind farms.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

The 1999 Irish Government Green Paper on Sustainable Energy, along with setting renewable energy targets for Ireland, set out a program of Sustainable Energy RD&D with a budget of 50 million € for the years 2000–2006. Sustainable Energy Ireland was charged with administering this budget. Of this budget, 16 million € was specifically allocated to renewable energy research, while other parts of the program also contain renewable energy elements. Priorities identified within the Green Paper were techniques for assessing the wind regime on land-based sites and their adaptation to Irish conditions and site evaluation techniques for offshore wind farms.

In August 2002, Sustainable Energy Ireland launched the Renewable Energy RD&D program outlined above. The focus of the program is to stimulate the application and further deployment of renewable energies, particularly those close to market viability. That could include measures to stimulate the development of the technologies and produce implementation plans for those with economic potential. The primary objectives are to remove barriers to the deployment of renewable energy technologies and help stimulate the development of an Irish renewable energy industry.

The Renewable Energy Research, Development and Deployment programme, with an indicative budget of 16 million €, will give priority to supporting:

- Research aimed at developing policy options for enhanced deployment
- Research to define the market structure for renewable energy technologies with high penetration potential
- Research aimed at cost reduction, improved reliability and/or opening new markets
- Demonstration of non-technical innovation

- Feasibility studies for renewable energy projects
- Demonstration aimed at high risk, high reward projects
- Investigation into core areas, common to many renewable technologies, such as the electricity system, regulation, technical standards, fiscal and support measures, finance, markets, planning, and policy.

For onshore wind energy, specific priorities that have been identified for the program are measures to address the creation of the correct electrical network, market, and social conditions for the wider acceptance of the expanding deployment of wind energy.

5.1.1 NEW 2005 INITIATIVE: ALL-ISLAND GRID STUDY FOR RENEWABLE ELECTRICITY

In 2005, an All-Island Grid Study was requested by the Governments of the Republic of Ireland and Northern Ireland to inform renewable energy policy to 2020. It is being overseen collaboratively by a steering group comprised of members from the relevant government ministries, the TSO's, and the renewable energy agencies from both jurisdictions. As wind power will be the dominant renewable electricity generation technology in Ireland up until 2020, the study has a primary focus on the system effects of a high wind penetration. It is being executed in four modules or "workstreams," which will run concurrently and be contracted to independent consultants. These workstreams are as follows.

Workstream 1 will examine renewable energy resources and produce a coherent renewable energy resource assessment for renewable electricity generation for both jurisdictions for the period up to 2020. For wind energy, it will have a particular focus on the spatial distribution of the wind farms for optimal exploitation of the wind resource and will create a number of alternative spatial deployment scenarios in order that the effects upon system operation may be modeled. This workstream will also produce wind resource cost

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curves, which take into consideration the variable costs in wind farm development including the costs of grid connection and site infrastructure and the variation of wind turbine maintenance costs with wind regime. Previous wind resource studies have not taken consideration of these factors and may therefore provide an overoptimistic impression of the economics of high wind resource sites.

Workstream 2 will be comprised of two stages; (a) an initial high-level modelling stage and (b) a detailed modelling stage, which will include simulations of actual 2020 generating plant commitment and dispatch with various projected penetration scenarios. The initial high-level modelling stage will use an economic optimisation technique to identify a profile of the lowest cost renewable energy mix to achieve a given set of potential renewable energy penetration targets in electricity generation in 2020. A set of renewable resource use scenarios will be generated from this analysis. Workstream 1 will provide the detail of the resources to meet these scenarios. The detailed modelling stage of workstream 2 will model operation of the generating system incorporating the renewable energy inputs generated in the high level modelling stage. As the operation methods for the system with future high RE penetration it is part of the study scope to propose a new operation methodology. This workstream will also develop a commitment and dispatch model and validate it using 2005 data. A wind generation time series will also be developed from the wind power spatial deployments generated in workstream 1.

Once the above elements are in place and validated, detailed dispatch studies will be carried out for base scenarios, estimating costs, emissions etc. Options to improve dispatch and integrate more renewable energy will be investigated; such options may include an altered conventional generation mix, demand-side measures and improvements in forecasting.

Workstream 3 will investigate electricity network development options for a range of renewable generation penetration levels based on the results

of workstreams 1 and 2(a). At each level, two geospatial scenarios are to be considered - dispersed and concentrated. Workstream 3 will iterate with workstream 1 to ensure that where exceptionally high network development costs are encountered in exploiting the renewable energy in a locality the scenarios are adjusted to reflect a higher resource cost from this area and re-optimised.

Workstream 4 will use the output of earlier workstreams to investigate the economic impact and benefits of various renewable generation levels. It will also investigate the stakeholder impacts and perceptions of various options for cost recovery. In this context, costs are incurred for variability management and network development. It combines the first three tasks to determine the impact of the rate of renewable energy penetration on the cost burden for the various electricity sector stakeholder groups. It will furthermore assess the economy-wide costs and benefits in both jurisdictions in moving to higher renewable energy penetration in the electricity generating system. The task will also recommend any likely/necessary changes to market arrangements to facilitate the various levels of penetration.

5.1.2 SEI WIND RD&D 2005 ACHIEVEMENTS

A demonstration wind turbine operating in auto-production mode was erected and commissioned at the Dundalk Institute of Technology. This was the first large grid-connected auto-production wind turbine in Ireland. An 850-kW wind turbine was used and received 50% funding from SEI. The project has generated significant interest in on-site wind auto-production in Irish industry, which has experienced high electricity price inflation in recent years.

The "Greenblade Project" is designed to develop manufacturing of wind turbine blades from thermoplastic glass reinforced polymer. The resulting blade is stiffer and lighter than conventional wind turbine blades and is also completely recyclable. A prototype blade has been produced and is now under test. The company is moving towards commercial production.

Results were also obtained from the SEI-funded Short-Range Ensemble Prediction System for Wind Energy Forecasting project which was carried out by the Sustainable Energy Research Group (SERG) at University College Cork. The computer and forecasting system was set up and trialled for a selected wind farm in Ireland and produced interesting initial results. An extension to the project for longer-term operation and evaluation of the system for more wind farms has been proposed by SERG.

SEI is also a signatory to IEA Wind RD&D Annex XXI on Dynamic Models of Wind Farms for Power System Studies. The Electricity Research Centre (ERC) at University College Dublin is the national participant for Ireland. Dynamic models for fixed speed wind turbines and variable speed DFIG wind turbines have been developed and tested by the ERC. These have been incorporated within a large scale dynamic model of the Irish generating system. Simulations using this model will be carried out during the course of 2006. Among the objectives of the simulations will be to verify that the requirements of the transmission system grid code for wind turbines will ensure that system stability is not compromised during system faults.

SEI also funded research evaluating of wind turbine foundation behavior carried out by ESBI and University College Dublin. The research was carried out during 2005 and a final report has been received by SEI. The study produced several interesting findings on specific details of foundation design and stability.

SEI also commissioned the consultants ILEX Energy to carry out a study and produce a report on Metering Options for Small Scale Renewable and CHP Electricity Generation in Ireland.

The report provides an analysis of metering options appropriate to all types of small scale electricity generation including wind power and can be downloaded at <http://www.sei.ie/index.asp?locID=74&docID=-1>.

5.2 COLLABORATIVE RESEARCH

In addition to work in the IEA Wind RD&D Annex XXI on Dynamic Models of Wind Farms for Power System Studies, Ireland also intends to join IEA Wind Annex XXV "Design and Operation of Power Systems with Large Amounts of Wind Power. Ireland's proposed participation will focus on the conventional generation mix required to complement high wind penetration and issues including:

- Adequacy
- Reserves
- Unit commitment & dispatch
- Complementary conventional generator characteristics
- Economics/system operation costs
- Emissions
- New system operation methods.

6.0 THE NEXT TERM

In the longer term, at the close of 2005 there was a total of 676 MW of new capacity in contracted grid connection agreements up to 2011; this additional capacity is sufficient to meet the projected increase in wind power required to meet Ireland's 2010 renewable energy target and more agreements may yet be signed to connect wind capacity during this period.

Author: John McCann, Sustainable Energy Ireland, Ireland



NATIONAL ACTIVITIES

CHAPTER 18

ITALY

1.0 INTRODUCTION

The new positive trend, in terms of wind exploitation, which began in 2004, is still continuing. In 2005, a new record was achieved with 452 MW of new installations and an expectation that further important goals will be reached in the near future (Table 1). This is a consequence in part of the green certificate system, which, after two years of transition, is now running well and is attractive to Italian and foreign investors.

As regards manufacturing, two prototype wind turbines are currently being tested and several small-medium enterprises are engaged in making components, with a growing number of people employed. Despite this good news, there is still a strong opposition to wind energy at the decision-making level in some regions and in a minority of environmental associations. Looking at the general energy framework in Italy it is quite clear how wind energy could play an important economic and environmental role in substituting the equivalent amount of electricity generated by imported coal, gas, and oil.

In 2005, domestic net electricity production was similar to the previous year and corresponded to 290 TWh. Total electricity imported increased by 8.3% to 50 TWh, and domestic electrical demand was 1.2% more than 2004 at 329 TWh. As usual, hydropower was the most important renewable source, with its 42.5 TWh of electricity produced in 2005. This was 14.9% less than in 2004, and includes also the production of some pumped-storage plants. Geothermal plants generated 5.3 TWh, a reduction of 2.1% on the previous year. Electricity generated from wind rose by 15.7% in 2005 with a total production of 2.14 TWh. Wind is the renewable source that, unlike hydropower and geothermal, increased its share of electricity production compared to 2004, but its share in total electricity generation is still limited to a very low 0.65%.

Thermal production of electricity, with its 252 TWh, increased by 2.6% in 2005 and represented the most important energy source. Fuel is almost completely imported, with gas, coming from Russia, the Netherlands, and Algeria taking a growing share.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

Legislative Decree No. 387 of 29 December 2003, aimed at implementing EU Directive 2001/77/CE, confirmed the target of 76 TWh/year from

Table 1 Key Statistics 2005: Italy

Total installed wind generation	1,717 MW
New wind generation installed	452 MW
Total electrical output from wind	2.14 TWh
Wind sector turnover	Est. 450 million €
Wind generation as % of national electric demand	0.65 %
Target:	2,500 MW by 2008-2012

NATIONAL ACTIVITIES

renewable sources (RES hereafter), to be achieved in 2008-2012. This target was established in 1999 in the National White Paper for Exploitation of Renewable Energy to comply with the Kyoto Protocol (Italy is bound to reduce annual greenhouse emissions to 6.5% less than the 1990 level by 2008-2012) and was subsequently included in the Directive as well in order to increase the contribution of RES to gross electricity consumption from 16% in 1997 to 22% in 2010.

Against this background, despite the growing demand for electricity and the difficulty in obtaining an anticipated contribution from biomass, the target fixed for wind energy for the period 2008-2012 has remained the same as in the 1999 White Paper, i.e. 5 TWh corresponding to 2,500 MW. Such a wind capacity, taking into account the increasing power connected to the grid in the last two years, corresponding to 357 MW in 2004 and 452 MW in 2005, should be achieved within the next two years, but will not be enough to comply either with the European Directive or the Kyoto Protocol.

In fact, wind power capacity, at the end of 2005, was 1,717 MW and in 2006 at least 500 MW should be installed. This result, considering the constraints continuously facing wind opera-

tors, particularly at the regional level, has to be considered good. In the future, with sufficient knowledge about wind energy and its benefits at the decision-making level and among the general public, other achievable targets, which are perhaps too ambitious for the time being, could be established.

2.1 COMMERCIAL DEVELOPMENT

With 452 MW of wind farms connected to the grid in 2005 and an annual growth rate corresponding to 35% (just a little less than in 2004), Italy has continued the recent favorable trend, thanks to a great interest shown by a substantial number of investors in developing larger projects, with 1.5- to 2-MW wind turbines. In 2005, 378 turbines were added, bringing the total to 2,258 on-line machines; 203 of these units ranged from 1 MW to 2 MW, totaling a power capacity of 355 MW. This corresponded to a cumulative share of slightly more than 20% of on-line capacity (Figure 1 and Figure 2).

Large wind turbines, ranging from 1 MW to 2 MW, are rapidly and steadily increasing their presence even in mountain areas, where wind farms are mostly located. Vestas Italia completed two large wind farms in the Campania and Sardinia regions of 70

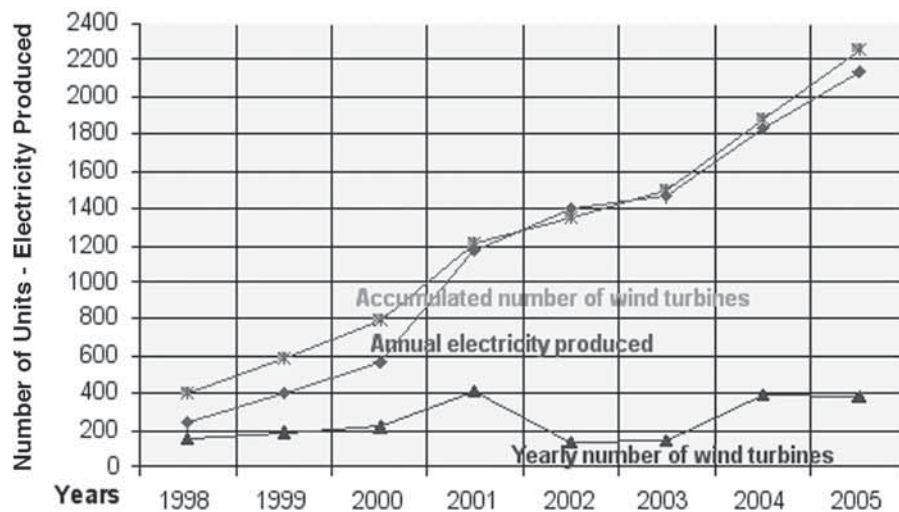


Figure 1 Number of wind turbines and electricity produced (GWh) at the end of 2005.

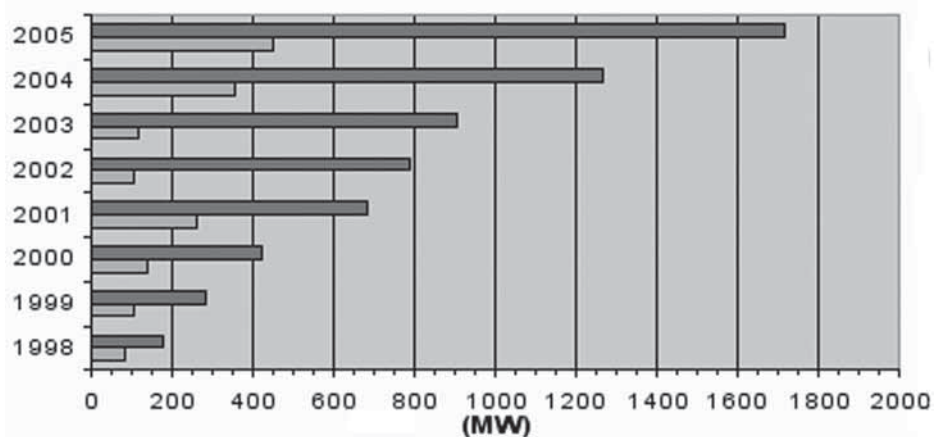


Figure 2 Annual and cumulative wind power capacity in Italy.

MW and 72 MW respectively. These wind farms are owned and managed by FRI-EL and Sardeolica and composed of 2-MW Vestas turbines. Through these installations and other ones in Sicily composed of 850-kW machines, Vestas has confirmed again that it is the main manufacturer in the Italian market, with a market share of 62%.

Gamesa with its 850-kW and 2-MW models, GE with its 1.5-MW turbines, and Enercon were other manufacturers that installed several MW in 2005. Enercon, in particular, started installing its new 2-MW wind turbines in the mountains of Apulia in the summer; by December these machines obtained a very high performance, as demonstrated by a capacity factor of 0.4. GE Wind Energy and REpower have completed their wind farms, respectively at Littigheddu and Troia. At Troia, GE has just connected five units of its 1.5-MW model to the grid, thus completing the first step of a project that will be enlarged through the installation of another 10 units foreseen for the beginning of 2006.

Gamesa, the third manufacturer in Italy, after Vestas and Enercon, with a 10% market share, is currently engaged in several activities in the central and southern Italian regions with medium, 850-kW, and large, 2-MW, machines (Figure 3).

Sicily, Sardinia, Campania, and Apulia were the locations for the main wind installations. As to Sicily

and Campania, more than 100 MW were added in each region in 2005. This increase in power capacity, according to manufacturers and investors, is likely to be at least doubled in 2006.

Meteorological conditions for wind energy and hydropower were not satisfactory in 2005, except for December. In fact, the total wind output in the year was 2,140 GWh, only 16% more than the previous year. Taking into account the extra power capacity of some 40%, it is clear that wind energy output was substantially below expectations.

No wind turbines were replaced in 2005, but Enel is now going to dismantle its wind farm at Collarmele composed of 35 250-kW turbines, which will be substituted by 4 or 5 GE 1.5-MW machines.

2.2 CONSTRAINTS

The installing of wind plants is underway mainly in just a few Italian regions, but some articles of Legislative Decree No. 387/03 on RES have still not been completely put into effect. The moratorium established by the Sardinia region in 2004, followed by a regional energy and environmental plan, issued in December 2005, with a wind target by 2010 of only 550 MW, is hampering the completion of many projects planned in the island and other new initiatives. Other main constraints

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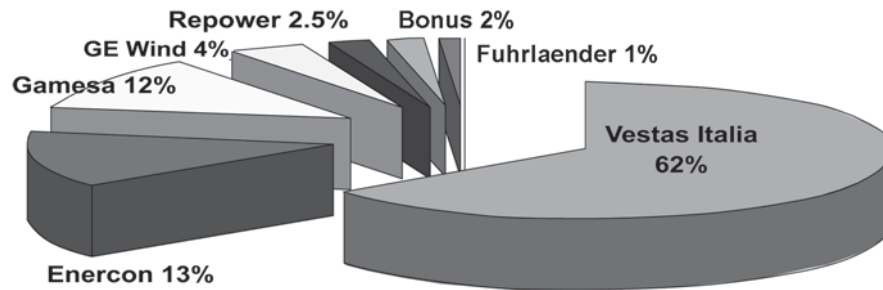


Figure 3 Market share of wind turbine manufacturers at the end of 2005.

are: delays in decisions by some regional governments, in part due to a continuing opposition by minor environmentalist groups, which are active especially at the local level; another temporary regional moratorium on authorization procedures for new wind plants, recently approved by the Apulia region; and the problem of connecting to the grid, which still generally requires a long time. Finally, in December 2005, a resolution was issued by the Regulatory Authority for Electricity and Gas regarding new rules and tariffs for the connection to the grid of renewable plants, partially solving one of the main problems in the sector.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Wind energy has been exploited so far mostly in Southern Italy and the main islands where, as a consequence, there are more wind turbine and component manufacturing activities and consulting, plus the operating structure of the main wind producer acting in Italy. All these activities as well as connected civil works make a contribution both to reducing unemployment, which is higher in this part of the country, and to the economic balance of small municipalities. Landowners in these rural areas also receive a benefit from having turbines, which, depending on the number of the installations, sometimes double the income from their fields.

IVPC, Enel, and Edison (Edens) own about 70% of wind power capacity in Italy. IVPC has the main share, 38%, and directly employs some 200 persons. This company, fully engaged in electricity production from wind, is located in Avellino, and in 2005 installed around 130 MW with 850-kW turbines, most of them in Sicily (Figure 4).

Enel, the most important utility in the country, has a strong involvement in RES, particularly in the hydroelectric, geothermal, and wind sectors. Enel's activities in wind energy started at the end of the 1970s with siting and testing of prototypes in its test and demonstration fields. Enel commissioned its first commercial wind farm in 2001, installing medium-sized turbines in Sicily followed one year later by seven large turbines in Sardinia. Its cumulative wind power capacity at end 2005 was 278 MW, corresponding to a share of 16%.

Edison is another producer, importer, and distributor of electricity and gas. Among its electricity production facilities there is the wind sector, where activities are performed by the subsidiary Edens with about 40 people currently engaged. Like Enel, only 20 MW of wind capacity were added in 2005, leading to a year-end share of 15%.

One should note the presence of new private investors in the sector like EnerTAD, Sardeolica, and Fortore Energia as well as the confirmation of FRI-EL, all of them involved in 2005 in the installation of large wind farms composed of 2-MW turbines.

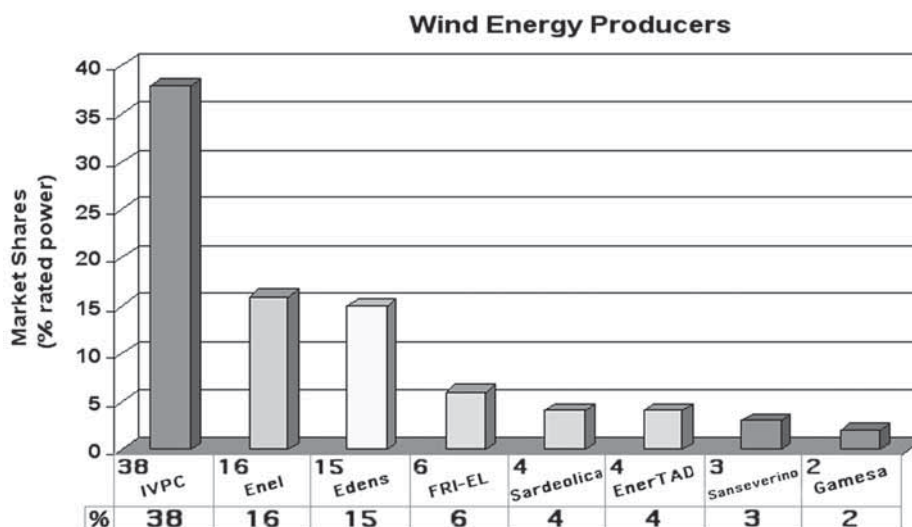


Figure 4 Contribution by electricity producers from wind at the end of 2005.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

3.2.1 MANUFACTURERS OF MEDIUM-SIZE WIND TURBINES

In the manufacturing of medium-sized wind turbines, Vestas Italia is the only company operating in Italy. Vestas Italia is a 100% owned Vestas subsidiary. The company was founded in 1998 with the objective of launching Vestas' experience and technology into the Italian market. Vestas Italia is composed of two units: a Sales and Service Business Unit for Italy and the East Mediterranean area (South Balkans, Turkey and Cyprus, Switzerland, North Africa, and Middle East) and a Production Unit making V52 850-kW turbines for the whole world. Vestas Italia is located in the industrial area of Taranto. By the end of 2005 Vestas Italia had about 500 employees.

The main activities of the Vestas Italia Sales Business Unit are sales, marketing, and maintenance of wind installations. Vestas Italia can supply all kinds of wind power installations: from single ones to complete turnkey wind power plants.

The Vestas Italia Production Unit has a factory with three production lines dedicated to the V52 850-kW and V47 660-kW medium-sized turbines. The Vestas Italia factory can produce over 400 wind turbine generators per year. It produces blades, nose cones, and nacelle covers and performs the assembly of all the wind turbine components. In 2005, the Italian factory in Taranto manufactured 140 turbines for the Italian market and another 225 for other markets (China, France, Greece, Ireland, Netherlands, Sweden, United Kingdom, USA, and other countries). By 31 December 2005, Vestas had installed more than 1,000 MW in Italy and had reached a market share of 62% of total accumulated capacity (Figure 5).

Vestas Italia is QSE (Quality, Safety and Environment) management systems certified and has obtained the following certifications: ISO9001 for Quality Management Systems, ISO14001 for Environmental Management Systems, OHSAS 18001 for Occupational Health and Safety Management Systems. Germanischer Lloyd issued all the certificates.



Figure 5 At the end of 2005, Italy enjoyed more than 1.7 GW of total installed wind capacity including these 2-MW Vestas V80 turbines of FRI-EL in the Campania region.

3.2.2 MANUFACTURERS OF SMALL-SIZE WIND TURBINES

In the small machine sector, Jonica Impianti is currently manufacturing wind turbines of 20 kW, with a total capacity of 60 units per year. This sector is expected to extend its market when Law No. 387 becomes fully operational and also thanks to the reduction of the threshold energy amount requested for obtaining a green certificate from 100 MWh to 50 MWh.

3.3 PROTOTYPES

In 2003, the Leitner company developed and installed a 1.2-MW prototype (Figure 7). After positive testing for two years, in 2005 it completed the construction and installation, in the same mountain area of a second unit for low wind speed sites. This second turbine has a rotor diameter of 77 m, and a rated power of 1,350 kW at 10.6 m/s.

The Leitwind 77/ IEC is a three-bladed, upwind, horizontal axis, variable-speed, pitch-regulated wind turbine. The generator is driven directly by the rotor (gearless). The nacelle is a modular structure, based on three main mechanical groups: rotor, generator, and machine carrier. This concept allows simpler transportation and easier separate assembling of these main groups. The core of the Leitwind wind turbines is the use of an innovative, patented generator with permanent magnets and an especially developed and optimized control system.

Another company, Moncada Costruzioni, developed a 750-kW gearless prototype, which was installed in Sicily by end 2005.

3.4 ECONOMICS

Total turnover in 2005 was about 450 million € and the total people employed in the sector, in-



Figure 6 This 14-MW wind farm in Campania contains seven 2-MW Gamesa G83 wind turbines. Gamesa stands in the Italian market as both machine supplier and plant developer.

cluding those engaged as consultants, developers, component manufacturers, and private producers of electricity from wind, (Figure 6) were roughly 3,000. The total average investment cost is around 1 million €/MW, while the maintenance and operational cost is 10 €/MWh. The cost of electrical

and civil work corresponds to 30% of total investment cost for smaller turbines (capacity <1MW) and 20% of total investment cost for larger turbines (capacity >1MW).

4.0 NATIONAL INCENTIVE PROGRAM

4.1 MAJOR RES SUPPORT INSTRUMENTS

Going back to the past, on 29 April 1992, CIP (the Inter-ministerial Committee for Prices) issued its Provision No. 6, which dramatically changed the incentive policy for RES production by establishing premium prices to be paid for the whole energy produced by RES plants connected to the national grid. These feed-in tariffs were to be updated every year and were different for the various sources. In 2005, the overall preliminary rates paid over the first eight years to RES plants providing their full energy to the network are as follows:

- hydropower plants with a reservoir and run-of-river plants above 3 MW: from 0.1899 €/kWh (peak hours) to 0.0445 €/kWh (off-peak hours);

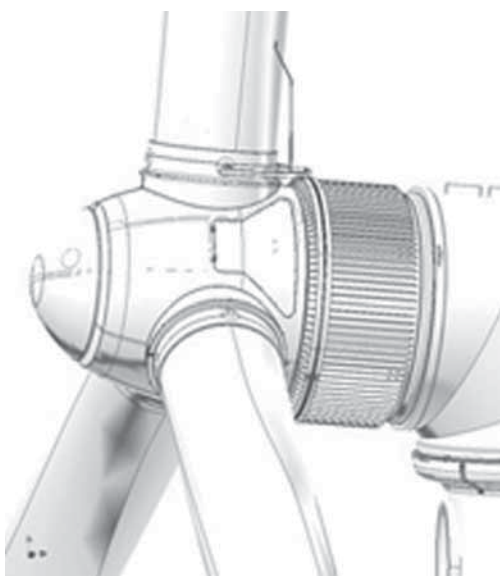


Figure 7 The Leitwind 1.2-MW prototype wind turbine has performed well for two years.

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- run-of-river hydropower plants up to 3 MW: 0.1062 €/kWh;
- wind and geothermal plants: 0.1316 €/kWh;
- PV, biomass, and waste plants: 0.1873 €/kWh;

Legislative Decree 79 of 16 March 1999 restructuring the electricity market, besides granting RES the right of priority in generating plant dispatching, set up a new RES support scheme which was based on a mandatory RES quota and Tradable Green Certificates (TGC). The scheme has been regulated in detail by the following Decree of the Minister of Industry of 11 November 1999 and further adjusted by another, very recent Decree issued by the Ministry of Production Activities (MAP) on 24 October 2005 (the latter Decree has repealed the former one). This scheme is intended as the major support instrument currently available to RES investors entering the market in Italy (the availability of CIP 6/92 for new projects expired long ago).

Since 2001, the RES quota obligation has been imposed on operators who, in the reference year, have produced or imported electricity from non-renewable sources exceeding 100 GWh/year (electricity from CHP plants, auxiliary service consumption, and exports of energy are excluded from this computation). These operators must feed into the Italian grid, by the end of the subsequent year, an amount of RES equaling at least 2% of this non-renewable electricity. For non-renewable energy referring to the period 2004 to 2006, this mandatory percentage has then been raised by 0.35% a year by Legislative Decree 387 of 29 December 2003 implementing RES Directive 2001/77/EC (for instance, in 2005 the RES quota has become 2.35% and so on).

Compliance with this obligation must be shown by presenting GRTN (body in charge of managing all Italian RES support schemes) with a corresponding number of Tradable Green Certificates (TGC) by March of the following year. These TGC are granted by GRTN to qualified RES plants, but only over the first eight years of plant operation. One TGC now corresponds

to 50 MWh of RES (formerly 100 MWh). Only new or re-powered plants that have gone into operation after 1 April 1999 are entitled to get TGC, provided they have applied to GRTN for the relevant IAFR qualification (IAFR = Impianto A Fonti Rinnovabili).

The TGC market price is currently biased by the fact that TGC that should have been granted to plants also getting CIP 6/92 tariffs, are retained by GRTN, which must sell them at a price fixed every year according to a methodology set by the above-mentioned legislation. This fact has been compelling IAFR producers to sell their TGC at a price close to that of GRTN's. As for the 2005 RES production, GRTN has fixed the price of its own TGC at 0.10892 €/kWh (Table 2).

Some additional guarantee to RES investors against possible less favorable developments in the future has been provided by the recent Decree of 24 October 2005. Among others, this Decree has stated that, whenever the TGC offer by IAFR producers should exceed demand as a consequence of failure in stepping up the RES quotas in accordance with Italy's RES targets, GRTN will be obliged to buy all the unsold TGC at its standard price fixed as said above.

In addition to the income from selling TGC, RES producers are currently given the following chances of selling energy in accordance with Legislative Decree No. 387 of 29 December 2003 and Law No. 239 of 23 August 2004. Energy from a programmable RES plant (e.g. hydropower plant with a reservoir or biomass plant) rated at least at 10 MVA can take part in the free electricity market, thus getting an average income of about 0.05 to 0.06 €/kWh. Energy from a non-programmable RES plant (e.g. run-of-river hydropower plant or wind plant), or from any plant rated below 10 MVA, has to be bought by the operator of the relevant network at a price set by the AEEG (Regulatory Authority), which is on average 0.04 to 0.05 €/kWh. Energy from RES plants not exceeding 20 kW capacity can be yielded to the network only on a net metering

Table 2 Italy's Tradable Green Certificates (TGC) Market

Year	2002	2003	2004
TGC demand (TWh)	3.3	3.5	3.9
TGC offer (TWh)	3.3	3.5	3.9
IAFR plant TGC	0.9	1.5	2.9
GRTN's own TGC	2.4	2.0	1.0
Number of TGC issued to IAFR plants	9,144 (100 MWh)	14,814 (100 MWh)	59,972 (50 MWh)
Price of GRTN TGC €/kWh	0.08418	0.08240	0.09739

Source: GRTN - In October 2005, GRTN fixed the price of its own TGC for the 2005 RES production at 0.10892 €/kWh.

basis, up to the amount of consumption in the same period.

Summing up, the current situation of support instruments looks fairly promising to Italian RES investors. Also looking back, feed-in support schemes have already been a decisive driver especially in developing some sources such as wind and small hydropower. The setting-up of the Quota/TGC system, while hampering some sources like PV (which have been given special feed-in tariffs), should encourage the development of more efficient plant thanks to the competition between sources and plants of the same technology. In addition, following the Kyoto Protocol and EU Directive 2003/87/EC on Emission Trading, the Italian PNA (National Allocation Plan) has recently assigned greenhouse gas emission permits and relevant emission allowances for 2005-2007 also to thermal power stations above 20 MW in thermal capacity. Compliance will have to be shown by submitting CER (Certificates of Emission Reduction) owned by the plant or bought on the market or Credits obtained from projects developed within the framework of the Joint Implementation or the Clean Development Mechanism. The latter mechanism should therefore give Italian wind energy investors some chance to build wind farms also in developing countries.

5.0 RD&D ACTIVITIES

5.1 NATIONAL EFFORTS

In Italy, wind energy RD&D is mainly carried out by a few universities in different research areas and without any kind of coordination. Some manufacturers also carry out research. For example, the Leitner group in the development of its large wind turbine, and Jonica Impianti, engaged in the development and marketing of small wind turbines. Among Italian universities that have recently been involved in wind projects, Bologna University has been particularly concerned with lightning protection and offshore foundations, Trento University with cold climate applications, and Milan Technical University with integrated aeroelasticity simulation software. The Milan Technical University Department of Aerospace Engineering has also been carrying out research in the fields of control and supervision logics and wind models, as well as a preliminary project with non-conventional configurations. In particular, some of this research is focused on:

- Aeroelastic modeling and simulation of generic wind turbine generators using finite element based multibody procedures;
- Study of the effects of flap-pitch coupling in teetering wind turbine generators;
- Preliminary design of non-conventional geometry 'Windkraft-like' HAWT generators;

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- Preliminary design and optimization of a 1.5-MW-class VAWT generator;
- Control gain optimization for the reduction of wind turbine fatigue;
- Adaptive neural-based predictive control for wind turbine generators;

Genoa University is still involved in the study of wind potential onshore and offshore, as well as in the simulation of wind flow through the application of WINDS, which is a mass-consistent model for numerical simulation of wind fields in the presence of complex orography. The WINDS model graphical outputs are available daily for the Liguria region at the Physics Department (DIFI) of Genoa University.

Offshore applications are not likely to be implemented in Italy at least in the short term, but the regional government in Sicily, which seems to have some promising offshore potential, has been showing some interest in ordering feasibility studies to verify the opportunities currently available along its coasts.

5.2 COLLABORATIVE RESEARCH

Italy, through Trento University, is participating in the IEA Wind annex XIX "Wind energy in cold climates."

6.0 THE NEXT TERM

A general estimate of the wind market in 2006 and the following years, in terms of expected power capacity growth, according to the main operators and on the basis of the activities currently in progress, is summarized below.

For each year 2006 and 2007, new wind plants installed should range between 500-700 MW in capacity. Total wind power capacity by 31 December 2010, according to this trend, is estimated to be 4,000 MW or, in the most favorable case, up to 5,500 MW. This forecast of continued growth in the near future is supported by the awareness of some decision makers that the failure to comply with the Kyoto Protocol in terms of reduction of CO₂ emissions is going to cause the country heavy environmental and economic consequences.

Authors: Luciano Pirazzi (ENEA) and Claudio Casale (CESI RICERCA), Italy.



CHAPTER 19

JAPAN

1.0 INTRODUCTION

At the end of Fiscal Year 2005 (March, 2006), the total wind-power capacity in Japan is estimated to be 1,078 MW with 1,048 turbine units, which corresponds to one-third of the national target for wind-power capacity by 2010. Having experienced severe damage by typhoon attack or lightning strikes in the past few years, several activities have been organized to promote sound development of wind technology under governmental initiatives. However, grid connection issues have become rather significant. New wind farm projects are often regulated by electric power companies and candidate projects are chosen by lot. Moving to offshore installations has not yet begun due to deep water conditions.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

2.1 STRATEGY

At the UN Climate Change Conference in Kyoto on December 1997, the Japanese government agreed to reduce the output of greenhouse gases by 6% by 2010, compared to the 1990 level. To attain this target, the government set the target for wind power for 2010 as 3,000 MW in the latest Primary Energy Supply Plan. The government started to figure out the next target by 2030 after the results of COP3.

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. With natural and social obstacles to wind power development as mentioned above, the government will bring about new measures in the next financial year to attain the present target of 3,000 MW by 2010.

Table 1 Key Statistics 2005: Japan

Total installed wind generation	1,077 MW*
New wind generation installed	150.8 MW*
Total electrical output from wind	1.4387 TWh/yr**
Wind sector turnover	NDA
Wind generation as % of national electric demand	0.166%
Target:	3,000 MW by 2010

* Predicted by the end of March 2006 **From April 2004 to March 2005.

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2.2 INSTALLED CAPACITY

Japan's cumulative wind power capacity was 924 MW at the end of March 2005 (1) and will be 1,078 MW at the end of fiscal year 2005 (March 2006). Figure 1 shows the history of wind turbine development in Japan. Every value of capacity was taken at the end of each fiscal year. The graph has the vertical axis in log-scale, which shows that the wind power capacity has exponentially expanded in the past. However, it is growing more slowly in the latest few years.

2.3 CONTRIBUTION TO NATIONAL ENERGY DEMAND

Wind power generation from April 2004 to March 2005 was 1,438.7 GWh. The national energy demand in the same period was 865.4 TWh, and the contribution of wind power counts for 0.166%.

2.4 RATES AND TRENDS IN DEPLOYMENT

Most commercial wind farms have been developed with governmental promotional subsidy programs, which accelerated the development very quickly. Figure 2 shows the trend of wind power deployment fit on an exponential curve. Although the cumulative capacity has increased by 8 times in the past 5 years and by 140 times in the past 10 years, the recent annual percent increase is getting smaller as shown in Figure 2. Wind power development in Japan is meeting with its own natural and social environments.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Wind power development in Japan has brought certain benefits to the wind industry. Japan had

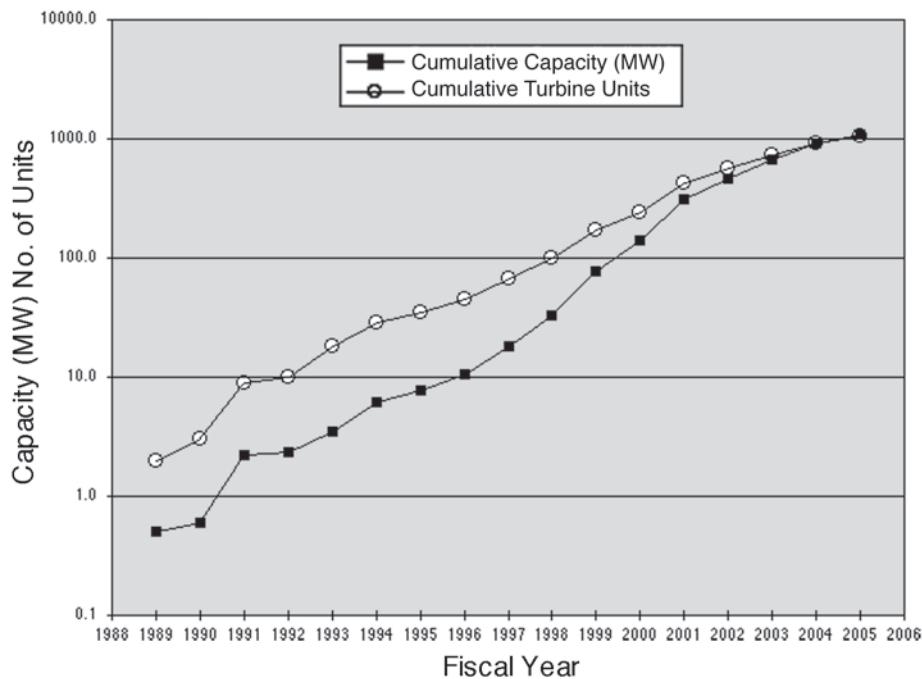


Figure 1 History of wind turbine development in Japan [Data source: NEDO].

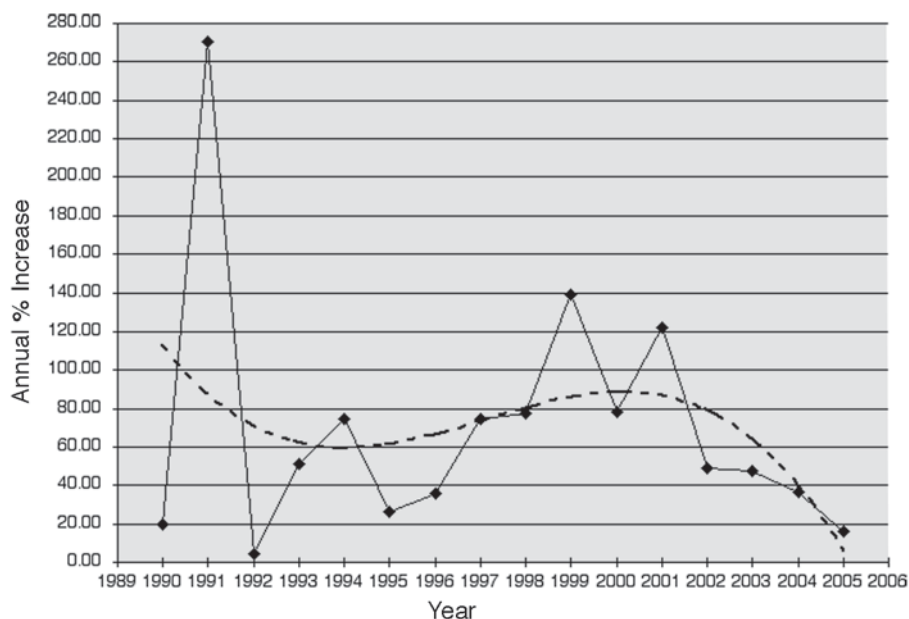


Figure 2 History of annual percent increase in wind power capacity.

only one wind turbine manufacturer that produced large turbines larger than 1 MW before 2005. Now there are two: Mitsubishi Heavy Industries Ltd. (MHI) and Fuji Heavy Industries Ltd. (FHI). The Japan Wind Power Association (JWPA) has grown to have more than 100 member companies. Japan enjoys the benefits from wind generation both in economical and environmental aspects corresponding to the present 1,000 MW of capacity.

However, the Japanese market is deeply influenced by external conditions both natural and grid related. Grid connection is one of the biggest issues. Japan is a long island with the huge cities of Tokyo, Osaka, and Nagoya located in the middle. This means the heavy demands are concentrated to the center of the country. On the other hand, most windy areas are located in the more rural areas in the northern and southern ends of the country. These areas have high wind energy potential but less electricity demand. Figure 3 shows the grid system in Japan, where nine electric power companies own each regional grid (3). The upper limit of wind power capacity for grid connection

is declared by regional electric power companies as shown in Table 2. The ratio of allowable wind capacity to grid capacity ranges from 3.5% to 5%.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

Mitsubishi Heavy Industries Ltd. has long been the only national manufacturer that supplies medium-to-large wind turbines. In the beginning of 2006, MHI erected a new 2.4-MW wind turbine in Yokohama (Figure 4). Fuji Heavy Industries Ltd. became the second large-scale wind turbine manufacturer in Japan and developed a 2-MW wind turbine (Figure 5). The main features of both turbines are shown in Table 3.

There are many other new manufacturers who deal with small turbines. Zephyr Corporation developed a new model Z-1000 Airdolphin (Figure 6). This turbine is a horizontal, up-wind machine of 1.8 m diameter with power output of 1,000 W at a wind speed of 12.5 m/s. It has three light weight carbon blades. Zephyr started a round robin campaign by installing the new model at more than 15 sites around the world. These sites include flat

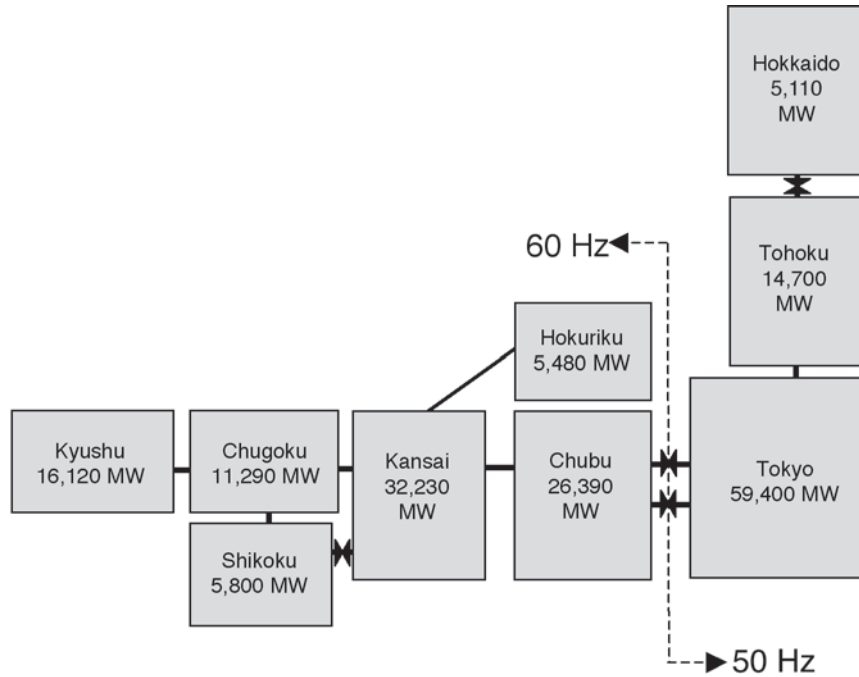


Figure 3 The electric grid system in Japan. Nine electric power companies own each regional grid.

Table 2 Upper limit of wind power capacity for grid connection

Electric power company	Grid capacity (MW)	Allowable capacity for wind (MW)	Ratio (%)
Hokkaido	5,110	250	4.89
Tohoku	14,700	520	3.54
Chugoku	11,290	400	3.54
Shikoku	5,800	200	3.45

places, coastal areas, mountains, lake sides, and the tops of buildings in the areas of Tarifa (Spain), Soria (Spain), Rimini (Italy), and the UK.

In Japan, the outstanding technical issues are grid connection (power quality), typhoon attacks, lightning strikes, and high turbulence at hilly sites. In September 2003, severe wind turbine accidents occurred on Miyako Island. All seven wind turbines there were either knocked down or lost blades and/or nacelles from a huge typhoon. The official maximum wind speed was 74.1 m/s at

Miyako, but the extreme wind speed at hub height is considered to have been more than 90 m/s. In principle, the typhoon accident is considered a kind of natural calamity. However, it is necessary to improve the design technology for regions where S-class wind turbines will be installed. Other accidents have been recorded at various wind plant sites, and both national and imported turbines have suffered.

Lightning strikes are also an important issue in Japan. Many turbines have been hit by lightning

Table 3 Main features of MWT92 and SUBARU 80/2.0

Wind turbine	MWT92	SUBARU 80/2.0
Manufacturer	MHI	FHI
Rated power	2.4 MW	2 MW
Hub height	70 / 80 / 90 / 100 m	80 m
Number of blades	3	3
Blade material	GFRP	-
Rotor diameter	92 m	80 m
Orientation	Upwind	Downwind
Cut-in/rated/cut-out wind speed	3.0/12.5/25 m/s	3.0/13/25 m/s
Survival wind speed	60 m/s	-
Generator	Rotor current control/double-fed	Double-fed
Speed	1,200-1,340 / 690-1,300 (50 Hz) / 830-1,550 (60 Hz) rpm	10.0-19.5 rpm (rotor)
Transmission	3 stage gear	-
Regulation & control	Active yaw & individual pitch	Active yaw & individual pitch
Brake	Individual pitch brake & high speed shaft brake	Individual pitch brake & high speed shaft brake
IEC Class	Class II A	Class I A
Tower	Monopole taper steel	-



Figure 4 MHI's new 2.4-MW wind turbine, the MWT92, installed in Yokohama.

and winter lightning poses a specific threat due to its intense power and electric current that are much higher than the world average.

For these reasons, the government set up several committees to investigate external conditions in order to find reliable measures. One of them is a guideline committee to produce a so-called “J-class Guideline” to prevent severe accidents due to the Japanese external conditions.

3.3 ECONOMIC DETAILS

3.3.1 UNIT COST REDUCTION

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, some other factors, such as transportation cost and the additional cost needed for grid connection, require additional plant costs.



Figure 5 FHI's new 2-MW, down-wind type wind turbine, the SUBARU 80/2.0, installed at Hazaki.

According to model estimation for a 25-MW wind farm discussed at a national committee, COE is 10.20 JPY/kWh with subsidy. Today, the COE is from 9.00 to 11.00 JPY/kWh for medium-scale wind turbines (unit capacities between 500 kW and 1,000 kW) and is 7.00 to 9.00 JPY/kWh for large-scale wind farms comprised of wind turbines with capacities of more than 1,000 kW.

3.3.2 TRENDS IN INITIAL COSTS, UNIT COSTS OF GENERATION AND BUY-BACK PRICES

The current wind turbine cost is approximately 100,000 JPY/kW. The installation cost is de-

creasing as the number of large-scale wind power plants increases. The cost differs depending on wind conditions, grid conditions, and plant size. For 2003, the average initial cost was estimated as 190,000 JPY/kW. However, recent accidents may hinder decreases in plant costs. The average electricity purchase price is about 18.00 JPY/kWh.

4.0 NATIONAL INCENTIVE PROGRAMS

After closing national wind energy R&D programs in fiscal year 2002, most of the national efforts are focused on incentive programs consisting of subsidies and investigations. The national activities are shown in Table 4. Most of the programs are supported by the Ministry of Economic Trade and Industry (METI) and one is supported by the Ministry of Land, Infrastructure and Transport and is mainly conducted by the New Energy and Industrial Technology Development Organization (NEDO) and the Japan Electrical Manufacturers Association (JEMA).

4.1 MAIN SUPPORT INITIATIVES AND MARKET STIMULATION INCENTIVES

Among the national program subsidy measures, the New Energy Business Supporting Program



Figure 6 Zephyr's New Wind Turbine "Airdolphin" 1 kW.

Table 4 Japanese national incentive programs

Program	Purpose	Type	Category	Budget (Million Yen)
Field Test Program	Measure wind to develop wind plant candidates (Subsidy rate: 100%)	Subsidy	Wind	230
New Energy Business Supporting Program,	Subsidize business development of generation plant for initial cost (Subsidy rate max. 30%)	Subsidy	New energy	42,100
Regional New Energy Development Stimulation Program	Subsidize local new energy development of generation plant for initial cost (Subsidy rate: Max. 30% local authorities and Max. 50% for non-profit organizations)			
Demonstration of Grid Stabilization with Battery Back-up System	Demonstrate grid stabilization technology with battery back-up system at wind farm sites	Demonstration	Wind	980
Wind Turbine Availability Improvement Committee	Investigate accidents, draw future load map and discuss measures to improve availability	Investigation	Wind	254
J-Class Wind Turbine Guideline Committee	Investigate all standards, technical guidelines, and measure wind characteristics including typhoons and gusts, turbulent intensity, aerodynamic loads on machine and lightning attacks			
Wind Atlas Revision	Revise Japan Wind Atlas			
Investigation of Prediction Technology of Wind Generation	Investigate new technology for prediction of wind generation from wind farms using computational tools within a couple of days			
Committee of WTGS design against survival wind speed	Investigate new design guidelines for structural parts of wind turbine against extreme wind speeds	Standard	Wind	108
Revision of Technical Guideline of WTGS	Revise and improve the present Technical Guideline of Wind Turbine Generation Systems			
Committee of Wind Turbine Standards	Cooperate with IEC and create JIS standards			
Committee of Technical Conformity of Wind Turbine Systems	Investigate possible certification system for wind turbine systems			
Investigation of New Technology for Wind Turbine Performance Measurements	Investigate and develop new technology of wind turbine performance measurement applicable for complex terrain using numerical site calibration			

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and the Regional New Energy Development Stimulation Program, play the main role. In fiscal year 2005, the former supported 10 projects that total 122.87 MW and the later also 10 projects that total 27.9 MW. The subsidy rate is 50% with the New Energy Business Support Program and 30% (private sector) or 50% (non-profit organization) with the Regional New Energy Development Stimulation Program. The contribution of the subsidy is evaluated through the COE. For example, the COE was 12.50 JPY/kWh without subsidy but 10.20 JPY/kWh with subsidy in 1999.

4.2 WIND TURBINES DEPLOYED

As mentioned above, 20 commercial wind farms were developed during fiscal year 2005. The largest newly installed wind plants were the 57-MW plant in Wakkanai, Hokkaido and the 20-MW plant in Hayama, Kochi.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

As shown in Table 4, most of the national programs are focused on market incentives (subsidy programs) and investigations/standards/guidelines. No technical R&D programs are running, however, the Demonstration of Grid Stabilization with Battery Buck-up System is a kind of technical

development. Since Japan is blessed with abundant marine resources, development of offshore wind is a potential target for the future.

5.2 COLLABORATIVE RESEARCH

GWEC Japan (Japanese Wind Energy Association and Japanese Wind Power Association) became a member of the Global Wind Energy Council (GWEC) in March 2005 when GWEC was established. In December 2005, GWEC Japan held an International Wind Energy Symposium, having key presentations by Professor Arthouros Zervos, President of GWEC, and others. Although this symposium was not collaborative research itself, it was made clear that Japan and the world have many common technical concerns, such as deep offshore technology, grid connection of large wind farms, and so on.

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- (2) METI: The Ministry of Economic, Trade and Industry
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Author: Hikaru Matsumiya, Kyushu University, Japan



CHAPTER 20

KOREA

1.0 INTRODUCTION

The year 2005 was a turning point in Korea for the deployment of wind power generation facilities. Through 2004, the cumulative installed capacity of commercial wind power generators of the 100-kW class or more was 28 MW. New capacity in 2005 alone was a whopping 70 MW, for a total cumulative installed capacity of almost 100 MW by year-end. The market in Korea for wind power generation facilities is expanding, and deployment would increase even more steeply if wind power could be proven competitive against other energy sources. Deployment of wind power generation facilities is still difficult in Korea due to a number of technical, geographical, and institutional restrictions. Most of the data used in this report was gathered and analyzed by the New and Renewable Energy Center under the Korea Energy Management Corporation (KEMCO).

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

In December, 2003, the Korean government established the “Basic Plan for New and Renewable Energy (NRE) Technology Development and Dissemination,” as a mid- to long-term policy to proactively facilitate technology development and dissemination of NRE. Accordingly, the government is implementing detailed annual plans to raise the share of NRE to 5% of Total Primary Energy Supply (TPES) by 2011.

Development and deployment of hydrogen-fuel cells, photovoltaics, and wind power would have considerable positive ramifications for many different industries, so they have been designated as three priority technologies. R&D organizations have been established for each, and support is being offered to mainly large-scale projects being conducted to secure key future technologies to ensure rapid deployment as soon as the technologies become feasible. The government targets a cumulative installed wind power capacity of 2,250 MW by 2012, and has drawn up plans to carry out development of localized technology for a large, 3-MW-class wind power generation system.

Table 1 Key Statistics 2005: Korea

Total installed wind generation	100 MW
New wind generation installed	70 MW
Total electrical output from wind	.146 TWh*
Wind sector turnover	NDA
Wind generation as % of national electric demand	NDA
Target:	2,250 MW by 2012

* Estimate

3.0 BENEFITS TO NATIONAL ECONOMY

Installation of commercial wind power generators through private investments has been especially strong since May 2002, when the feed-in-tariff system for NRE-generated electricity took effect. An application period of the base price is designated to ensure that private wind power generation companies secure investment soundness for a certain period of time.

To make adjustments to the base price and application period, which will take effect after October 2006, measures to improve the feed-in tariff system are underway. These measures include analysis of profits made until now, subsidies that have been provided for each energy source, usage rates of facilities, and case studies in other countries.

3.1 DEPLOYMENT AND CONSTRAINTS

As of the end of 2005, there were 78 wind power generation systems in operation in Korea, and their cumulative installed capacity was 98 MW (100 kW-class or more). Of this total, the capacity

of 41 systems constructed in 2005 alone was 70 MW, or 71.4% of the total. The average rated output of wind turbines installed in 2005 was 1,711 kW, which was almost a 2.4-fold increase from the average of 713 kW up to 2004. Most of the wind turbines constructed in wind farms recently have a rated output of 2 MW each.

One of the obstacles toward deployment of wind power generation facilities in Korea is the relative scarcity of geographically suitable locations for wind farms. Most areas outside population centers are mountainous, so the infrastructure (road, power grid, etc.) is inadequate despite the great potential for wind power. Establishing wind farms therefore entails huge up-front costs. In addition, these areas are usually designated nature preserves, such as public parks, so obtaining legal permits is difficult, if not impossible.

Private wind power generation companies are trying to reduce the unit cost of construction by pursuing large-scale deployment projects of more than 10 MW. Various measures are being taken to overcome the geographical limitations, such as the construction of offshore wind farms. To this end, the government is carrying out demonstration research to assess the feasibility of offshore wind

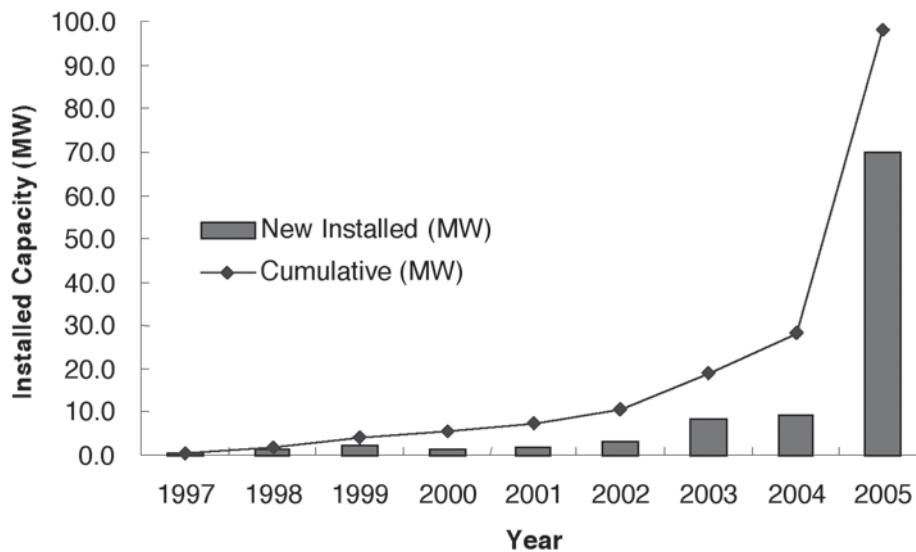


Figure 1 New annual capacity and cumulative installed capacity of WTG in Korea.

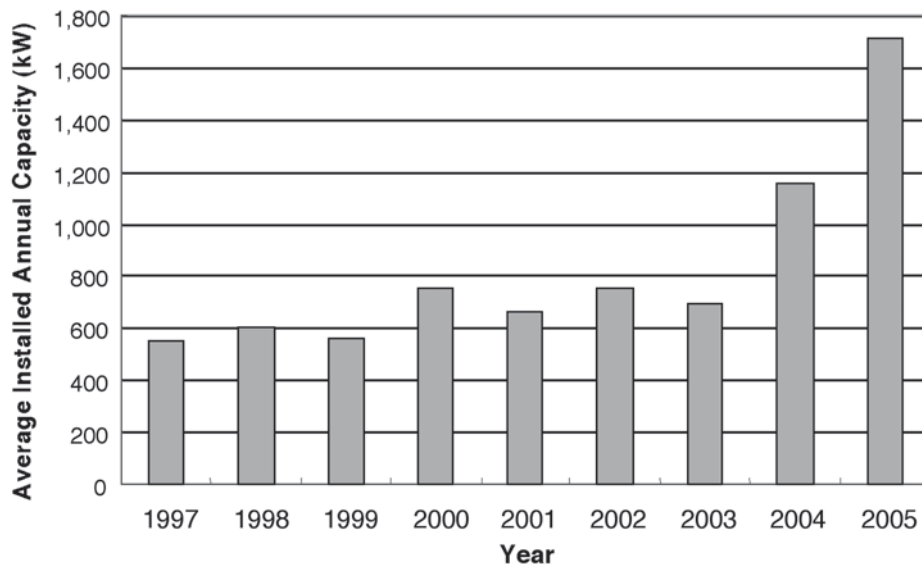


Figure 2 Average annual installed WTG capacity in Korea.

power generation as well as to create conceptual designs for development of offshore wind power generators.

3.2 INDUSTRY AND ECONOMICS

At present, four domestic manufacturers are developing mid- to large-class wind power generators with capacities of 750 kW to 2,000 kW. Two of the manufacturers have installed prototype wind power generators with capacities of 750 kW in demonstration sites, and the generators are now under pilot operation.

These wind turbines are the result of a national research and development project which began in December 2001, with the aim of localizing wind power generation systems and evaluating the applied technologies. A gearless model and a geared model were developed simultaneously. These two companies also began developing a 2-MW-class wind power generator and expect to complete a prototype in the first half of 2007.

The Korean wind power industry is growing rapidly, benefiting from the major wind power generation projects that are underway. Companies

operating wind farms, and manufacturers of wind turbines, turbine towers, and components, are expected to see steady growth into the foreseeable future.

4.0 NATIONAL INCENTIVE PROGRAMS

The “Promotion Act on the Development, Use, and Dissemination of New and Renewable Energy” was enacted to achieve mid- and long-term deployment targets through such means as deployment subsidies, loans, and feed-in-tariff system, which have already become crucial to the accelerated deployment of wind power generation facilities.

To secure and create an early deployment market, NRE facilities deployment subsidy program is underway. Preferential loans are being granted, and a feed-in-tariff system has been established (1). Moreover, various means of support are being provided to build an infrastructure for commercialization, including an NRE performance evaluation and certification system, RESCO (Renewable Energy Service Company) system, and standardization. For systematic training of

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human resources, support is being offered to establish core technology development centers and graduate school courses specializing in this area.

5.0 RD&D ACTIVITIES

Research and development of commercial wind power generation systems in Korea started in earnest at the end of 2001 and focused on 750 KW-class systems. These research projects mainly concerned geared induction generation systems, gearless synchronous generation systems, and a new concept – Dual Rotor Type wind turbines. Among these research projects, the Dual Rotor Type was upgraded to the 1-MW-class in 2003, and the other projects succeeded in developing prototypes in mid 2004, for which demonstration research is now being carried out. The development of a 2-MW-class multibrid type wind power generation system as well as research on the basic design of a 3-MW-class offshore wind power generation system have been ongoing since 2004. A demonstration research project was launched in December, 2005, in the offshore wind farm with two 2-MW-class systems.

6.0 THE NEXT TERM

The government is taking a comprehensive approach to realize this goal: cumulative installed wind power capacity of 2,250 MW by 2012. It has drawn up plans to carry out development of localized technology for a large, 3-MW-class wind power generation system. It is strengthening the foundation of its policy by revising applicable laws and ordinances as well as by expanding relevant organizations and the budget.

NOTES

(1) Feed-in-tariff system: A base price is determined for every new and renewable energy source to compensate for the difference with the SMP (System Marginal Price).

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CHAPTER 21

MEXICO

1.0 INTRODUCTION

At present, there is a constructive environment for the implementation of wind power in Mexico. More than a few official documents recognize that Mexico's wind resource would be sufficient for the installation of at least 5,000 MW of wind power. In a topical workshop carried out in May 2005, 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 within the next ten years; this institution has already granted a contract for the construc-

tion of the first plant. 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. A regulatory instrument has been approved that improves the economic feasibility of self-supply wind power projects; it will be issued next year. In December 2005, the Federal Congress approved an initiative of Law for the Use of Renewable Energy; early in 2006, the Senate will decide whether to endorse it or not.

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 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 10 years at capacity factors ranging from 30 to 40%, which compares favorably to 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

Table 1 Key Statistics 2005: Mexico

Total installed wind generation	2.2 MW
New wind generation installed	0 MW
Total electrical output from wind	4.2 GWh
Wind sector turnover	NDA
Wind generation as % of national electric demand	NDA
Target:	400 MW by 2012

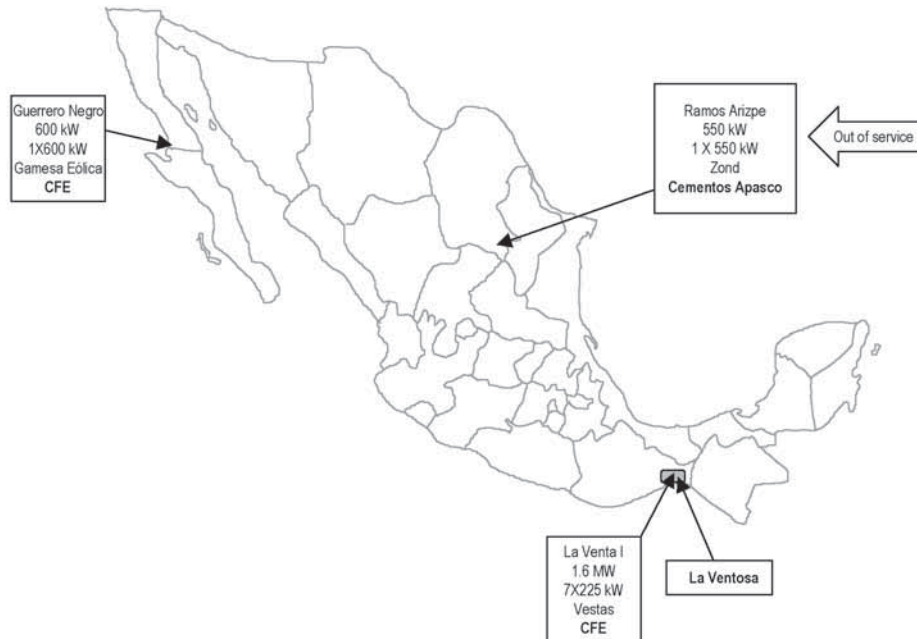


Figure 1 Location of wind turbines installed in Mexico (December 2005).

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 non-committed 15.9 GW of new capacity using Mexico's wind energy resource.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

At present, it is clear that both the energy and the environmental policies in Mexico consider renewable energy as a fitting way for diversifying energy supply within a sustainable development framework. The current National Development Plan as well as the Energy Sector Programme takes into account the promotion of renewable energy, giving an important role to wind power. On the other hand, energy supply in Mexico must secure projected economic development. Therefore, the Government of Mexico, within both the execu-

tive and the legislative powers, is formulating the official instruments that will lead to a suitable mix of conventional and renewable power, considering the short, medium, and long terms.

2.1 STRATEGY

The main official instrument aimed at including renewable energy in Mexico's electricity generation mix, is an initiative of Law for the Use of Renewable Energy. In December 2005, the Federal Congress approved it. Early in 2006, the Senate will decide whether to endorse it or not. Upon positive decision, the Law would come into force by mid 2006. The initiative of Law includes the creation of a green fund to improve the economic feasibility of wind power projects under the current constitutional and legislative mandates. The green fund would grant a premium price for electricity generation (kWh) based on renewable energy. The initiative includes the obligation of 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 sector are promoting the use of renewable energy in Mexico. However, some detractors of these innovative technologies are delaying the progress on its implementation. The major stakeholders of wind power are removing different kinds of barriers by means of a systematic approach with the following major components.

By the end of 2003, the Electrical Research Institute (IIE), together with the United Nations Development Programme (UNDP), achieved sponsorship from the Global Environmental Facility (GEF) of the project Action Plan for Removing Barriers to the Full-Scale Implementation of Wind Power in Mexico. The project began in January 2004. The first phase (2004-2006) is addressing capacity building, wide promotion of wind energy at the national and regional level, human resource development, strategic studies (including those for supporting the recognition of the capacity credit of wind power), and assessment of 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. The construction of a Regional Wind Technology Centre is also one of the goals of this project. Furthermore, the IIE will carry out a set of comprehensive feasibility studies, in conjunction with any required preparatory activities, all geared towards the formulation of business-demonstration wind power plants. Phase 2 of the wind power action plan (2007-2009), will launch a competitive bidding process for three prototype projects. GEF will consider supporting these projects by implementing temporary production incentives.

Next, the IIE will monitor and document the technical and economical performance of the commercial wind power plants, and will conduct a national campaign – based on lessons learned

and best practices - for promoting the progressive replication of successful projects. This project organized the workshop mentioned above, where a shared vision of the implementation of wind power for the year 2030 - and the paths to reach it - was agreed to by consensus of the major promoters of wind power. The implementing agency for this project is the UNDP while the prime mover and execution agency is the IIE.

The wind power action plan is paving the way to a more extensive project originated by the Secretariat of Energy (Sener): the Large Scale Renewable Energy Development Project. The GEF will also be the sponsor of this project; the World Bank will be the implementing agency, and Sener will be the execution agency. The Large Scale Renewable Energy Development Project could start formally in 2006 (insertion into GEF's work plan has already been approved, but final endorsement is pending). This project focuses at launching an IPP renewable energy market by creating a green fund, targeted to complement regulated buy-back prices for renewable energy.

2.2 PROGRESS TOWARD NATIONAL TARGETS

The Secretariat of Energy (Sener) and the Regulatory Commission for Energy (CRE) have been preparing and lobbying for legislative, regulatory, and planning instruments that are improving the framework for the implementation of renewable energy. As one of the results of this lobbying, the Federal Electricity Commission (CFE) launched a bidding process to construct an 83.3-MW wind farm (La Venta II). The project will be carried out under the modality of Financed Public Work (FPW). This means that a private contractor is responsible for financing and construction of the wind power plant, and that CFE will pay to the contractor the total amount of the contract upon commissioning of the wind power plant. Subsequently, CFE will own and operate 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

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operation and maintenance issues, and to assess direct and indirect benefits.

La Venta II will be the first project to be commissioned by the end of 2006, and work to prepare construction was initiated by late 2005. Unfortunately, La Venta II will not reach the 101 MW planned capacity, since the approved budget was not enough. Offers to construct the plant ranged from 1,370 to more than 1,500 USD per installed kW, in a turnkey modality. CFE had to decrease the capacity of the plant to 83 MW. CFE awarded the contract to the Spanish consortium Iberdrola-Gamesa. La Venta II will be constructed with 98 wind turbines rated at 850 kW (G52-850kW).

The official Program of Investment for the Electric Sector (2004 – 2013), prepared by the Federal Electricity Commission, is considering the installation of 404 MW of wind power capacity. CFE planned the construction of four wind power plants, 101 MW each, from 2006 to 2013.

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 will be issued by early next year. 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 of 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 annual Colloquiums on Opportunities for the Development of Wind Power in the Isthmus of Tehuantepec. So far, this has been the most important Forum on the wind energy at the national level.

A number of prestigious private companies formally integrated a Mexican Association of Wind Power (-AMDEE-). During 2005, this association 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 a more than fifteen-year labor on renewable energy promotion.

Up to December 2005, besides the 404 MW of wind power capacity planned by CFE, there is not any other official target that takes into account other kinds of wind power projects (neither for self-supply nor for small producers). Nevertheless, there are several private projects for more than 400 MW, which are waiting for better conditions.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

The total installed capacity of wind turbines in Mexico is 2.2 MW and there was no additional capacity installed during 2005. The number of wind turbines installed in Mexico is eight (Table 2). Taking into account the size of the national electrical system it is evident that the contribution from wind energy to the national electricity demand is negligible.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

During 2005, electricity production from La Venta I wind power station was 4.2 GWh. The facility operated at an annual capacity factor of 31 % (Reported by Eng. Carlos García Aguilar,

Table 2 Wind turbine installations in Mexico by the end of 2005

Location	Manufacturer	Wind turbines (kW)	Capacity (MW)	Commissioning date	Owner
La Venta, Oax.	Vestas	7 x 225	1.57	1994	CFE
Guerrero Negro, B.C.S.	Gamesa Eolica	1 x 600	0.60	1998	CFE
Total		8	2.20		

General Manager of La Venta I Wind Power Station). The capacity factor of this plant decreased with respect to previous years because of the premature degradation or recurrent failures of some of the wind turbines. In early years of its operation, the whole plant reached more than 40% capacity factor which has steadily declined. Seven Vestas V-29, 225-kW wind turbines are installed there. During 2005, the wind turbine with maximum capacity factor reached 36% while the lowest capacity factor was 24%. The seven wind turbines are exposed to the same wind regimen (plain terrain, unidirectional wind, 3 diameters of separation between wind turbines). A possible reason for such operational changes after only 50% their 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 height could require a special class of 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 revealed 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 above ground. However, CFE has not released performance data for the years 2003 to 2005.

A 5-kW wind turbine of Mexican design is currently manufactured in Mexico, primarily for export markets. A Mexican company has manufactured a number of 750-kW electric generators for an international wind turbine manufacturer. A number of wind turbine components - including towers, generators, gears, conductors, and transformers - could all be manufactured in Mexico using existing infrastructure. More than 200 Mexican companies have been identified as having 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, which 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 different 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 buy-back 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 subsidised.

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Table 3 Electricity prices in Mexico for 2005

Sector	Average price (Mexican Pesos/ kWh)
Industrial	0.85
Agricultural	0.38
Residential	0.88
Commercial	1.80
Public services	1.40

- There is a critical need to generate a confident and stable business environment that can provide appropriate guarantees to international and national financial institutions on the viability and profitability of wind power projects.
- A 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 wind-landowners (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 Regulatory Commission for Energy issued the first incentive for renewable energy. Embedded in the existent legal and regulatory frameworks, this new incentive consists of a model of agreement for the interconnection of renewable energy power plants to the national electrical grid. It allows self-supply generators to interchange electricity between different 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 a certain period

can be credited to compensate for the electricity extracted from the grid during a different period. The interchange is allowed based on the ratio of the marginal costs between different billing periods; therefore, it is required to generate more than 1 kWh 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 its 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 in order to achieve the recognition of certain capacity credit for wind power. By the end of 2005, a modification of the model of agreement was accepted. 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 will be issued 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 are allowed to deduct 100% of the investment in one year (1-year depreciation). Before, investors in equipment for electricity generation were allowed to deduct only 5% in one year (20

years depreciation). The equipment shall operate at least for the next five years following the tax deduction declaration; otherwise, complementary declarations are obligatory.

5.0 RD&D ACTIVITIES

The first demonstration project the “La Venta” 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/PNUD, the IIE is working on the implementation of a Regional Wind Technology Centre, which aims to offer the following provision.

1. Support to interested wind turbine manufacturers for the characterization of their products under the local conditions at La Ventosa
2. A means to train local technicians for operation and maintenance of a diversified range of wind turbines
3. 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
4. A modern and flexible installation to obtain hard operational data on the interaction of specific types of wind turbines with the electrical system
5. A means to understand international standards and certifications (issued abroad) in order to identify additional requirements to fit local conditions

6. 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.

Wind data currently available in Mexico is scarce (except for few sites). The wind energy resource in several promising areas has not been evaluated. 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 2005, one full year of data collection was acquired for six new promising areas. During 2006, one full year of data collection will be completed for ten additional areas.

Furthermore, by contract with CFE, the IIE carried out a feasibility study for a wind power station in the state of Baja California Sur.

6.0 THE NEXT TERM

In 2006, construction of the La Venta II 83.3-MW wind power plant will be completed. It will contain 98 wind turbines rated at 850 kW (G52-850kW). In December 2005, the Federal Congress approved an initiative of Law for the Use of Renewable Energy; early in 2006, the Senate will decide whether to endorse it or not. Also in 2006 an approved new regulatory instrument that improves the economic feasibility of self-supply wind power projects will be issued.

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NATIONAL ACTIVITIES

CHAPTER 22

THE NETHERLANDS

1.0 INTRODUCTION

The share of renewable energy in the Netherlands energy supply increased to 4.2% in 2005 of the total primary energy consumption of 3,314 PJ. The domestic production of renewable electricity in 2005 increased to 7.3 TWh or 6.2% of the total electricity consumption of 118 TWh. The target was 6% electricity from renewable sources in 2005, so it has been met.

In 2005, the net increase in installed wind capacity in the Netherlands was 140 MW, bringing the total installed capacity to 1,213 MW. The production of wind electricity in 2005 increased to 2.0 TWh or 1.7% of the total electricity consumption (1).

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

The national targets in 2005 were 5% of total energy consumption from renewable energy in 2010 and 10% in 2020. The partial targets for electricity were 6% of total electricity consumption from renewable electricity in 2005 and 9% in 2010.

In 2005, in total 113 turbines were installed with a total capacity of 153 MW and 44 turbines with a total capacity of 14 MW were removed. The net installed capacity in 2005 was 140 MW and the total installed capacity at the end of 2005 was 1,213 MW. In 2005, in total 13.6 MW, being 66 turbines with an average capacity of 206 kW were decommissioned. Of the decommissioned turbines in 2005, 20 with a total capacity of 4.1 MW were replaced with 17 turbines with a total capacity of 19 MW. The net repowering effect was 15 MW.

During discussions in Parliament in 2005, the Minister of Economic Affairs confirmed that national targets are 5% of total energy consumption from renewable energy in 2010 and 10% in 2020. The partial targets for electricity are 6% of total

Table 1 Key Statistics 2005: The Netherlands

Total installed wind generation	1,213 MW
New wind generation installed	140 MW
Total electrical output from wind	2.0 TWh
Wind sector turnover	≈168 million €
Wind generation as % of national electric demand	1.7%
Target:	6.0% RE electricity in 2005

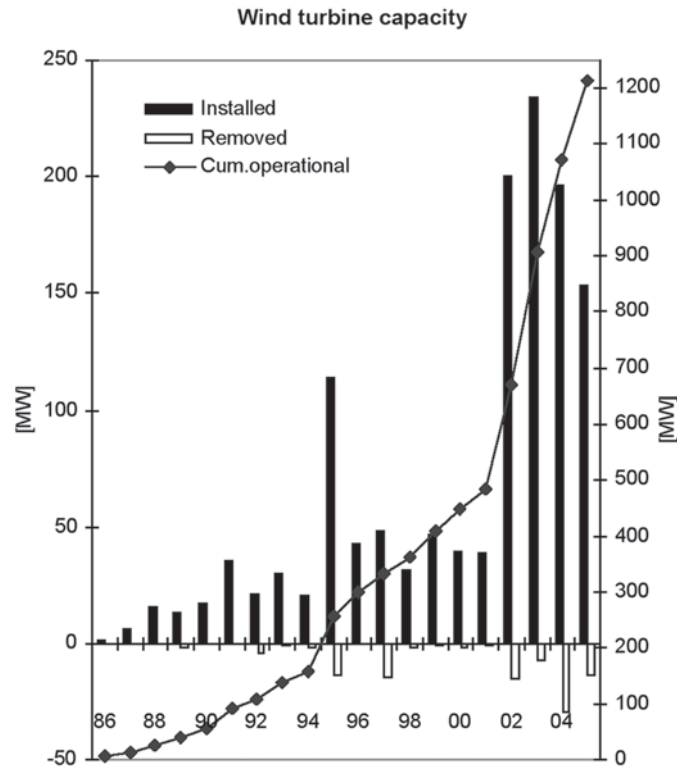


Figure 1 Installed, removed, and cumulative wind turbine capacity in the Netherlands.

electricity consumption from renewable electricity in 2005 and 9% in 2010.

The specific target of 6,000 MW of wind energy offshore was changed into an aspiration.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Based on an estimated average investment cost of 1,100 €/kW the total investment in 153 MW of new wind capacity was 168 million € in 2005.

On 29 December 2004, the Minister of Transport, Public Works and Water Management published the policy rules to issue building per-

mits for the construction of wind farms under the Public Works and Water Management Act. During 2005, up to May 17, seven initiators supplied 57 inception memoranda to the Ministry for a wind farm location (3). For a complete updated list see http://www.senternovem.nl/Offshore_Wind_Energy/locations_and_licences/licence_system.asp. The initiators selected locations with a total surface of 2,200 km² on which, dependent on the layout, the installed capacity can be between 17.5 GW and 21.5 GW. However, the overlap in locations is about 1,200 km². That is why the installed capacity can at the most become around 8 GW to 10 GW. If realized, this wind capacity could yearly generate approximately 24 TWh to 29 TWh of electricity. This is roughly 20% to 25% of the present electricity consumption in the Netherlands.

Table 2 Wind generated electricity, avoided fuel, and national energy consumption

	Wind generated electricity [GWh]	Primary energy savings [PJ]	National electricity consumption [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	114,667
2005	2,036	16.85	117,658
CBS	* 2005 CBS estimate (2)		

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

The financial closure and signing of contracts for the Near Shore Wind Farm took place on 31 May 2005. The Egmond Building Combination (EBC) will build and transfer the wind farm to NoordzeeWind a legal entity of Shell Renewables and NUON. Shell and NUON finance the 200 million €, 108-MW wind farm on balance. The EBC consists of Ballast Nedam and Vestas. The contract includes a 5-year maintenance and performance guarantee.

The planning foresees the installation of the foundations in April 2006, and the installation of the

last turbine in October 2006. The end of October 2005 the tubes/pipes for the dune crossing of the electrical cables were installed at the beach of Wijk aan Zee (Figure 2).

The average installed capacity per turbine increased sharply from 671 kW in 2001 to 1,301 kW in 2002. This marked the introduction of wind farms of 5 to 20 MW with multi-megawatt turbines in the Netherlands. It decreased again to 1,266 kW in 2003 and 1,203 kW in 2004 and in 2005 rose again to 1,358 kW. The average hub-height seems to have stabilized around 60 m and the installed swept area per unit of power at around 2.3 m²/kW. See Figure 3.



Figure 2 Tubing for cables Offshore Wind farm Egmond aan Zee. Photo courtesy NoordzeeWind.

Table 3 Distribution of new wind turbines by manufacturer				
Manufacturer	Turbines [-]	Installed		Rotorarea [m ²]
		[MW]	[%]	
Vestas	82	101.6	66	237,967
Enercon	22	36.8	24	73,872
GE Wind	6	9.8	6	30,223
Siemens	2	4.9	3	12,011
Bonus	1	0.3	0	755
Total	113	153.4	100	354,828

Of the wind turbines installed in 2005, the Vestas' share was 66%. See Table 3. Enercon's share of 26% in 2003 fell to 4% in 2004 and went up to 24% again. Nordex's share has gone to zero in 2005. GE Wind and Siemens make up the rest.

New turbine prototypes at the Energy Research Center of the Netherlands (ECN) test field in the Wieringenmeer were the GE Wind 94 m diameter 2.3 MW with a hub-height of 100 m and the Siemens 104 m diameter 3.6-MW turbine with a hub-height of 80 m. This also is now the largest wind turbine in the Netherlands.

Harokasan, a Japanese investment company with involvement of Japan Steel, took over bankrupt Zephyros. Production facilities are at Den Helder and producing 2-MW turbines for Taiwan.

Two wind farms, with an installed capacity of 10 MW to higher were installed in 2005. The largest is 12 MW, with 6 Enercon 2-MW, 71-m diameter turbines at Delfzijl, the first turbines of this type in the Netherlands. The farm at Amsterdam-Westpoort has the first three turbines of the Vestas V90.

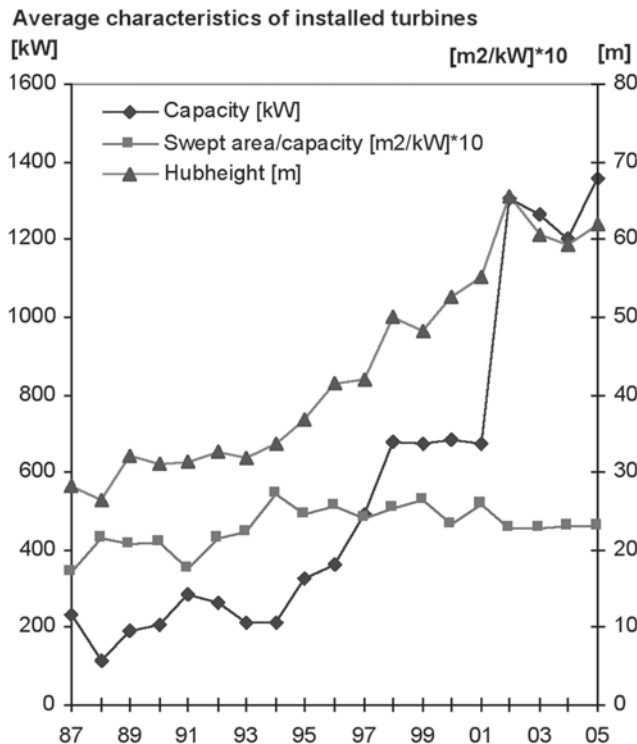


Figure 3 Annual average characteristics of installed turbines in the Netherlands.

3.3 ECONOMIC DETAILS

Please refer to the IEA Wind Energy 2004 Annual Report, pages 171 to 173 for a detailed description of trends in investment and financing.

4.0 NATIONAL INCENTIVE PROGRAMS

Please refer to pages 162 and 163, IEA Wind Energy 2004 Annual Report, for a description of support initiatives and market stimulation instruments.

The Ministry of Economic Affairs evaluated the MEP scheme in November 2004 and published the new tariffs for the period 2005 to 2007 (see IEA Wind Annual Report 2004). For offshore wind, a production subsidy of 0.097 €/kWh is available for an operational period of 10 years.

Members of Parliament voiced their concerns about the costs of offshore wind to society and asked for a detailed social cost/benefit analysis of offshore wind energy.

On 10 May, the government announced an immediate standstill for new offshore wind production subsidies in light of the possibility of over achieving the 9% sustainable electricity target for 2010. The Minister of Transport, Public Works and Water Management also suspended accepting and processing applications.

The energy report 'Now for later' of 8 July emphasizes an energy conservation goal of 1.5% per year. The target of 10% renewables in 2020 remains but is not specified per option.

The Minister sent social cost/benefit analyses to Parliament on 19 September 2005. Central in the

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Table 4 Size of wind plants installed in 2005

Wind farms > 5MW	Manufacturer	Turbines [-]	Height [m]	Diameter [m]	Capacity [MW]	Swept area [m ²]
Delfzijl	Enercon	6	85	71	12.0	23,755
Rotterdam	Vestas	5	67	80	10.0	25,133
Willemstad	Vestas	11	44	52.2	9.4	23,541
A'dam-Westpoort	Vestas	3	80	90	9.0	19,085
R'dam-Dobbelsteen	Vestas	3	78	92	8.3	19,943
Herkingen	Vestas	3	80	80	8.3	15,080
Waalwijk	GE Wind	5	85	77	7.5	23,283
Culemborg	Vestas	3	80	80	6.0	15,080
Lelystad	Vestas	6	70	54.5	6.0	13,997
Zutphen	Enercon	3	85	71	6.0	11,878
Various < 5MW	Danish/German	-	-	-	70.8	163,300
Total					153.1	354,073

study was the finding that building 6,000 MW of offshore wind will only become economically viable with gradual investments under the so-called Strong Europe scenario (with strict climate policy) until 2030. This finding was amongst others based on assumptions that costs decrease over time, fuel prices remain high, and emission prices for CO₂ are higher or discount factors low.

The Minister of economic Affairs agreed with the national parliament on a policy effort for a maximum of 700 MW of offshore wind in 2010. This means the possibility for another 480 MW on top of the 100-MW Near Shore Wind farm and the 120-MW wind farm Q7. The minister further announced that for those 480 MW the MEP production subsidy will be tendered for the lowest kWh price.

5.0 R&D ACTIVITIES

5.1 NATIONAL R&D EFFORTS

EOS Long Term (EOS-LT) supports researchers with promising plans that in the long term lead to a sustainable energy supply. The EOS-LT R&D program aims at research that strengthens the Netherlands knowledge position and frees

the way for the introduction of innovative energy technologies. One of the themes of the program is 'Offshore wind generation and electricity grids'. This theme has the four focal points:

1. knowledge for the design of wind conversion offshore with the objective of making wind conversion offshore competitive with fossil based generation in 2020
2. integration of 6,000 MW of offshore wind in the Netherlands electricity grid with the objective of it being economic, reliable, and stable.
3. technical transition of electricity networks
4. management and maintenance of electricity networks.

In 2005, under this program about 2 million € was granted to two wind projects with the main contractor of ECN. The first one is Rotorflow I a projects that researches new methods for the calculation of aerodynamic loads that combine the computational efficiency of Blade Element Impulse methods while aiming for the accuracy of Computational Fluid Dynamics. The second one is Sustainable Control that aims to reduce turbine costs through Optimized Feedback Control; Fault Tolerant Control; Extreme Event Control, and 'Optimal Shut-down Control'.

5.1.1 INTERESTING COMPLETED RESEARCH

In 2005, ECN completed the wind resource atlas of the Dutch part of the North Sea. (Figure 4) ECN made the atlas by combining data from two sources: the numerical weather prediction model Hirlam and the meteorological stations at the North Sea. In the final report, the public maps with the mean wind speed at 60, 90, 120, and 150 meter above sea level are presented. The local wind resource anywhere in the Dutch part of the North Sea is sufficiently described by the wind resource

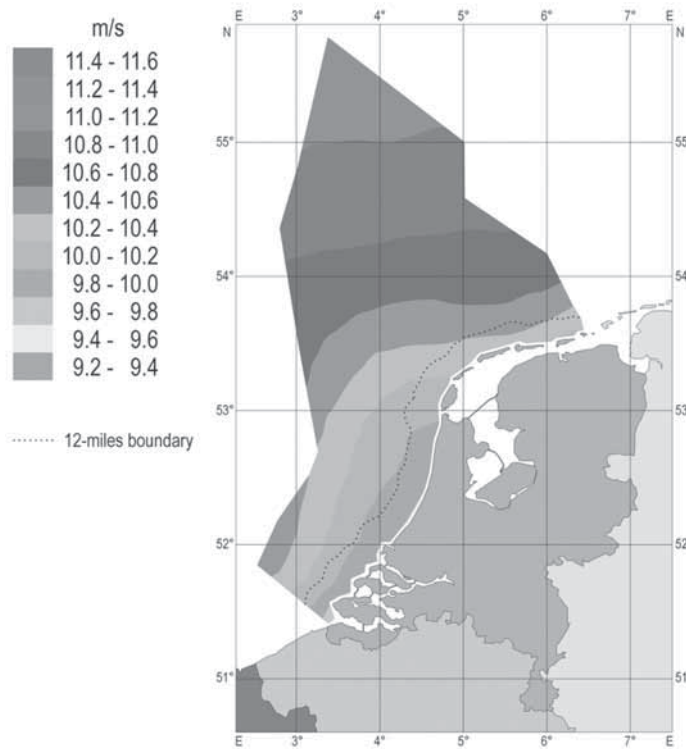
in one of five characteristic locations. The wind resource in such a location is expressed in terms of the wind speed and wind direction distribution, the turbulence intensity distribution, and the stability class distribution. The formats for these distributions are presented. The tables with the mean wind speeds and with the distributions are confidential but can be obtained from ECN.

Delft Technical University conducted Model Testing of a Motion Compensated Platform for Access to Offshore Wind Turbines. This gave a

Mean Wind Speed at the Netherlands' Exclusive Economic Zone (NEEZ)

Period: 1997 - 2002

Height: 120 m above mean sea level



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Supported by the Programme "Duurzame Energie in Nederland" as operated by SenterNovem for the Dutch Ministry of Economic Affairs

Figure 4 NL EEZ offshore wind map.

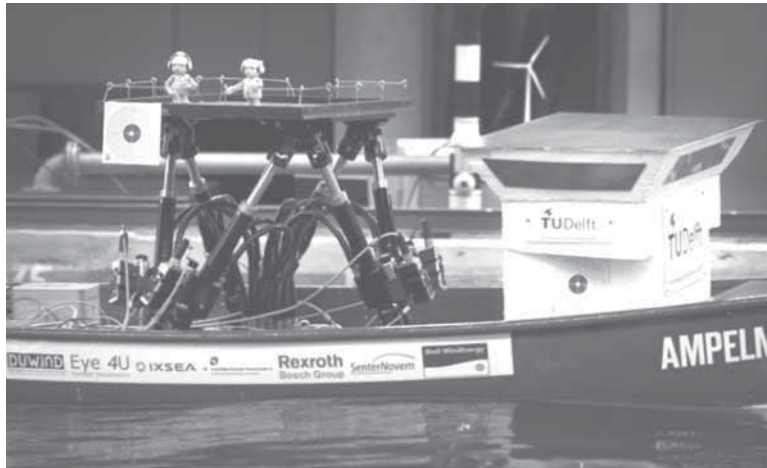


Figure 5 Model testing of Der Ampelmann Delft Technical University. Photo courtesy Delft Technical University.

proof of principle for an interesting new concept coined Der Ampelmann. (Figure 5)

Offshore access methods currently available are dangerous, very expensive or limited to calm weather conditions. To make offshore access safe, easy, and continuously possible, the Delft University of Technology invented the “Ampelmann”. This system consists of a transfer platform on six hydraulic legs, a Stewart platform often used for flight simulators, mounted on a vessel. By measuring the vessel motions and real-time control of the actuators in the platform, the top plate becomes stationary compared to the fixed world.

To prove this concept, the Delft University of Technology made a test plan and had custom-made software written, while manufacturers provided a motion sensor and a small size Stewart platform available. The Ampelmann system was mounted on a small boat, creating a scale model of what the actual system should look like on an offshore supply vessel. The boat was tested in a wave basin leading to good results with wave frequencies between 0.2 and 0.55 Hertz. This is equal to wave periods between 1.8 and 5 seconds, which are the wave periods that cover about 90% of all sea states in the Dutch North Sea.

The proof-of-concept of the Ampelmann was a success, but moreover, a great deal was learned about the system’s sub-components and the software, and the system was enhanced to perform in a wider range of frequencies.

5.1.2 INTERESTING NEW RESEARCH EFFORTS

In a series of projects with names like ‘Fyndfarm’, ‘Heat & Flux,’ and ‘Controlling Wind,’ ECN is conducting research that :

- tries to describe wind farm boundary layers,
- the effects that wind farms have on roughness length,
- the reduction of wind speed within a wind farm
- and the mutual influence on wind speed of large offshore wind farms,
- measures to mitigate reduction of wind speed due to these effects.

ECN studies all these effects with the aid of model wind turbines in the boundary layer wind tunnel of TNO in Apeldoorn (Figure 6).

5.2 COLLABORATIVE RESEARCH

EGMOND POLICY DECLARATION

The Egmond Policy Declaration (5) is the leading

document for work on offshore development in the Netherlands. As a follow up on that declaration the Copenhagen Policy Seminar on Offshore Wind Power produced the Copenhagen Strategy 2005 (6). Amongst other things, it recognized the importance of R&D for cost reductions of offshore wind energy. In relation to a Technology Platform for Wind Energy, the participants recognized the Strategic Research Agenda for the European Wind Energy Sector up to 2013. Long-term R&D priorities include: wind resource estimation and mapping; availability of robust, low maintenance offshore turbines; state of the art laboratories for accelerated testing of large components; planning and design processes for Trans-European grid with sufficient connection points to serve future large-scale wind power plants; and research and development of storage systems. Short-term operational measures include: standards and certification; acceptable operational and technical system integration measures; communication strategy as to the findings on impacts from wind farms on the eco-system, targeted at the general public and policy makers. Recognition

of this Strategic Research Agenda in the Egmond Policy Declaration and in the Copenhagen Strategy 2005 have now made these R&D priorities part of the Netherlands R&D strategy.

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Author: Jaap L. 't Hooft, SenterNovem, Netherlands agency for innovation and sustainability, the Netherlands.

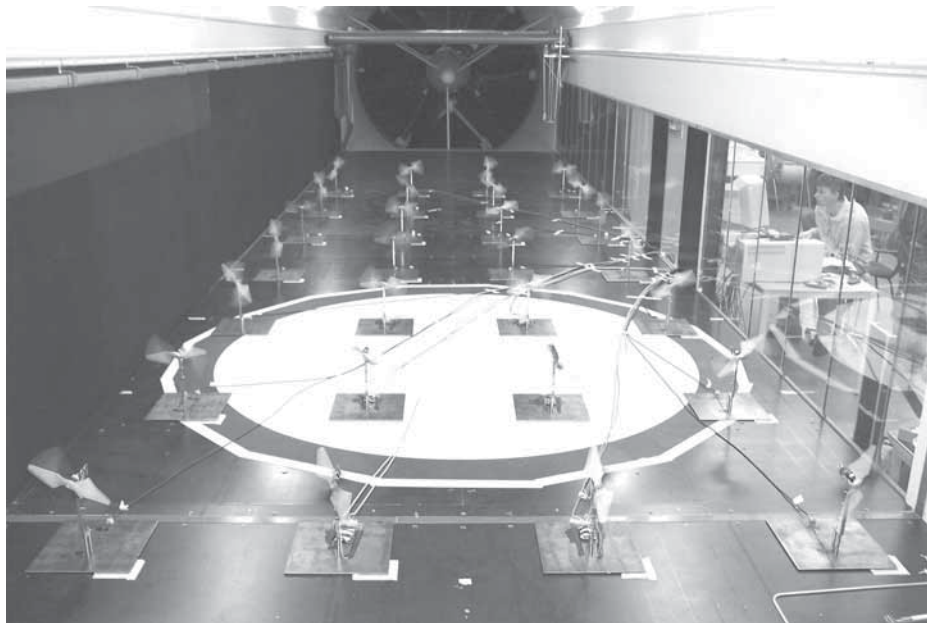


Figure 6 Model wind turbines in the boundary layer wind tunnel of TNO in Apeldoorn. Photo courtesy ECN.



NATIONAL ACTIVITIES



CHAPTER 23 NORWAY

1.0 INTRODUCTION

In 2005, the installed wind power capacity in Norway increased from 160 MW to 270 MW.

In Norway, the interest in wind power, as a commercial source of electricity is high. By the end of 2005, there were project plans for over 8,000 MW in Norway. However financing and public acceptance remain substantial hurdles to overcome for the installation of wind turbines. The price for long-term future electricity prices has risen during the last year, but still the price is not strong enough incentive to spur new investments in wind energy.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

2.1 STRATEGY

Key features of Norwegian energy policy strive to improve energy efficiency, create more flexibility in the energy supply, decrease dependence on direct electricity for heating, and increase the share

of renewable energy sources (other than large hydropower) in the energy supply mix.

When the state enterprise Enova SF was established in 2001, the Norwegian Parliament set up an Energy Fund and indicated grants within a framework of up to 5 billion NOK (approximately 650 million €) over a ten-year period. Enova is managing the Energy Fund. Enova's objectives, adopted by the Norwegian Parliament in the spring of 2000, are:

- to limit energy use considerably more than if developments were allowed to continue unchecked;
- to increase annual use of water-based central heating based on new renewable energy sources, heat pumps, and waste heat of 4 TWh by the year 2010;
- to install wind power capacity of 3 TWh by the year 2010; and
- to increase environmentally friendly land-based use of natural gas.

Enova focuses its efforts on both the energy supply and the energy demand side, and the development and adoption of reliable methodologies for performance measurement and verification of results are high priorities.

In 2005, the production of renewable electricity was 9% larger than the electricity consumption. Since electricity production in Norway mainly comes from hydro power the share of renewable

Total installed wind generation	270 MW
New wind generation installed	110 MW
Total electrical output from wind	0.504 TWh
Wind sector turnover	NDA
Wind generation as % of national electric demand	0.4 %
Target:	3 TWh in 2010

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energy will vary considerably from one year to the next. It turns out that 2005 was a very wet year and with an average hydropower production, the renewable share of electricity consumption would have been 95%, of which 0.5% comes from wind power.

The renewable target set by the government is 90% in 2010. According to a statement from the government, this target corresponds with approximately 6 to 7 TWh new production capacity of electricity from renewable energy sources being introduced from 1997 to 2010.

2.2 PROGRESS TOWARD THE WIND TARGET

The interest for wind power is high and several projects have been notified. More than 1,100 MW has received concession. This indicates that the 3 TWh target can be reached by 2010, although it depends on effective economic incentives being put in place. In addition, projects totaling annual production of 25 TWh have been notified, including a 1,400-MW (4.5 TWh/year) offshore wind power project, suggesting substantial development also 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 energy production of 1.56 TWh/year (approx. 500 MW). By the end of 2005, approximately 230 GWh (68 MW) is under construction. In 2005, Enova signed contracts with two new projects which represent an estimated energy production of 400 GWh (Table 2).

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Wind power production 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, which 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 Norwegian-based manufacturer of large wind turbines (3 MW and larger) for use in Class 1 wind areas. The com-

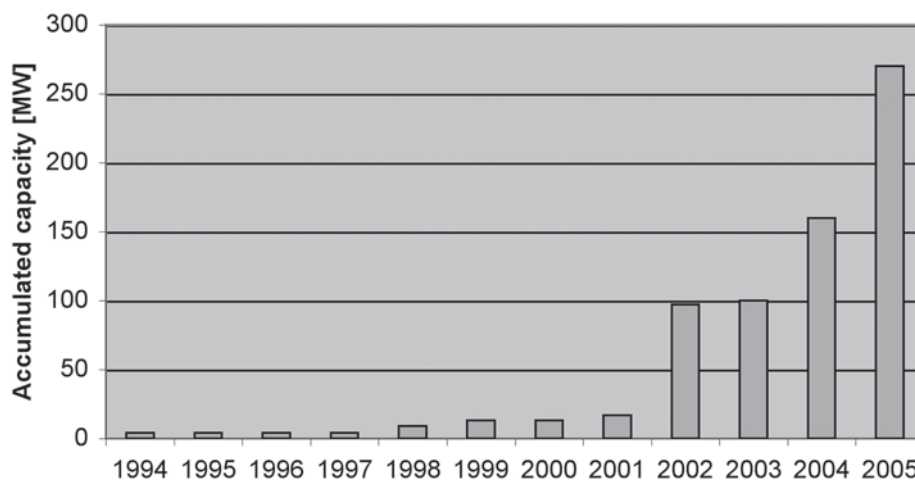


Figure 1 Installed wind power capacity in Norway.

Table 2 Granted wind power projects 2004-2005

Energy utility	Project	Estimated energy production (GWh/Year)	Investment grant (€)	Grant given
Statkraft Development	Kjøllefjord Vindpark	155.0	10,670,000	2004
Statkraft Development	Skallhalsen Vindpark	191.0	13,390,000	2004
Nord-Trøndelag e-verk	Hundhammerfjellet vindmøllepark	140.0	3,720,000	2004
TrønderEnergi AS	Valsneset Vindpark	35.1	3,810,000	2004
TrønderEnergi AS	Bessakerfjellet vindpark	155.0	12,410,000	2005
Nord-Trøndelag e-verk	Ytre Vikna Vindmøllepark	248.4	18,610,000	2005

pany has developed a 3-MW directly-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 2005 was in average 8,200 NOK/kW (1,000 €/kW), including infrastructure and grid connection. In some remote areas with favorable wind conditions, the cost of grid connection is too high for an economical development of wind energy. In addition, the capacity of the existing grid is a limiting factor many places and restricts the

size of the wind farms being constructed. Most of the 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 generating costs in the north, due to more favorable wind conditions in the north, does not make up for the additional cost of building new lines.

Estimates of production costs from sites with average wind conditions suggest a production cost of about 320 NOK/MWh (40 €/MWh), including capital costs (discount rate 6.5%, 20-year period), operation, and maintenance. During the last year, the spot market electricity price on the Nord Pool (Nordic electricity market place) has increased noticeably leading to the long-term expected price to be more than 300 NOK/MWh (40 €/MWh). Increasing electricity prices and more or less stable

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wind energy costs, make wind energy more competitive, and wind energy is now close to being able to compete on commercial terms.

Wind energy is, however, not competitive with the price of many new hydropower projects, which still is an option for new green power. Even though the resources are large, the development of hydro power is more controversial than wind power.

4.0 NATIONAL INCENTIVE PROGRAMS

The last Norwegian government had put forward a proposal to implement a green certificate model to support electricity from renewables.

A new market for green certificates will primarily stimulate new production from hydro and wind power plants. Other renewables (e.g. power from biomass) will hardly be able to compete. There is still a considerable amount of hydro power in Norway, which is cheaper to develop than wind power. However, due to many temporary hydro power deployment constraints, it is expected that the certificate market will contribute with 3 to 4 TWh new wind power in 2010 and 6 to 9 TWh in 2015, depending on the volume of the certificate market settled by the government.

The new government, initially supporting the green electricity certificate system, has now been sending unclear signals and created doubts as to whether the system will be implemented in due time. The reason is internal disagreement within the Center-Labor parties' coalition on whether all types of hydro power should be included in the system. Yet the new government has strongly declared its support for green electricity.

Since 2002, Enova has administered investment grants for wind power. In the white paper number 9 (2002-2003) Stortinget asked Enova to suggest an interim arrangement from the existing investment grant system to the green certificate market. In October 2004, Enova announced the interim

arrangement, an investment aid with a payback rule if the investor chooses to enter the certificate market. This arrangement was for wind power only. Enova offered up to maximum 25% investment grants for new wind farms. The following projects in Table 2 have been granted.

5.0 RD&D ACTIVITIES

The governmental research program for sustainable energy is called RENERGI. The budget for wind energy R&D in 2005 was 8.9 million NOK (1.1 million €)

The wind energy R&D projects which have been approved for funding include:

- A study on the offshore wind energy potential
- Two different concepts for floating wind turbines are under development. The systems are designed for operating at deep water (200-800 m) areas. A prototype is expected to be operation during 2008.
- Several projects dealing with wind resource mapping and micrositing in complex terrain
- In 2001, in order to assist the development of wind energy in Norway, SINTEF Energy Research, the Institute for Energy Technology (IFE), and the university in Trondheim (NTNU), took a joint initiative to develop a test station for wind turbines at the western coast of Mid-Norway. The test site was opened summer 2005 and is now in operation. For more information : www.viva-test.no
- The wind/hydrogen demonstration project at Utsira has now been in operation for one year. The purpose of the project is to demonstrate how renewable energy can provide safe and efficient energy supply to isolated areas. The system is based on wind energy as the only energy source. Excess power is used to produce hydrogen which later on is used in a fuel cell. The system is developed and operated by Norsk Hydro ASA.

- **Wind and Hydropower Integration.** A study has been initiated to establish a set of data to represent the wind regime during the last 30 years to be compared with the hydrologic data we already have. The Norwegian energy supply system is characterized by a large share of hydropower. The system is then critically vulnerable to annual variations in precipitation and prolonged droughts. An increasing share of wind power gives topical interest to the integration of wind and hydro power, since both resources are naturally intermittent. The question is whether wind and hydropower can be complementary and combined to improve the overall performance, or whether they combined tend to increase

the problems of energy supply. The last eventuality can be the case if the occurrences of drought years generally coincide with periods of low mean wind speed.

6.0 THE NEXT TERM

By the end of 2005, project plans for over 8,000 MW of new wind capacity were underway and more than 1,100 MW had received concession. However the availability of financing and public acceptance will determine how many turbines are installed in the coming term.

Authors: Knut Hofstad, NVE and Viggo Iversen, Enova SF, Norway



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CHAPTER 24 PORTUGAL

1.0 INTRODUCTION

During 2005, Portugal reinforced the tendency shown during 2004 of high growth rate of wind capacity installation. Also visible was some simplification of critical administrative processes concerning the implementation of renewable energy projects and, for the second year in a row, Portugal almost doubled the installed wind power capacity.

In the following sections, a synthesis of the actual situation is presented with a main focus on the Portuguese current state of development and trends.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

2.1 STRATEGY

The bulk of renewable energy production in Portugal is supplied by hydropower, biomass/waste sources, and recently a steadily growing

capacity of wind power. In view of the country's very high dependence on imported fuels in recent years, the government has established a number of policies to increase the level of renewable energy development. The Resolution of the Council of Ministries (RCM) 169/2005 established that the energy policy of Portugal must reduce its external dependency. This gave rise to the establishment of new objectives to attain by 2013 for the electricity produced by RES in general, having the wind as its main component.

During 2005, new legislation was published (Dec. Law 33 -A/2005) concerning the applicable procedures and tariffs for renewable energy production, with a main focus on wind parks. Following the environmental change scenarios (projects SIAM and PNAC -National Plan of Climatic Changes RCM N.º 119/2004 in I SÉRIE-B N.º 179) and the Portuguese ambitious goals both on the installation of RES and on the European Union emissions reduction directive, studies were carried out in order to evaluate the sustainable wind energy resource in continental Portugal. As a result of several studies and the Portuguese government commitment on RES, a new national goal for wind power was established, and 5,100 MW of wind capacity will be available in the electric grid by 2013 to connect wind parks under the Governmental Resolution RCM 169/2005.

Total installed wind generation	1,060 MW
New wind generation installed*	529 MW
Total electrical output from wind	1.773 TWh
Wind sector turnover	154 million €
Wind generation as % of national electric demand	3.6 %
Target:	3,750 MW by 2010
* Operating	

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Until 2010, the Portuguese goal for the wind sector remains the installation of 3,750 MW of wind capacity. Since the new Dec. Law 33-A (published on 16 February 2005) will be applicable only for new grid connection permits issued after its publication date, the RES investments for installation in 2005 are still regulated by previous legislation and tariffs, mainly the legislation package published in December 2001 within the Decrees of Law 312/01 and 339-C/01; the first covers the technical and licensing procedures and the second the tariffs for renewable energy production. (Table 2)

2.2 PROGRESS IN 2005

In the beginning of 2005, the installed wind capacity in Portugal had only reached 15% of 2010 goals, and 2005 was considered a decisive year. If the country had the infrastructures to install 500 MW (approx.), the capacity goals for 2010 would be achieved, once the yearly growth rate at constant capacity was calculated to be 530 MW/yr from 2005 to 2010. This proved to be feasible. Approximately 634 MW of wind capacity was installed in 2005, 529 MW of which had grid

connection completed and full official operation permits issued. A full 27% of the capacity goals for 2010 were achieved by the end of the year. This constant growth rate is expected to continue for the next few years. However, in the 2007/2008 period, the limited production capacity of the manufacturers of wind turbines, as well as the necessity to construct new transmission lines (that traditionally face very slow environmental impact assessments) may still affect the full achievement of the national goals.

The accumulated wind capacity and number of turbines installed and operating in Portugal by 31 December 2005 are presented in Table 3.

Due to the high growth rate of the wind sector in Portugal, it should be noted that, although a large number of wind turbines were already installed in wind parks by the end of 2005, they were contractually still under test or commissioning phase. To highlight that fact, Table 3 shows both the installed and fully operational data about the wind sector by December 2005.

In 2005, the electrical energy produced by wind parks was 1,773 GWh, according to the statistics

Table 2 Objectives for national planned capacity in 2010 and 2013 compared to status in 2005

RES type	Operating in 2005 [MW]	Goal 2010 [MW]	Goal 2013 [MW]
Wind	1,060	3,750	5,100
Small Hydro (<= 10 MW)	272	400	400
Biomass	12	150	150
Biomass (with cogeneration)	345	n.a.	n.a.
Solid waste	88	130	130
Biogas	7.1	50	50
Ocean	0.5	50	50
Photovoltaic	2.3	150	150
Eq. Solar thermo (0.7 kW = 1m ²)	193	700	700
Large Hydro (>10 MW)	4,476	5,000	5,000
Geothermal	18	n.a.	n.a.
Total	6,474	10,380	11,730
Source: DGGE, INETI			

Wind capacity trend (1994-2010)

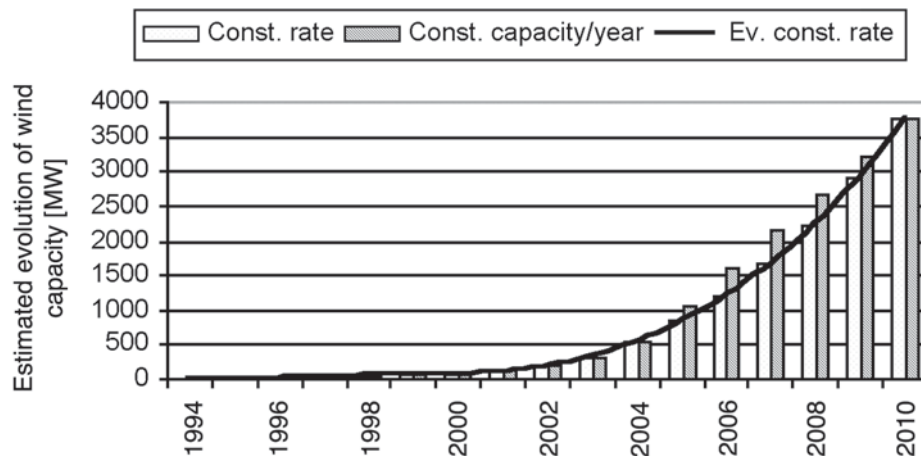


Figure 1 Trend of the wind power capacity installation towards the 2010 national targets.

of the official energy board, DGGE - General Directorate for Geology and Energy, for the continent and the estimated production values for the Azores and Madeira archipelagos.

Uncorrected by the date of entry under industrial production this production would give about 1,764 hours of production at nominal power. Introducing this correction, the value for this equivalent parameter is 2,362 hours of operation at equivalent to nominal power. Figures 2 and 3 show respectively the evolution in the capacity installation and the wind energy production. Figure 4 depicts the location of wind parks in continental Portugal.

A rate of growth of approximately 118% was observed in 2005, significantly higher than in the

previous years, after steady growth was initiated in 1999.

A representative number of wind park projects reached their final installation phase during 2005, enabling the installed (and commissioning phase projects) capacity to more than double. The rate of development for the last ten years is displayed in Figure 5.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

During 2005, the unit cost of wind turbines remained constant with the actual mean cost of the conversion equipment, per installed kW, varying

	Wind Capacity [MW]		Total number of wind turbines [turbines]	
	installed	operating	installed	operating
Continent	1,149	1,043	717	672
Azores	7	7	28	28
Madeira	10	10	43	43
TOTAL	1,165	1,060	788	743

NATIONAL ACTIVITIES

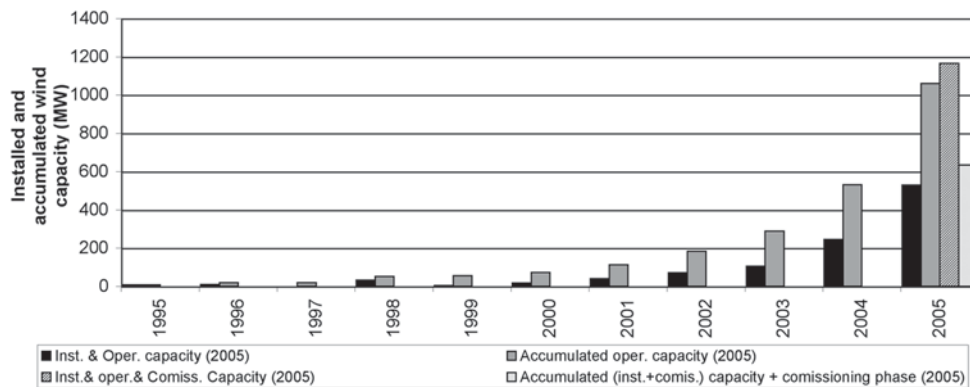


Figure 2 Installed and accumulated wind power capacity (1995-2005).

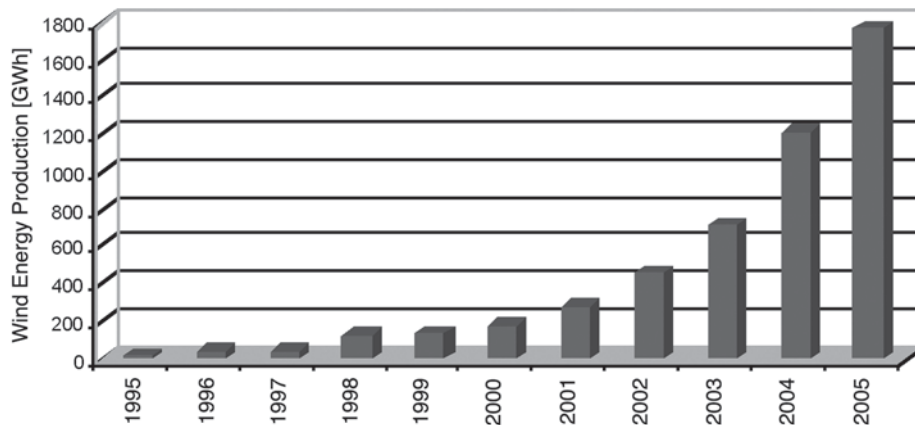


Figure 3 Wind energy production (1995-2005).

in the range from 650 € to 950 €, depending on the country of origin of the turbines, its individual capacity, and the ratio of this capacity to the turbine diameter. The effects of the sector “learning curve” on the unit cost reduction has not been as visible in Portugal as in other countries, due to the tendency to install large wind turbines, sometimes equipped with the larger available rotors, thus with higher individual costs than smaller units.

The major constraints in Portugal, as in 2004, and which are not exclusive of wind park projects, remain the excessively bureaucratic and long authorization system to obtain all the different permits required to install and operate a wind park. In some sites such as in environmentally

protected areas, it may take from 4 to 5 years until the first permit is issued to begin construction. The permits required to develop a wind park that tend to be more difficult (and take longer) to obtain continue to be related to the environmental institutions.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

In 2005, about 290 wind turbines were installed in Portugal with individual capacities ranging from 0.6 to 3 MW. The shares of installed power by wind turbine manufacturer and wind park developer are displayed in Figure 6.

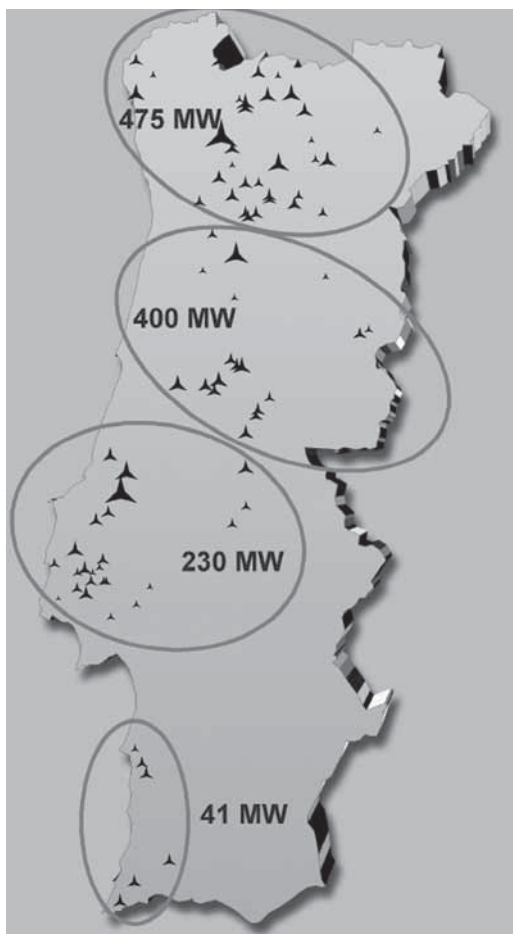


Figure 4 Location of wind parks in Portugal.

According to REN – Rede Eléctrica Nacional, the Portuguese TSO - Transmission System Operator, by the end of 2005 the ratio between the wind power capacity installed and the total capacity was approximately 10%.

There is no industrial production of wind turbines in Portugal. However, there is incorporation of technology for the towers with three Portuguese manufacturers active in this field, and in what relates to electrical equipment, namely power transformers and wind park cabling.

The call for wind park grid connection opened in February 2005 and showed the government's clear objectives to create the needed conditions to develop an industrial cluster in Portugal. Although the initial call was reformulated in July 2005, those objectives were maintained and amplified, including incentives for technology transfer, industrial investment, and job creation in order to increase the social value of this form of renewable energy and distribute locally its externalities.

Actually, the industry in Portugal is mainly focused on tower production for the domestic and foreign markets with three factories currently active.

Operational experience has been good. During 2005, there was one reported serious fire in one

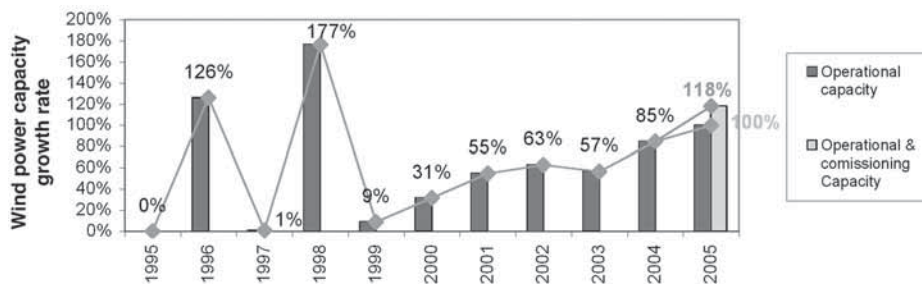
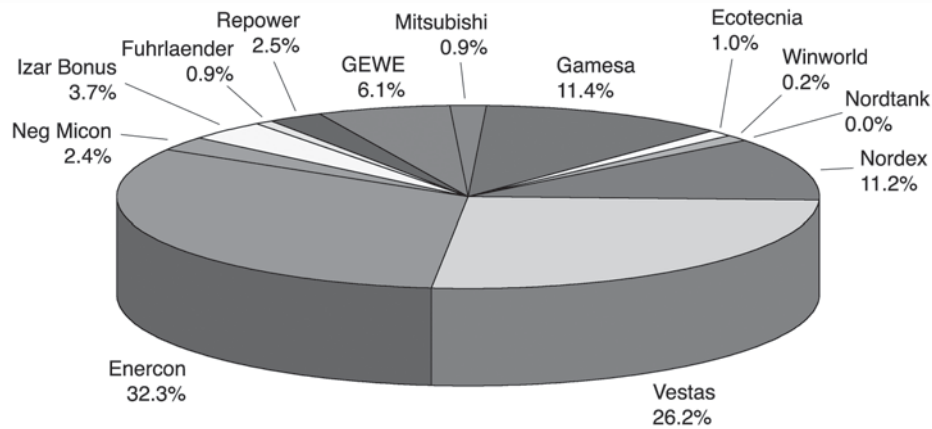
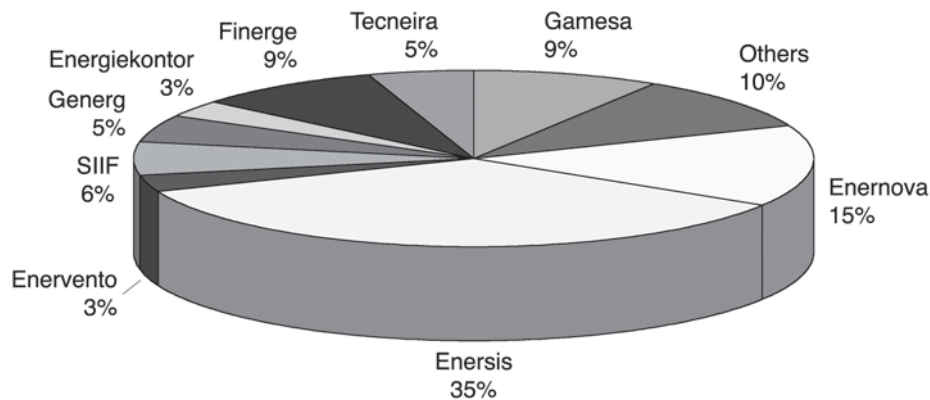


Figure 5 Wind capacity growth rate in the 1995-2005 period.

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a) by wind turbine manufacturer.



b) by wind park developer.

Figure 6 Share of installed capacity by (a) manufacturer and (b) developer.

of the wind turbines located north of Lisbon resulting in the replacement of all components except the lower sections of the tower. Another accident with one wind turbine in operation in the extreme south of the country resulted in the total loss of the turbine.

3.3 ECONOMIC DETAILS

The trends in the Portuguese wind sector investment are moving towards multi-megawatt wind machines due to high cost and the terrain orography. Although the cost structure of the wind park projects is considered a classified subject by

most private investors and financial institutions, the total costs in 2005 are in the range of 900 to 1,100 € per installed kW. Annual contracted costs for maintenance vary between 17 and 19 million €/MW/year.

During 2005, new legislation was published regarding renewable energies tariffs – (Dec. Law 33-A/05). The tariff trend for wind energy based production in the period 1998 to 2005 is depicted in Figure 7.

According to the data published by the Portuguese utility (EDP – Electricidade de Portugal) the net

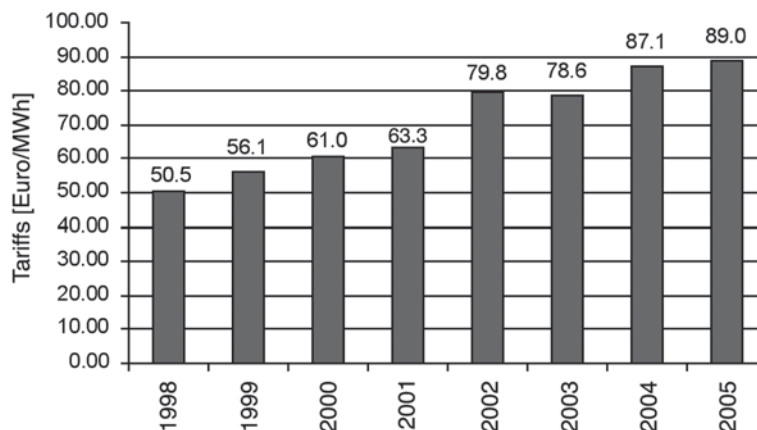


Figure 7 Evolution in tariffs for wind energy based production in the period 1998 – 2005.

electric energy consumption during 2005 was 47,971 GWh which represents an increase of 5.4% with reference to 2004 (4.7% when corrected by the temperature and working days). The wind energy contribution to the total consumption was, according to the Portuguese (TSO) REN, 3.61%.

4.0 NATIONAL INCENTIVE PROGRAMS

The installation of wind power capacity has been stimulated in recent years by a number of national policies, almost doubling its capacity in 2005 and reaching the level of 634 MW. The supporting policies have been provided to promote an increase of national renewable energy production. Following the publication of DL 33-A, in February 2005, an official call for wind park grid connection was opened by DGGE. For administrative reasons, this call was closed shortly after opening, had its main terms revised, and was reopened in July 2005 with a deadline for January 2006. Its evaluation will be programmed during 2006.

Among the changes introduced by DL 33-A with high impact on new wind projects is the reduction of applicable tariffs (~15% at the date of publication in February). This tariff reduction has

a practical direct consequence on the reduction of the national sustainable wind power capacity – that preliminary studies indicated to be about 6,000 MW. However, the main factor for wind park developers is the non-actualization of the electricity tariff with inflation, a factor that may drastically limit this sector's revenues for future projects and limits its deployment due to the lack of economical sustainability of new wind power investments.

In what concerns the interconnection of micro-generators and small distributed sources of electrical energy (up to 150 kW) to the low voltage grid, the applicable legislation during 2005 was stated in the Dec.-Law no. 68/2002, which defined mechanisms intended to speed up administrative and technical procedures associated with the implementation of small units.

Although the governmental agreements between Portugal and Spain regarding the constitution of the Iberian Market of Electric Energy (MIBEL) were decided in 2004 and officially ratified by both the Portuguese Assembly and Presidency in the Dec-n.o 19-B/2004 (in I SÉRIE-A N.o 93), the MIBEL is still not operating. The main reason for that is normally attributed to the postponing of some practical measures to merge the two systems

and operate an integrated market as well as the necessity to implement the agreed political decisions.

5.0 R,D&D ACTIVITIES

Portugal does not have a specific governmental program for sponsoring R,R&D activities related to renewable energies in general and wind energy in particular. Research in the wind energy area is funded by several programs under the general topics of Energy, Electrical, and Mechanical Engineering. There are various active research groups, mainly located in Lisbon and Porto.

The National Institute for Engineering, Technology and Innovation I. P. (INETI) is a part of the Ministry of Economy and Innovation is the most active and visible National Laboratory in this area. INETI activities and R&D projects in the wind energy field are partly financed by the national government.

The R,D&D needs and trends in what concerns wind energy in Portugal were identified in the following issues:

- Wind power production forecast;
- Wind resource assessment in complex terrain;
- Wind power production monitoring by economic dispatch and remote operation by clusters of wind parks;
- Local grid planning and wind park power quality assessment according to IEC/CEN standards;
- Wind/hydro production correlation and use of pumping facilities for regulation and storage of excess wind power production;
- Urban and constructed environment for wind power applications;
- Development of low-cost small wind turbines;
- Offshore wind power studies.

The projects currently underway are mainly oriented to the development of wind/hydro common regulation (wind for hydro pumping use under excessively high penetration), due to the high hydro capacity installed in this country and the

high correlation between availability (and sometimes excess of) hydro resource and wind during the winter months. This issue is being studied also by INESC in cooperation with the Portuguese utility (EDP).

5.1 NATIONAL R,D&D ACTIVITIES

In the North of Portugal (Porto) R&D activities are mainly carried out by research groups based at FEUP - Faculty of Engineering of the University of Porto and INEGI - Instituto de Engenharia Mecânica e Gestão Industrial and are part of the research network established by the Portuguese Foundation for Science and Technology (FCT), namely within the associate laboratory INESC Porto (Instituto de Engenharia de Sistemas e Computadores do Porto) and the Research Centre for Wind Energy and Atmospheric Flows (RCWEAF). During 2005, INESC Porto continued the research activities of project DIPTUNE (Nº POCTI /41614/ESE/2001). Development of techniques for controlling DFIG for the provision of primary frequency control and response to System Operator control requests was further pursued and successfully implemented under PSS/E simulation environments. As an outcome of this project, more papers were published in IEEE PWRS transactions.

5.2 COLLABORATIVE RESEARCH OFFSHORE SITING

INETI participated in the identification of sites for offshore wind parks installation in the Atlantic coast based on the construction of the Portuguese Wind Atlas. The methodology for this Atlas development was applied to represent the spatial distribution of the wind potential offshore, and the results were then introduced in a Geographic Information system, to enable the selection of areas of interest to install wind parks in coastal areas.

Unlike previous common public opinions, the preliminary results of this work (Figure 8) enhance some interesting areas for developing

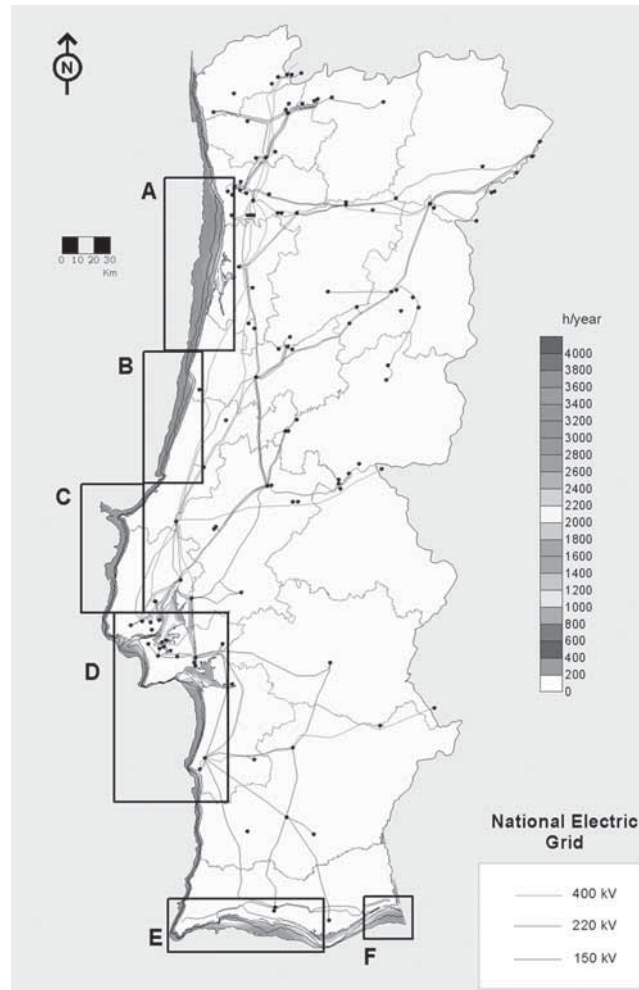


Figure 8 Offshore Wind Atlas preliminary results, with a 1,500-kW wind turbine for $h=60\text{m}$.

offshore wind parks. A more sophisticated study must be realized in order to deal with the presence of navigation channels, bridges, and other hydro-dynamical estuarine phenomena (in the case of area D).

6.0 THE NEXT TERM

Results obtained in the offshore preliminary studies lead INETI to start a new monitoring campaign in a coastal region, in order to perform a validation study on the Offshore Wind Atlas

for Portugal. Therefore a high resolution resource assessment campaign in the most relevant coastal areas of continental Portugal is being prepared with outputs “combined” from long term mesoscale simulations and microscale models to estimate a rigorous and highly accurate assessment for offshore wind power in Portugal. Although the sustainable wind resource is not as high as in the North of Europe due to the sharp bathymetry of the continental platform, some sites were already identified and are currently under study by potential developers.

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ACKNOWLEDGMENTS:

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REFERENCE

(1) According to General Directorate for Geology and Energy (DGGE).

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CHAPTER 25

SPAIN

1.0 INTRODUCTION

Wind energy in Spain continues the growth started several years ago. The addition of more than 1,600 MW to the electrical grid is evidence of the very good health of the sector and implies its consolidation as one of the more active industrial activities in the country.

The new power connected to the grid in 2005 is a little lower than that added in 2004 (during 2004 more than 2,000 MW of wind generation was connected to the electrical system). Several reasons could explain slower growth. One reason is administrative aspects: several delays in the permit procedures, availability of grid connection points, or new definitions of the strategic plans of the local authorities. Other reasons are the lack of high voltage power lines for the connection of wind farms.

The electricity generated by wind power plants represents nearly 8% of the total electricity demand with a total value of 236,000 GWh (data from the Spanish operator of the electrical system

REE). The total installed capacity at the end of 2005 was more than 10,000 MW, which makes Spain second in the world for amount of wind generation capacity. The main data of the year are summarized in Table 1.

During 2005, two main factors have contributed to the consolidation and stability of the wind energy sector:

- The new Spanish Renewable Energy Plan 2005-2010 (1) has the goal of meeting 30% of total electricity demand from Renewable Energy Sources at the end of 2010, including large hydro. The specific target for wind energy is 13,000 MW and is now expected to increase to 20,000 MW.
- The new support scheme for renewable energy was consolidated according the 436/2004 Royal Decree. The price paid for electricity generated by wind farms is guaranteed during the life of the installation and is strongly related to a very stable economic indicator, the Average Electricity Tariff (AET). These regulations also include a strong incentive to incorporate wind farms to the electricity market.

Wind energy is one of the contributors to the electricity supply in the country. Figure 1 shows electricity generation during 2005. The generation by wind farms was higher than by hydro during 2005 and contributed in a strong way to the sta-

Table 1 Key Statistics 2005: Spain

Total installed wind generation	10,028 MW
New wind generation installed	1,630 MW
Total electrical output from wind	20.236 TWh
Wind sector turnover	20,000 million €
Wind generation as % of national electric demand	7.78 %
Target:	20,155 MW by 2010

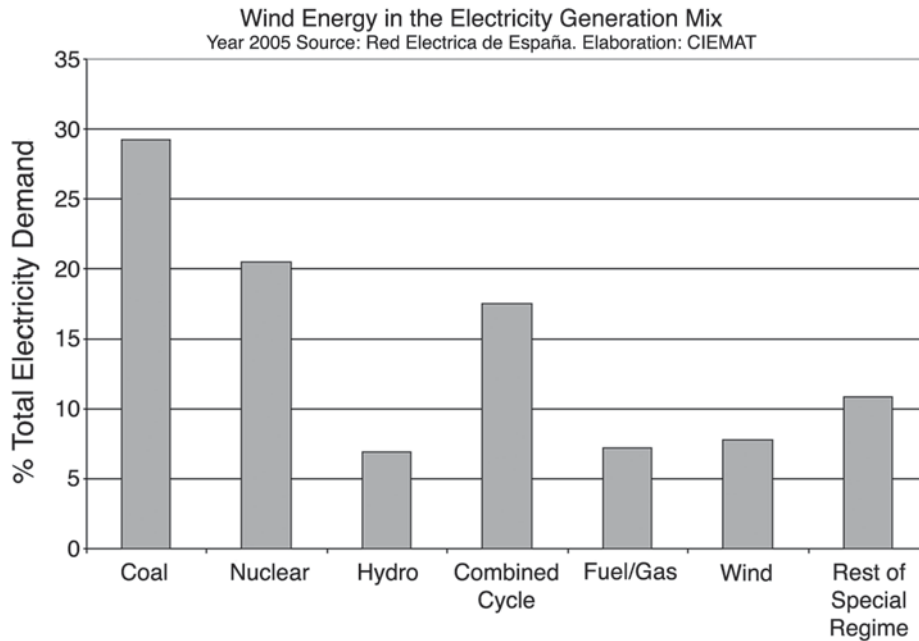


Figure 1 Wind energy and other generation sources for 2005.

bility of the system. It represents an additional clean and indigenous energy source and also represents an important industrial development. The wind industry in Spain is a solid sector with more than 400 enterprises involved. It has great potential and strong investments in R&D activities and job creation.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

An important development during 2005 was the approval of the “Spanish Renewable Energy Plan” (Plan de Energías Renovables en España PER) (1) for 2005-2010. This plan represents a revision of the previous one (the last revision was performed in 2002). The aim of this revision is to maintain the commitment to meet at least 12% of total energy use from renewable sources by 2010, while incorporating other indicative targets (29.4% of electricity generated from renewable sources and 5.75% of transport fuel needs to be met from biofuels).

Several reasons justify the revision of the plan: the primary energy consumption and energy intensity have grown faster than envisioned. This fact alone makes it necessary to revise the growth in renewable energy sources in order to achieve the 12% target for 2010. Also, following the approval of the previous plan two further indicative targets have been set. These need to be taken into account in the new Plan.

Wind energy is the area which has been developed most rapidly and is supported by a range of business initiatives in the market. Over the last three years there has been an average growth in installed generating capacity over 1,600 MW/year. According to the general targets of the Plan, the new objective for the wind energy sector will be increased by 12,000 MW of new power capacity over the period 2005-2010. This implies ending the decade with a total installed potential of 20,155 MW capacity. Figure 2 shows the power installed and planned in Spain and shows the joint objectives of the Renewable Energy Plan 2005-2010.

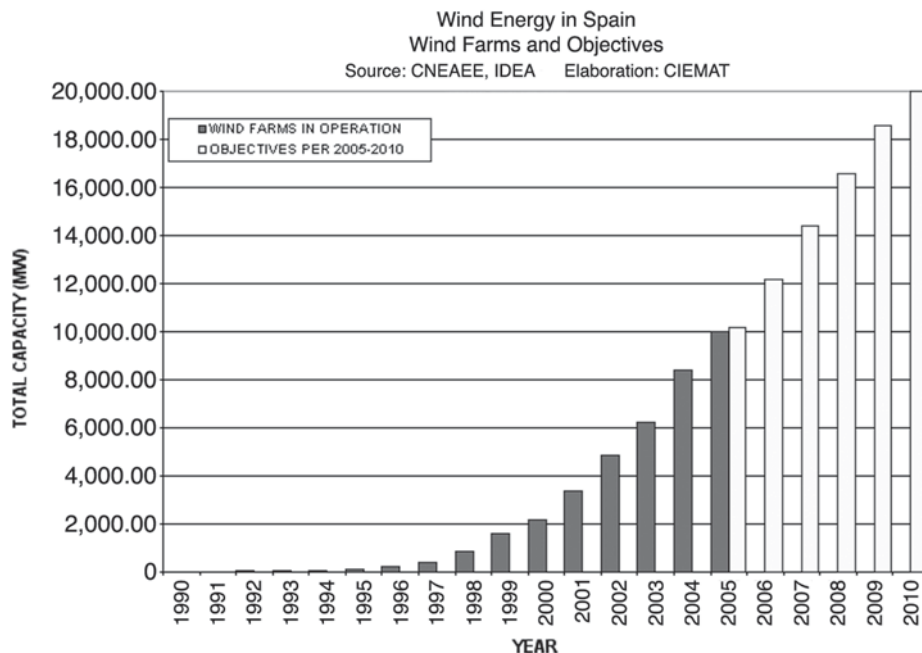


Figure 2 Wind Energy in Spain. Wind farms in operation and objectives for 2010.

The total value of the electricity generated by wind energy was higher than 20,000 GWh according to the data of “Red Electrica de España,” the Spanish Transmission System Operator, which represents around 8% of the total electricity demand in 2005. Figure 3 shows the evolution of electricity generation by wind and the percentage of the electricity demand from 1990 to 2005. With these values, wind power remains the fourth largest electricity generation technology in Spain, despite an increasingly important complement of small hydro power as a variable-cost renewable source.

The amount of electricity generated by wind was very constant during all the months of 2005 as is shown in Figure 4. This behavior represents some 2,100 hours of full production per year on average.

The rate at which new wind farms were put in operation slowed during 2005 mainly due to administrative delays and issues with access to grid connection. The industry has maintained a steady and sustainable growth which if continued

will easily allow meeting the Spanish Renewable Energy Plan goal of 20,155 MW by 2010.

Wind power has helped in decreasing fossil fuel imports, achieving savings of more than 728 million € during 2005, mainly due to the reduction in natural gas and coal purchases. Also the wind farms have represented savings for the Spanish economy of around 15 million tons of CO₂ in emission permits not purchased during 2005. This figure represents near 300 million € of saving, assuming the price of 20 € per ton of CO₂ emissions.

Wind power is at present the renewable energy that contributes the most to the energy supply in the country. About 75% of the contribution of the renewable energy sources comes from wind energy. Using biomass for electricity production was 3.8% of the renewable sources; solar PV was 0.22%; and mini-hydro including in the special regime was 12.7%.

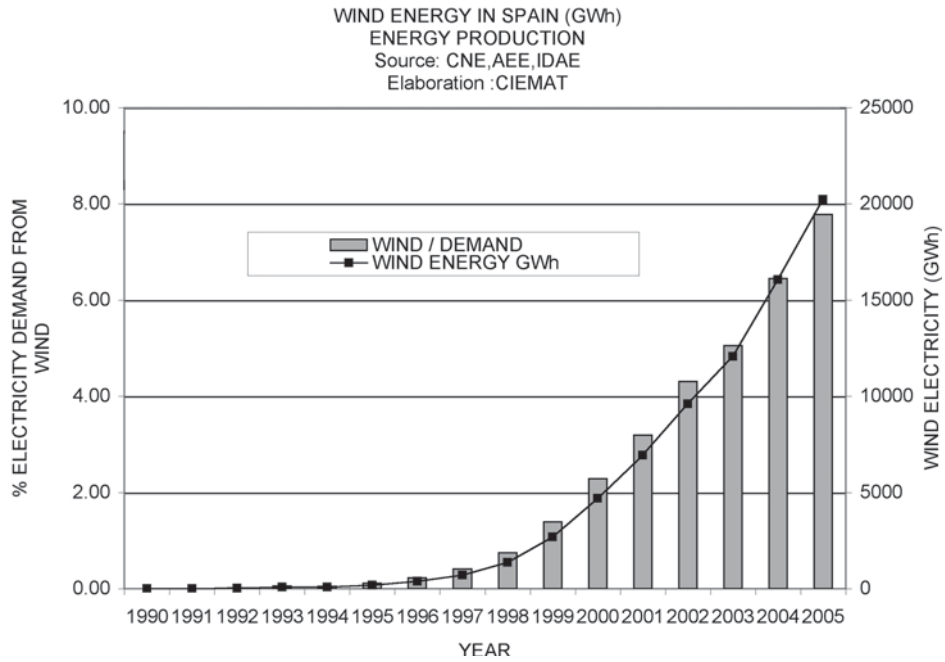


Figure 3 Electricity generated by wind farms.

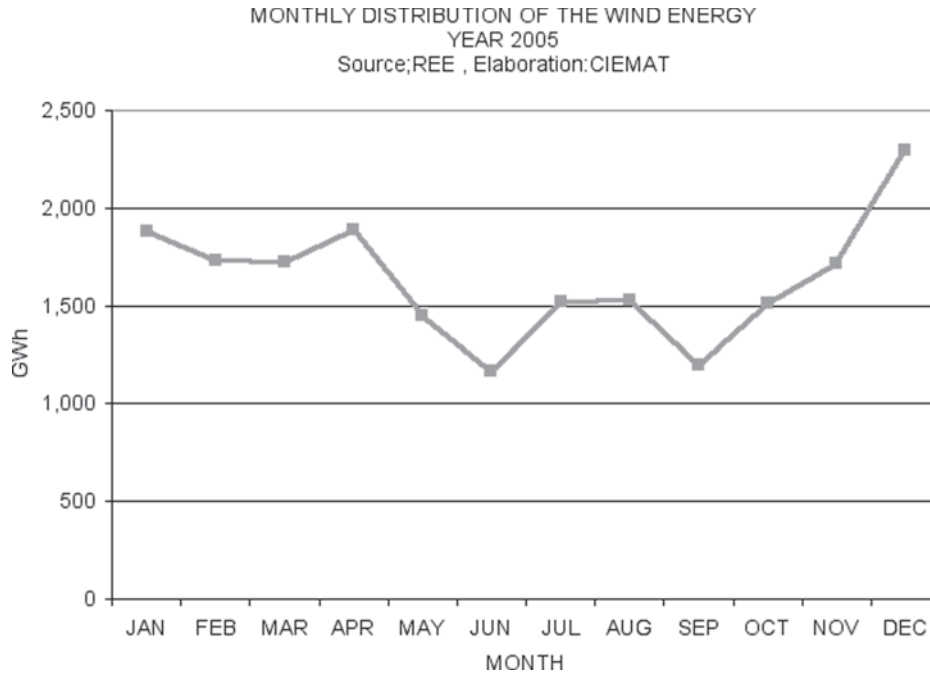


Figure 4 Electricity generated by wind, monthly distribution.

According to analysts of the sector, the situation for wind energy is optimistic for the fulfilment of the Spanish targets. The majority of the Autonomous Regions (that have responsibility for the regulation of wind installations) have made plans that imply a total installed potential of around 37,000 MW to a time horizon between 2010 and 2012. The most ambitious plans include: Andalusia (4,000 MW in 2010), Catalonia (3,000 MW in 2010), Castilla Leon (6,700 MW in 2010), Galicia (6,300 MW in 2010), Castilla La Mancha (4,450 MW in 2011), Aragón (4,000 MW in 2012), Canary Islands (890 MW in 2010), and Valencian Community (2,400 MW in 2010).

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Wind power development and promotion is a consolidated activity in Spain. The experience

obtained through the more than 10,000 MW in operation shows the maturity of the sector. So far, the promotion of wind farms has been an activity carried out by very big companies: utilities, finance entities, civil works, and industrial developers. The main reason for this is the administrative procedure used by the main part of the Autonomous Regions. It implies the approval of the Strategic Wind Energy Plan when an Industrial Plan is developed in the region. Several regional governments are interested in the promotion of small investors and municipalities, and new regulations for wind farms of less than 5 MW are being developed in several Autonomies.

The distribution of wind installations over the country is shown in Figure 5. The more active regions are Galicia, Castilla La Mancha, Castilla Leon, and Aragón. Catalonia and Andalusia have been seeing important growth during 2005, and Valencia recently approved an ambitious wind plan

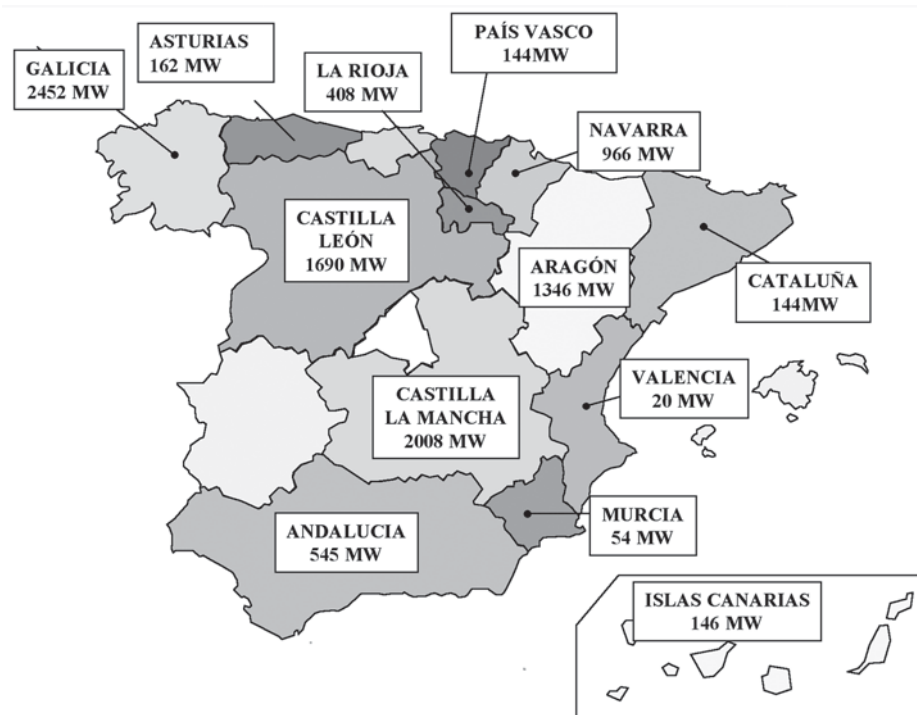


Figure 5 Regional distribution of wind farms.

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for more than 2,000 MW. (Figures 10 through 14 show various wind installations in Spain.)

Figure 6 shows the market share of wind farm developers at the end of the year 2005. As concerns companies, IBERDROLA represents 32.51% of the market, followed by ACCIONA at 10.47%. ENDESA is third with 8.66%, CESA (that is now part of the ACCIONA group) being fourth with 7.37%.

IBERDROLA is the second largest power utility in Spain. It has developed an impressive growth of wind capacity; the aim of the company is to reach a total wind capacity of 5,200 MW by January 2008. The company is very active in the promotion of new installations in several countries including Brazil, France, Greece, Italy, Mexico, Portugal, and the UK. The company operates a renewable energy operations centre (CORE) with the specific objective of improving the integration of RES in the grid.

ENDESA is present in the renewable energy and cogeneration sector in Spain through ENDESA COGENERACION Y RENOVABLES

(ECYR), which has an important presence in the sector. At year end, ENDESA was participating in Spain in Special Regime plants with a total power of 2,025 MW, of which 1,124 MW corresponded to renewable energy sources. It is also participating in cogeneration plants outside Spain, in Portugal, Colombia, and Mexico. During the period 2005-2009, ENDESA will build 2,224 MW of wind energy around the world.

ACCIONA is one of the principal players in the development, construction, operation, and maintenance of renewable energy facilities. It is focused primarily on wind power, in which it ranks third in the world in terms of installed capacity. It also develops projects and engages in considerable research in other areas such as bio diesel, solar, biomass, and small hydro. ACCIONA had installed 2,549 MW and had 249 MW under construction by 30 September 2005. It has built 91 windfarms for itself and other companies and operates and maintains almost all of these with nearly 3,000 turbines. The company has created its own 1.5-MW wind turbine on the basis of its experience as a wind energy developer and owner.

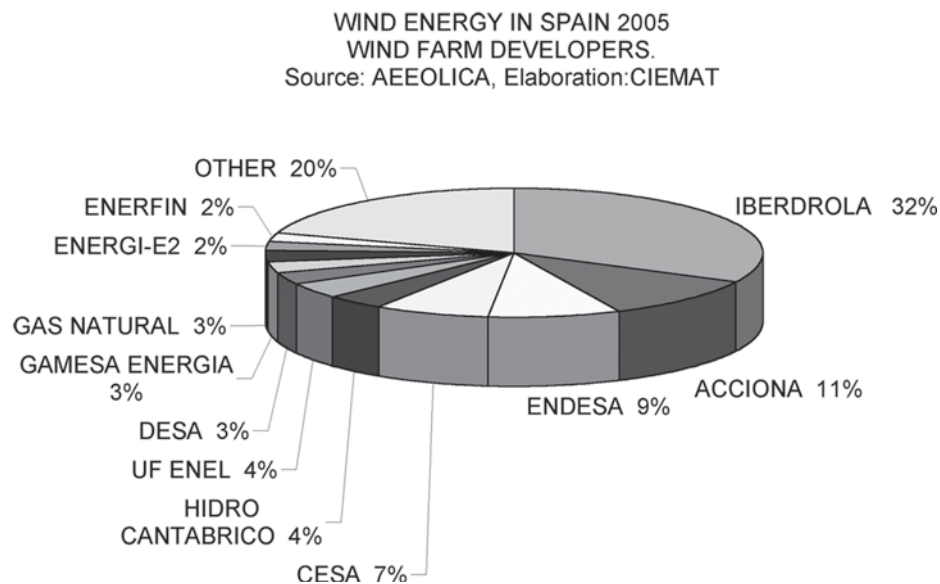


Figure 6 Wind farm developers in Spain.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

Regarding manufacturers, Gamesa (49.95%) remains the leader of the sector in Spain and has a predominant position in the total market. MADE, that is now part of the Gamesa Group, is the second manufacturer in the Spanish market. In total, more than 62% of the wind turbines installed in Spain are from the Gamesa group. Vestas (mainly with 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 a position with 8.5% of the total installations. General Electric (7.6%) and Siemens (3.3%) with the collaboration with the Spanish group Navantia are also present in the market.

It is important to note the consolidation of two new manufacturers: Acciona Wind Power (part of the Acciona group one of the major developers of wind farms in Spain) and MTORRES. MTORRES is active in the aeronautical field and has a 1.7-MW upwind, direct drive, multi-pole generator that is pitch regulated.

A number of new producers are entering the Spanish market. Figure 7 shows the share of power installed by manufacturers.

Wind turbines have grown in size. The average size during 2005 was around 1.3 MW; the average size for installations during 2004 was a little higher than 1 MW. In Figure 8 the increase in wind turbine size over the years is shown.

The wind farms that started the administrative procedure several years mostly used the 850-kW turbines for installations. In 2005, the 2-MW model is the size requested by the developers in order to obtain a better use of the land and a reduction of the visual impact for the same installed capacity.

3.3 ECONOMIC DETAILS

According to the data supplied by the Institute for the Diversification and Saving of Energy, the average cost of an installed kilowatt of wind energy in Spain is around 970 €; included in this value is all the required equipment for the operation of wind farms. During the last few years, the

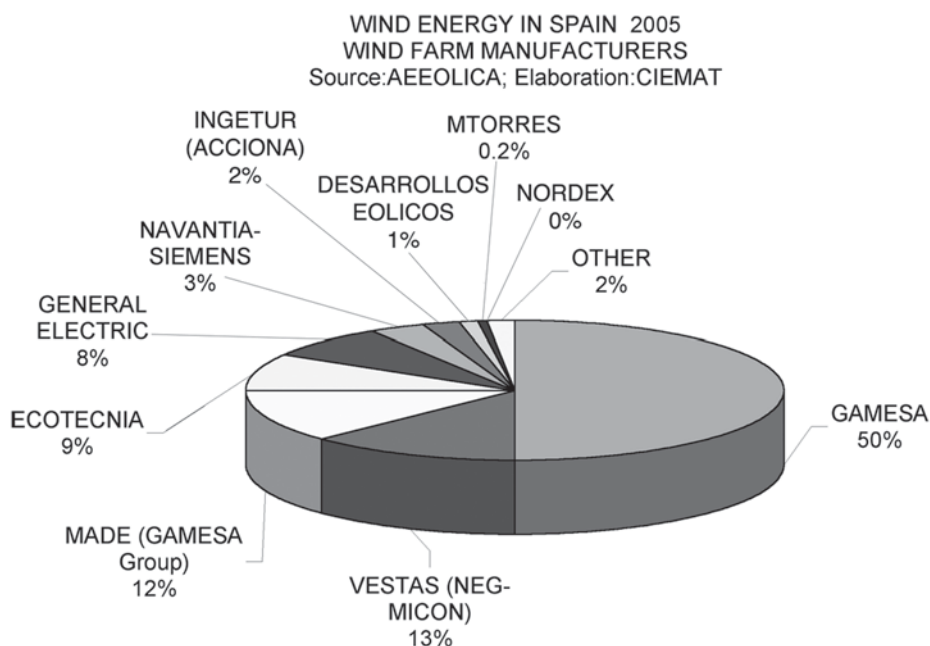


Figure 7 Wind farm manufacturers.

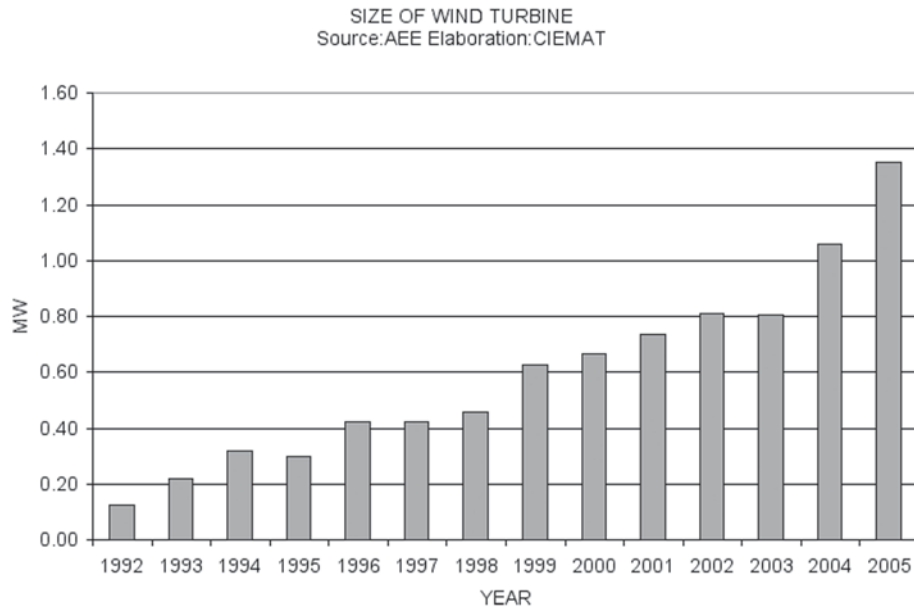


Figure 8 Wind turbine size.

installed cost has been rising slightly as a result of, among other factors, the increasing size of wind turbines. Of the total investment cost, the wind turbine represents approximately the 74%, the electro-mechanical equipment including the transmission line 17%, the civil work 5%, and the rest of components such as environmental impact study, promotion, engineering, and taxes 4%. Figure 9 shows the variation of the installation cost of wind energy in Spain from the middle of 1980 through 2005.

A study carried out by the Spanish Wind Business Association (AEE) about the history of wind farms in Spain shows an average cost of wind turbines of around 630 €/kW with a minimum value of 544 €/kW and maximum of 818 €/kW. The contribution of the electrical equipment and grid connection represent an average of 145 €/kW with variations of 19 to 212 €/kW depending on the difficulties of the grid connection. And the rest of the cost (civil work and other permissions, environmental impact studies, etc.) represents a value of 160 €/kW with variations from 83 to 225 €/kW. Within these values, the cost of an installed

kilowatt of wind energy in the typical Spanish wind farm until the year 2004 was around of 936 €/kW with a wide range of cost variation from 830 to 1,100 €/kW.

4.0 NATIONAL INCENTIVE PROGRAM

The promotion of renewable energy has been a stable national policy for several years. All political parties have kept similar policy regarding support to renewables. The main tools within this policy at a national level are:

- A payment and support mechanism established by the Parliament through an Act (Electric Act 54 /1997): Renewable producers are entitled to connect their facilities and transfer the power to the system through the distribution or transmission grid
- Renewable producers are entitled to receive in return remuneration
- The Renewable Energy Plan including Mid-Term objectives for each technology (Renewable Energy Plan 2005-2010).

WIND ENERGY IN SPAIN EVOLUTION OF INSTALLATION COST

Source: I D A E Elaboration: CIEMAT

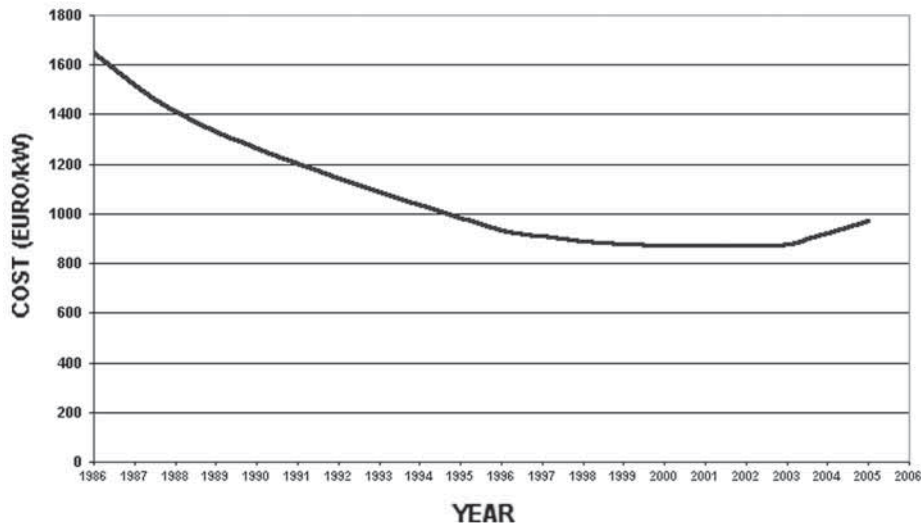


Figure 9 Evolution of installation cost.

Since March 2004, new legislation was put into effect for the payment of the electricity generated by Renewable Energy Sources connected to the grid, the Royal Decree 436/2004. During 2005, wind farm operators gained a lot of experience in selling electricity to the energy spot market. The application of this new scheme has had a positive effect on the implementation of new wind energy. The methodology makes prices more predictable, thus boosting confidence and encouraging private investment.

New payment options have been laid down. The owners of new renewable facilities have to choose between two options: to sell the electricity to the distribution company at a regulated tariff per kWh or to sell the electricity freely in the market through the market wholesale pool or through bilateral or term contracts. For the first option, the regulated tariff per kWh is between 80 and 90% of the Average Electricity Tariff (AET) plus a reactive power supplement and a supplement for continuity of the supply against voltage dips during the first four years of operation.

For the other option, for those operators who sell electricity freely in the market, the remuneration is as follows.

- The hourly price/kWh set in the electricity pool market
- Premium/kWh set out as a percentage of the AET
- An incentive for participating in the market
- A reactive power service supplement
- A capacity guarantee
- A supplement during the first four years of operation, for continuity of the supply against voltage dips.

In both cases, power production forecast obligations and deviation penalties are set out.

The AET is the total cost of the electricity system divided by the forecast demand of electricity from consumers. The AET is set and published every year by the government. The AET for the year 2005 was 0.073304 €/kWh. The AET for 2004



Figure 10 Wind turbines in complex terrain.

was 0.072072 €/kWh and the estimation is that it will be increasing between 1.4 and 2% every year at least until 2010.

An example application of the procedure is described in Table 2 that makes an evaluation of the electricity tariff for the wind farms during 2005 using the market option. It is important to remark that the management of the deviations between the forecast and the real production is one of the critical issues in the viability of wind farms.

5.0 RD&D ACTIVITIES

The Renewable Energy Plan 2005-2010 makes an exhaustive analysis of the technological innova-

tion required to achieve the objectives of the Plan. In the case of wind energy, the priority for the Spanish manufacturers is to make efforts leading towards the following goals:

- Advanced systems to control the quality of the power fed into the grid. In particular, to optimise 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 off-shore applications.
- Implementation of demonstration off-shore wind farms.



Figure 11 Wind turbines in Tarifa.



Figure 12 Educational tour of a wind farm.

The “National Energy Program for Scientific Research, Development and Technological Innovation (2004-2007)” centralized Spanish R&D projects in the energy sector. The target areas defined in the Plan for wind energy projects included such topics as:

- Development of infrastructures and tools for design of new wind turbines
- Improvement of efficiency, availability, reliability and maintenance, and security in operation
- Integration into the electric system
- Wind turbines designed for special sites
- New technologies and systems for the environmental integration of wind energy systems.

During 2005, a total of 18 wind energy projects were submitted to the program, covering all the target areas. A total of 12 projects were approved for a budget of 16.3 million €. The majority of the projects funded in this program are supported by the mode of soft loans. The projects were presented mainly by the industrial sector in collaboration with engineering companies, Research Centers, and Universities.



Figure 13 Wind farm in Central Spain.



Figure 14 Small wind turbine test site.

Table 2 Application of AET procedure 2005 for market option

	€/kWh
Average price of the pool	0.05573
Bonus over the average price	0.02932
Incentive for the market participation	0.00733
Capacity guarantee	0.00481
Cost of the deviations of production	-0.00585
Cost of the forecasting implementation	-0.00050
Cost of the commercialisation	-0.00080
Total payment for the wind generation	0.09004

The projects approved during 2005 covered the following topics.

- Develop wind turbine for hydrogen generation
- Develop and improve technologies of electrical connection of wind turbines
- Improve blade design and manufacturing of wind turbine blades
- Develop a multi-megawatt electrical generator
- Design a double electronic multilevel converter for distributed generation
- Design instrumentation and equipment for the evaluation of the electrical characteristics of wind turbines
- Research and development of new concrete manufacturing for renewable energy applications.
- Test laboratory for multi-megawatt components for wind turbines.

During 2005, a technological network that includes the industrial sector, the University, and Research Centers was created. The initiative called REOLTEC (Spanish Technological Network of Wind Sector) is promoted by the Spanish Wind Business Association (AEE) and the main objective is to maintain the positioning of the national industry through the reinforcement of technological knowledge and the selective diffusion of the results and experiences. A work plan that covers short term (2005-2007) and medium term

(2007-2010) strategies has been issued. The following topics are defined and the corresponding working groups were created: Applications (Hydrogen, Hybrid Systems, and Storage); Wind Resources (Forecasting, Wakes, and Complex Terrain); Wind turbines (Components and Life Cycle Assessment); Grid Integration; Offshore; Standards and Certification; and Environmental and Social aspects.

6.0 NEXT TERM

The Spanish wind power industry is a solid and consolidated sector. Over the last three years there has been an average growth in installed generating capacity of around 1,600 MW a year. The objective of the Spanish Renewable Energy Plan for the year 2006 is to increase wind power in Spain by 2,000 MW in order to reach the value of 12,000 MW for the period 2005-2010. So far, the national legislative framework, regional regulations, and the maturity and competitiveness of the technology used have made it possible to achieve the targets set in the Renewable Energy Plan.

Two important aspects must be taken into account to guarantee the fulfilment of the objectives. On one hand, a study of the alternatives compatible with the security of the system must be undertaken in order to progress toward a higher penetration of wind power in the electricity system. On the other hand, it is essential that the

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current legislative framework be retained without substantial changes over the period 2005-2010 (Law of the Electrical Sector and Methodology for Revision of Tariffs establish in Royal Decree 436/2004 on the Special System of Electricity Generation).

Therefore, along with maintaining the price paid for electricity at similar levels to those of 2005, several measures must be considered for the next year.

- Development of transport grid. Continuous activity during the period 2006-2010
- Revision of the plans for the gas and electricity sectors
- New regulations for grid connection of facilities operating under the special regime
- Creation of a single operation centre for the Special regime producers within the Spanish Transmission System Operator (REE)
- Development of coordinating centres for wind farms grouping together farms run by the same company or within a particular geographical area.

Spain does not yet have any offshore wind farms. There are a number of ambitious plans for offshore in several locations along the coast of Cadiz, Huelva in the South of Spain and in Castellon, and Tortosa in the Mediterranean Sea. For 2006, there is important legislative work in order to develop the pertinent regulations and remove barriers to offshore development.

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Author: Enrique Soria Lascorz, Renewable Energy Division, CIEMAT, Ministerio de Educación y Ciencia, Spain.



CHAPTER 26 SWEDEN

1.0 INTRODUCTION

The Swedish Energy Agency, under the Ministry of Sustainable Development has a mission to transform the Swedish energy system into an ecologically and economically sustainable system. One way of meeting the mission is to guide the state capital towards well-defined energy activities. The Swedish Energy Agency works in collaboration with industry, energy companies, municipalities and the research community. The Swedish Energy Agency decided in December 2005 to fund a new R&D wind energy program with duration of three years, 2006 – 2008 and budget of 4.9 million € (45 million SEK).

A specific wind power committee has been established by the government in order to answer for the overall coordination of the coming wind power deployment.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

The Swedish Energy Agency has distributed the national planning target of 10 TWh (4 TWh on-

shore and 6 TWh offshore) by 2015 into regional ones and follows them up annually. Regional volume targets take wind energy resources and regional electricity consumption into account. The first follow up was carried out during 2005 and included data from 19 of 21 county administrative boards. The result was that approximately 1.5 TWh was planned. The purpose of the target is to elucidate wind power installations on a regional and a local planning level. Moreover, the target shall reduce planning and permission obstacles to create opportunities for 10 TWh wind power by 2015.

The total installed wind power capacity in Sweden increased by 40 MW (+9%) during 2005 to 492 MW (23 MW of which was installed offshore). Despite the modest increase in installed capacity in 2005, the average growth in production was nearly 40% from 1990 – 2005. The preliminary production from 759 wind turbines (+ 5%) was 853 GWh (-/- 0%) in December 2005. Only 662 of 759 turbines had reported when this data was collected. The statistics show that the so-called wind index for 2005 was about 94% of a normal year. The nearly 1 TWh from wind energy corresponds to 0.6% of the electricity consumption in Sweden.

Two large utilities, Vattenfall AB and EOn are the main players when it comes to wind power project plans in Sweden. Vattenfall has plans for 900 MW and EOn is working on three projects summing up to more than 1,100 MW. Vattenfall

Total installed wind generation	452 MW
New wind generation installed	48 MW
Total electrical output from wind	.864 TWh
Wind sector turnover	NDA
Wind generation as % of national electric demand	.60%
Target:	10 TWh in 2015

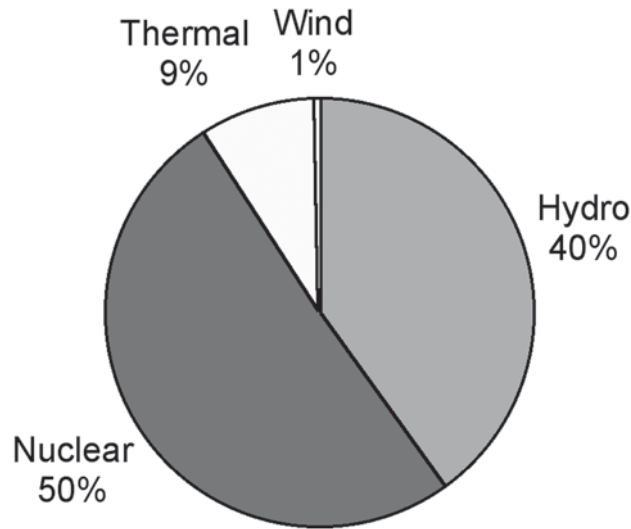


Figure 1 Energy resources in Sweden. The production from one nuclear reactor, Barsebäck 2, was stopped after a governmental decision in May 2005 (Swedish Energy Agency).

acquired about 460 MW of wind power in Denmark, England, and Poland during 2005, including four offshore wind farms (Horns Rev (60%), Kentish Flats, Utgrunden 1 and Yttre Stengrund).

The 3-MW prototype wind turbine Näsudden II on Gotland set a new world record for accumulated electricity generation by a single wind turbine. By 9 January 2006, it had generated 57.2 GWh of electricity from startup.

The deployment phase requires a great deal of time, especially for projects with an installed capacity greater than 10 MW. Such projects require permission by the court of environment.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

The utilities of Vattenfall and EOn are leading in the development of wind energy both onshore and offshore. Two smaller, yet active utilities are Falkenberg Energi and Göteborg Energi. Two

northern utilities that also co-finance the research program are Jämtkraft AB and Skellefteå Kraft AB. The utilities that develop projects own and operate them. Some utilities also buy projects from developers, when the permission process is finished. There are several developers; WPD, Vindkompaniet, RES Scandinavia, etc. with the strategy to sell either portions of, or the whole project. WPD developed, on the Sweden side of Kriegers flak, a project that Vattenfall then acquired. Airicole (owned by Edf) developed the offshore park Utgrunden – II, which EOn bought. When the large utilities' project plans are realized, the ownership structure may change. Today 80% of the installed capacity is owned by a non-utility and almost 20% of the installed capacity is owned by private persons. Gamesa is a new player as a project developer in Sweden.

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

There are two manufacturers of small turbines in Sweden; PitchWind AB and SVIAB. The worldwide large manufacturers Vestas, Enercon and GE Energy have sales offices in Sweden.

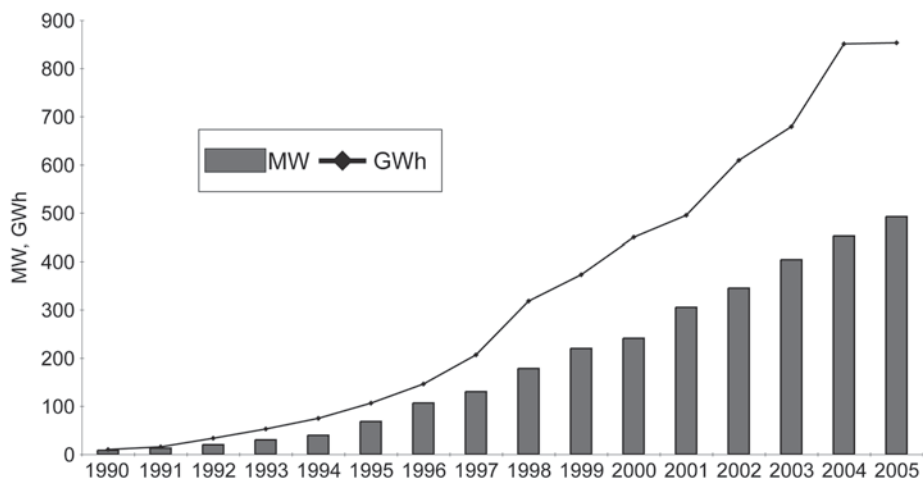


Figure 2 Installed capacity and production, preliminary data for 2005.

The Swedish manufacturer Nordic Windpower filed a petition of bankruptcy in 2005 and all assets were acquired by Deltawind AB. The company has become a market player in Sweden, China, and North America. The Swedish wind power market consists of subcontractors such as SKF (rolling bearing), ABB (electrical components), Vestas Castings, Guldsmedshyttan AB (former Guldsmedshytte Bruks AB), and EWP

Windtower Production. The subcontractors are multi-national companies as well as smaller entities that find the wind power market applicable to their know-how.

The average size of a turbine built in 2005 was 1 MW. One larger installation took place in Aapua (Northern part of Sweden), where seven turbines of 1.5 MW were installed. With a reduced cost

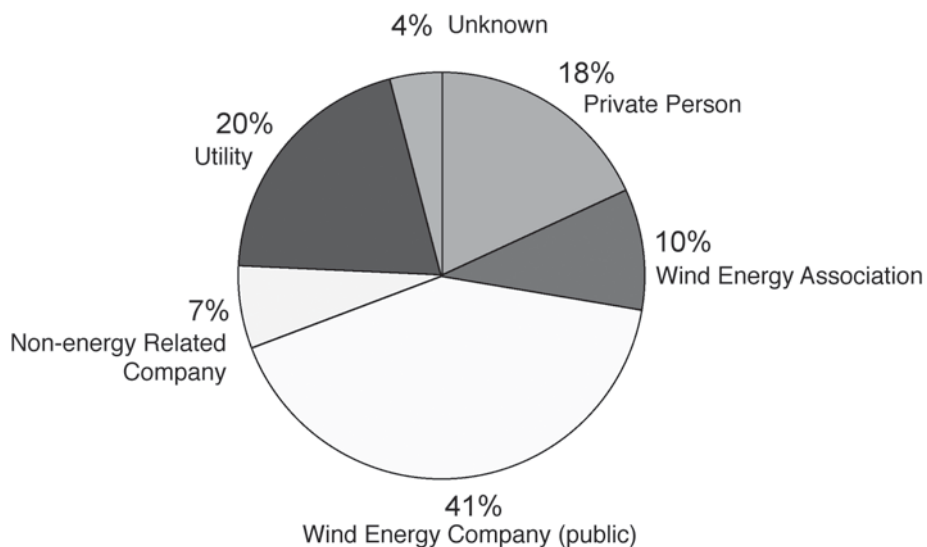


Figure 3 Ownership during 2004.

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of production in combination with the proposed changes to the electricity certificate system, reasonable conditions for further development are expected. According to Swedish wind turbine monthly and annual statistics, the average availability during 2004 was 99.1%. Availability in 2003 was 99.1% and from 1996 to 2002 it was 98.2%.

3.3 ECONOMIC DETAILS

Offshore wind power installations received a higher environmental bonus, 17 €/MWh compared with 9.7 €/MWh for onshore. The electricity price in Figure 4 below is an average of the monthly system price, based on NordPool's data.

4.0 NATIONAL INCENTIVE PROGRAMS

There are three main incentives programs for the promotion of wind power: a) electricity (green) certificates, b) production support (the so called environmental bonus) and c) national interests for wind power.

a) 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 level of the stipulated quotas (and the quota obligation fee) will drive the deployment of renewables where wind power plays a major role. A detailed description of the certificate system is covered in the annual report of 2004.

The government has suggested a number of changes in the electricity certificate system in order to improve its long-term efficiency. The suggestions include a limit on rights to receive certificates, a 15 TWh increase from 2002 to 2016 and an end date of the system by 2030. These amendments will be presented in a government bill in spring 2006 and is expected to result in lower economic risk for the project developer and in general a higher growth in deployment of renewables.

b) The level of the bonus is declining for each year until 2009, at which point the bonus for onshore wind power will be zero. The governmental budget bill from September 2005 contained a suggestion on extension of the "environmental bonus" for offshore wind power with 20 years.

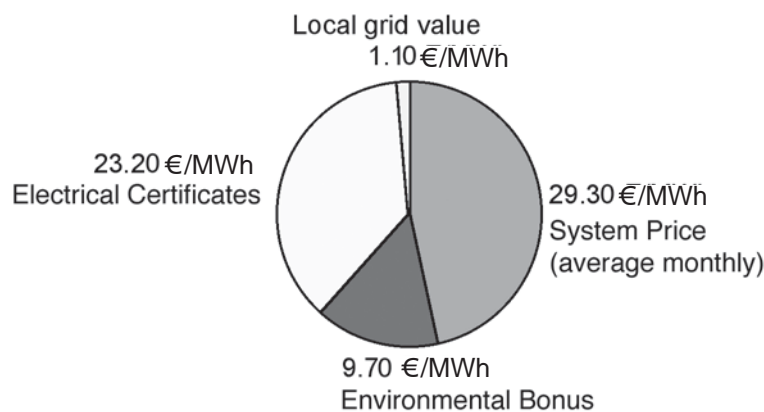


Figure 4 The elements of total income (63.3 €/MWh average) for a wind power plant owner in 2005.

c) The Swedish Energy Agency has assessed 49 geographical areas of national interest for wind power in 13 counties. The purpose is to facilitate the deployment of wind power by selecting suitable areas for wind power production. A national interest for wind power will in a permit context be judged against other national interests such as environment protection, fisheries, and navigation.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

Uncertainties in funding characterized the year, not only for the wind energy sector, but for all energy areas where the Agency is involved. A dramatic reduction in the R&D budget for the years 2005-2011 made the priorities on projects even sharper. This was, however, reset in the budget bill from the government in September 2005. It announced an increased budget for energy R,D&D at almost same level as before the reduction, at least for the three coming years.

The former wind R&D program ended 31 December 2004. Information on and results from that program are still available on the web-page www.vindenergi.org. The Swedish Energy Agency planned for a new program during 2005. On the budget of 2005, R&D projects were funded with a budget of only 0.2 million € (2 million SEK). Projects running with funding from 2004 totaled up to 3.6 million € (33 million SEK). The Swedish Energy Agency decided to join the IEA Annex on Wind and Hydro Integration. During the year, Swedish activities within Annex XIX on Cold Climate and Annex XX – HAWT Aerodynamics was reported.

In December 2005, the Swedish Energy Agency decided to fund a research program for wind power, Vindforsk - II. The program will run between 2006 and 2008 with a total budget of 4.9 million € (45 million SEK). Elforsk, the Swedish Electricity Utilities R&D Company manages the program. Vindforsk – II contains two parts, one

with basic research and one with applied. 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 a stronger co-operation between the utilities and the grid owners (including the Swedish TSO) than previous programs. Areas of research interests include grid integration, external conditions, standardising in general, O&M, project development, impacts on the environment, and public acceptance. The two latter areas have their own research program, Vindval, where such issues are covered more thoroughly. Six research projects on birds, fish, bats, and artificial structures were initiated during 2005. Vindval is a small part of a program called “Market introduction and technology development” which runs from 2003-2007 with a budget of 38 million € (350 million SEK). The Swedish Energy Agency is responsible for the program which supports wind power deployment offshore and in the arctic areas. The governmental budget bill from September 2005 contained a suggestion to prolong the support by another 38 million € (350 million SEK) between 2008 – 2012.

The work with mapping the wind climate in Sweden continued during 2005. Project manager Hans Bergström, Department of Earth Sciences Meteorology, Uppsala University, is using three-dimensional, higher-order, closure meso-scale modelling for wind resource estimates in Sweden. By improving the level of scaling, new suitable areas for wind energy are expected to be mapped. The resulting wind climate (yet preliminary and to be finalised in 2006/2007) is verified against some measurements. Statistics of the geostrophic wind are used for weighting model output together into the final wind climate. The project is financed by the Swedish Energy Agency.

A generator prototype has been developed on a patent application with a configuration of permanent magnets and wire-wound stator, with the bearing of the machine placed in the air gap. The

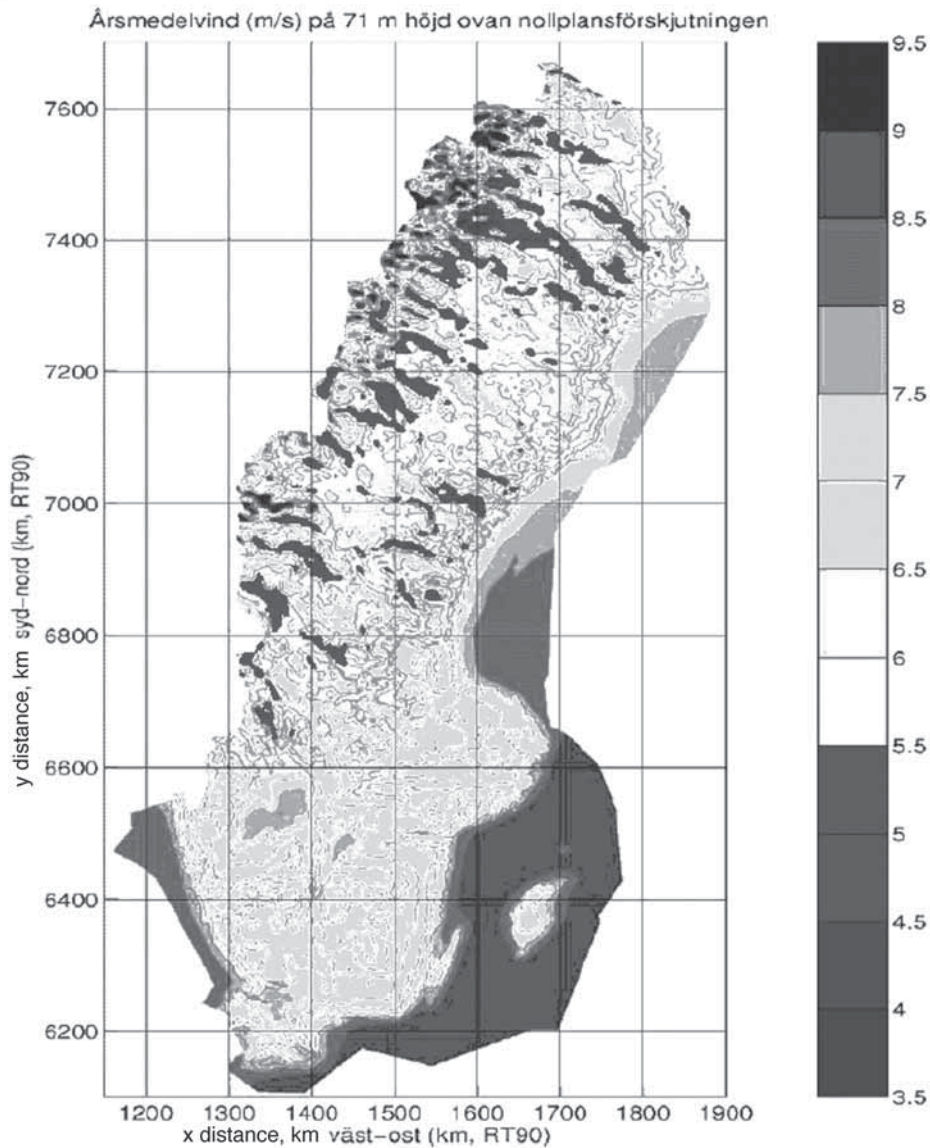


Figure 5 Average annual wind speed in Sweden at 71 m at 5 km horizontal resolution. Preliminary data. (H. Bergström, Uppsala University).

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 (max 177 kW). The tests show that the concept meets the estimated performance and has the potential to be scaled up to 4 MW, and even further to 10 MW. Calculations and construction has successfully been performed at VG Power AB. The founder of the concept NewGen is Staffan Engström,

Ägir Konsult AB. The next step is to demonstrate NewGen in a large wind turbine.

5.2 COLLABORATIVE RESEARCH

During 2005, Elforsk and the Swedish Energy Agency collaboratively ran a program of applied research. The budget was about 0.2 million € (2

million SEK). The program included work within the annex on dynamic models, statistics of wind power generation, and a report on environmental impacts of wind power offshore. Additionally, the largest Swedish utility, Vattenfall AB, has a wind energy development program of its own.

A separate project, also commonly funded by the Agency, the utilities, and the Swedish TSO (Svenska Kraftnät), was a two-part study of the impacts on the Swedish grid if 4,000 MW (base scenario) of wind power were installed in Sweden. The first study looked at the variations of installed capacity at various scenarios. Climatological data from 1992-2001 was used. The statistical result showed a 50% loss of installed wind power capacity during a 6-hour period of time, once a year. In terms of production, the main scenario with 75% of installed capacity offshore concentrated in southern Sweden resulted in about 10 TWh. The second study looked at the regulating power need for similar scenarios.

The Swedish Defence Research Agency, FOI, was the operating agent for IEA Annex XI on information exchange. See separate report on that annex in the beginning of the annual report.

6.0 THE NEXT TERM

For large wind power projects, the government will designate coordinators in order to facilitate the work between, utilities, authorities and other market players, on central, regional, and local levels easier.

A first version of the wind climate map on a 1-km scale will finish in early 2006. The improved data will primarily be used at the county administration boards in their work with assessing areas that are especially suitable for wind energy production. The progress with the regional planning targets will be measured during the spring of 2006.

A decision in the Parliament on amendments on the electricity certificate is expected during 2006.

Author: Sara Hallert, Swedish Energy Agency with input from Kenneth Averstad, Vattenfall AB, Sweden.



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CHAPTER 27

SWITZERLAND

1.0 INTRODUCTION

In 2004, the consumption of energy in Switzerland was 243.7 TWh and consequently 0.5% higher than the previous year. Quantitatively predominant was an increase in consumption of natural gas (+3.3%) and electricity (+1.9%), as well as long-distance heating (+3.6%), fire-wood (+1.4%) and renewable energies (+3.9%). (Figures 1 - 3)

Measurements to promote a more rational use of energy, like the ones carried out by the program SwissEnergy, are achieving considerable results in reducing the energy consumption in Switzerland. They succeed in dampening the effects of consumption increasing factors; however, fail to stop the constant overall growth of energy consumption.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

Since 2001, SwissEnergy, the implementation program of Switzerland for a sustainable energy

policy, has established clear goals. They are still valid. SwissEnergy, makes an important contribution towards the following goals:

- Goals for promotion of renewable energy (including small hydro power)
- Goals of the Swiss Climate Policy (-10% emissions until 2010 compared to 1990).
- Objective target of slowing down the increase of electricity consumption and to promote a more efficient use (maximum +5% increase of electricity consumption between 2000 and 2010).

In order to increase its effectiveness, SwissEnergy, is concentrating the program, during the second phase, on five main points. All activities of the program should focus on these core themes. All financial resources have to be concentrated on these main focal points:

- Modernization of buildings (a national sanitation program working together with regional and local governments, private enterprises, industry, house owners, tenants, and the program Klimarappen (Climate Cent).
- Renewable energies main focal points are established according to a “Roadmap” for each corresponding potential.
- Energy efficient appliances/engines (intensification of the program “energieEtikette” (energy tag), agreements with the industry and production companies as well as

Table 1 Key Statistics 2005: Switzerland	
Total installed wind generation	11.594 MW
New wind generation installed	2.921 MW
Total electrical output from wind	.0084 TWh
Wind sector turnover	4 million €
Wind generation as % of national electric demand	.016 %
Target:	100 GWh/yr in 2010
Note: 3 MW installed only in November 2005, which leads to a low capacity factor.	

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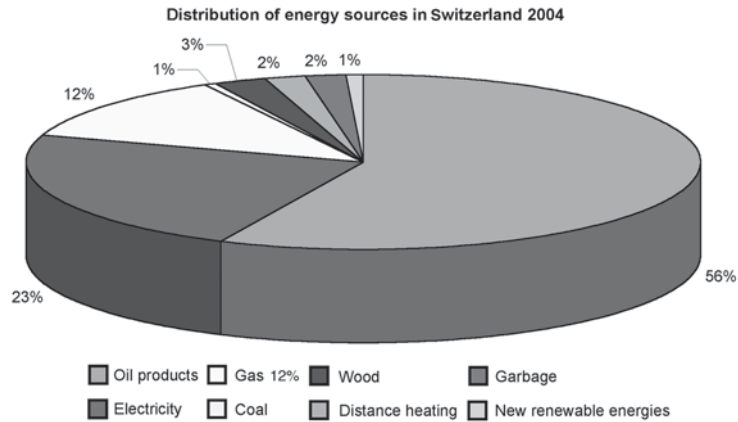


Figure 1 Distribution of energy consumption in Switzerland 2004.

eradication of high energy consuming appliances).

- Rational use of energy and waste heat by private enterprises (concrete programs and agreements with industry, municipalities and cities).
- Energy efficient and low emission mobility (intensification of the program “energieEtikette” (energy tag), promotion of new drive systems and use of renewable fuels).

The Federal Department of the Environment, Transport, Energy and Communications (DETEC) with its offices SAEFL (Swiss Agency for the Environment, Forests and Landscape), SFOE, and OSD (Federal Office for Spatial

Development), has elaborated on a concept (1) in the year 2003 to 2004 and is conducted on behalf of the SFOE1. The targets for wind energy production in Switzerland are: 50-100 GWh by the year of 2010. In 2005, wind energy in Switzerland has produced 8.4 GWh and achievement of 8.4% 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.

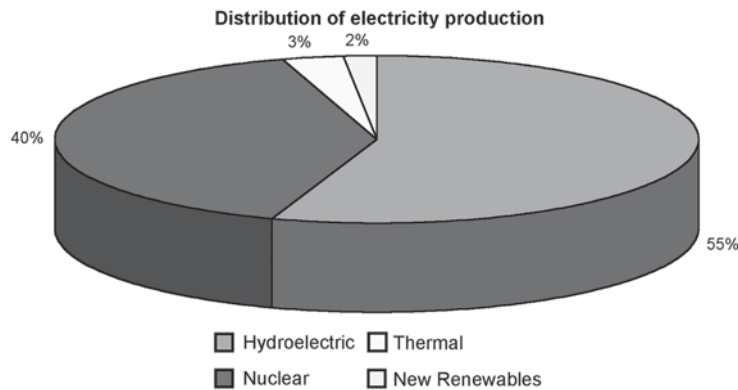


Figure 2 Distribution of electricity production in Switzerland 2004.

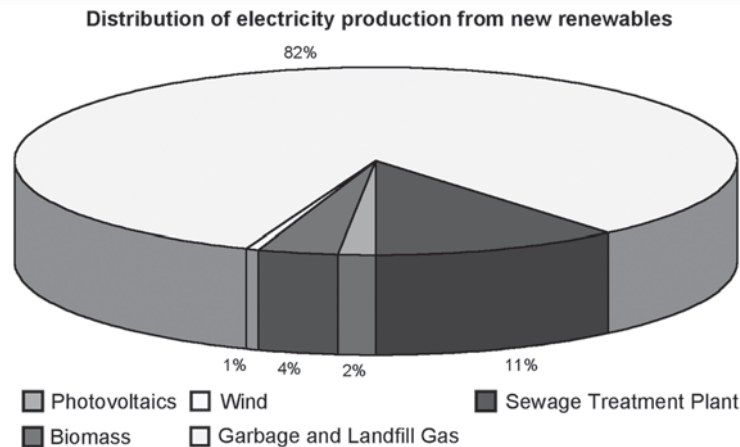


Figure 3 Distribution of electricity production from new renewables in Switzerland 2004.

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

In 2005, the installed capacity of wind energy in Switzerland has increased again. Due to an additional construction of a 900-kW wind energy plant in the Entlebuch region and a 2-MW plant in Collonges in the canton Valais, 31 wind energy plants are now installed in Switzerland, with a total capacity of 11.57 MW. In 2005, they have produced 8,400 MWh of electricity (Figure 4).

3.2 INDUSTRIAL DEVELOPMENT AND OPERATIONAL EXPERIENCE

In Switzerland, the company AVENTA AG is the only one producing wind turbines. It makes a small type of 7-kW machine (Figure 5). Due to its oversized rotor, this plant produces electricity even with relative low to medium wind speed, however its production costs are high. In 2005, three of these plants have been installed.

In 2005, research has continued on the project, Prototype Wind Turbine Rotor with cyclical adjustment of Pitch and Twist (“Prototyp Windturbinenrotor mit zyklischer Pitch- und Twist-Verstellung”) (Figure 6). The aim is to mount a functional prototype of an “intelligent rotor blade” on a model turbine. The goal of this project is to produce a new kind of structure for the rotor blade, with which the pitch angle of the blade as well as the blade twist can be made cyclically changeable.

In November 2005, the biggest wind power plant of Switzerland (Enercon E-70) with a production of 2 MW was installed in Collonges, in one of the valleys of the Swiss Alps (Figure 7).

3.3 ECONOMIC DETAILS

P+D projects have obviously a very high value for the implementation of the measurements to achieve the goals of the Wind research program in Switzerland. However, in 2005, few financial funds have been made available for this area. The activities of the program were concentrated therefore mainly for F+E Projects.

Under the title “Implementation of the concept Wind Energy Switzerland”, Suisse Eole can offer

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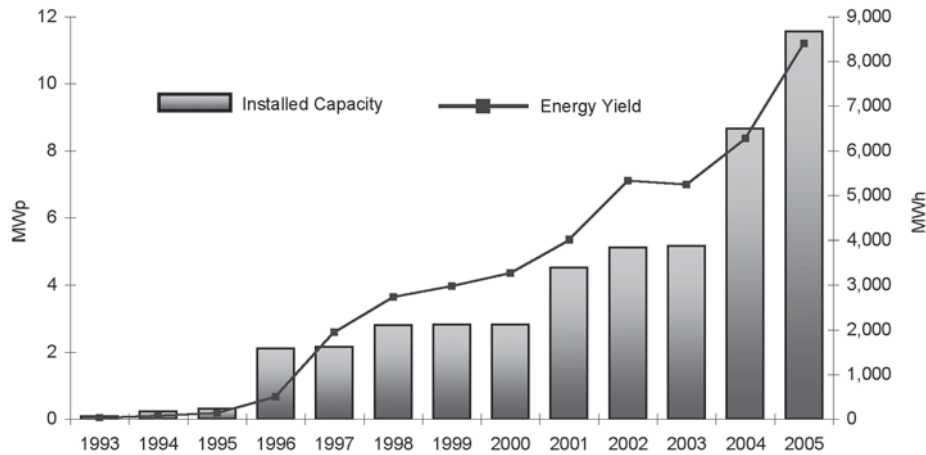


Figure 4 Installed capacity and energy yield of wind turbines in Switzerland 2005.

certain operational and financial support for site assessments and communication measures.

The specific costs of larger wind power plants amounts to about 2,000 CHF/kW (1,380 €/kW). Thus, the prime costs at windy locations are lower than 0.20 CHF/kWh. (0.135 €/kWh). The production costs of the newest (2004) installed 1.75-MW wind energy plants amount to about 0.12 CHF/kWh (0.085 €).



Figure 5 Aventa AV 7: Swiss-made wind turbine for low wind speeds.

The Swiss energy law obliges energy suppliers, to buyback the energy produced by independent producers at the price of 0.15 CHF/kWh (0.105 €). Since 1 January 2005, these costs have to be paid by the high-voltage grid operators.

The Swiss parliament is currently discussing a new law for opening the electricity market. Within this context, there will be a debate on changing the cost covering remunerations in the energy law to something similar to the German fixed feed-in-tariff regulation. The bills will probably be past in summer 2006.

4.0 NATIONAL INCENTIVE PROGRAMS

Within the framework of the project, a comprehensive strategy for the development of wind energy in Switzerland for the next 5 years has been elaborated, based on good contacts, discussions and detailed evaluations of wind energy projects.

Suisse Eole, the Swiss Wind Energy Association, has managed to position itself as the organisation with the highest authority on the use of wind energy in Switzerland. Wind energy has managed to position itself as an important mosaic stone within the sustainable energy supply in Switzerland. The participation of the big electric supply companies

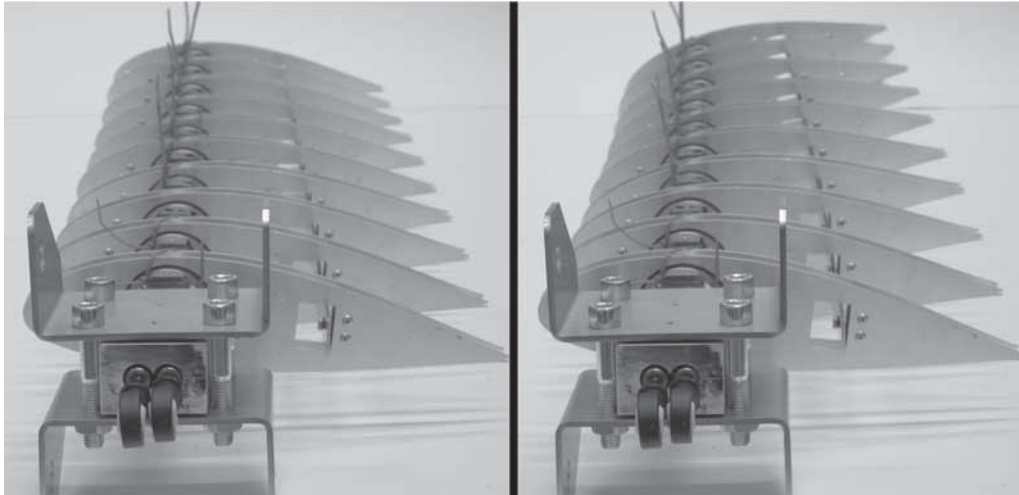


Figure 6 Functional model of an “intelligent rotor blade,” which adjusts itself to the different wind conditions during the revolution of the rotor.

on the research activities of the program is still relatively reserved. The numerous participants during an exchange of experience, with the theme “Wind energy and hydro power” that took place in Lucerne on 30 September 2005 has shown that the possibilities of wind energy have been recognized by the important players of the industry.

Suisse Eole coordinates all activities of the indirect promotion for the use of wind energy in

Switzerland, in collaboration with the cantonal institutes of energy, energy suppliers and energy planners. The management and the project administration Wind is being carried out by the same person, which guarantees an optimal coordination. Based on recommendations out of an evaluation, Suisse Eole will seek to position itself more as a competence centre for wind energy.



Figure 7 The 2-MW wind power plant in Collonges, canton Valais.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

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 2005, the budget for wind energy related R&D projects was 247,000 €. An amount of 300,000 € is spent on promoting activities.

The project, Alpine Test Site Gütisch is based on the performance of the IEA Wind Annex XIX “Wind Energy in Cold Climates” (Figure 8). Its results and recommendation are currently being verified within the range of the COST 727 project, a broader research program named “Alpine Test Site Gütisch, Meteorological measurements and wind turbine performance analysis” and will be made available to a wider public.

5.2 COLLABORATIVE RESEARCH

The concept of energy research of the Swiss government, 2004-2007, presented by CORE (2) during the energy research conference in November 2003 indicates the following issues on the wind program:

“The utilization of wind power in Switzerland is still confronted with problems of acceptance as well as with highly technological requirements due to the sites in the mountains. The planned goals of 50 GWh up to 100 GWh until the year 2010 should be concretized spatially with a national concept and the necessary planning tools should be developed. The specific problems for wind plants in mountains 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 on an international level.”



Figure 8 Alpine Test Site Gütisch, with a mit einer 600-kW wind power plant as well as a device for testing different measuring instruments under cold and icy conditions.

Wind energy is an important part of the national program “SwissEnergy.” Switzerland participates in the IEA Wind Implementing Agreement Annex XIX Wind Energy in Cold Climates and Annex XXIV Integration of Wind and Hydropower Systems.

All activities and projects within the Wind program focus on installing wind power generators at the evaluated sites in the short and medium term.

6.0 THE NEXT TERM

In 2007, a further energy research program (2008 – 2011) will be passed by the authorities. Special emphasis of the research efforts in the area of wind energy is given to the development of components which can serve as local suppliers for the international industries. In addition, different pilot and demonstration projects are set up in order to reduce non-technical barriers and therefore allow a better market penetration of wind energy and to close the gap between research activities as such and its implementation in practice.

The main focuses for research are therefore:

- Increase of acceptance for wind energy, under consideration of a social scientific competence

- Increase of availability and energy output of wind power plants on extreme locations (climate, turbulences, logistics)
- Development of components for equipment (Sensors, Nano-Technology)
- Increasing the “value” of wind energy, optimization of the integration of wind power plants in the power supply systems (Forecasting, regulating energy.)

Wind power generation holds an 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 industry.

REFERENCES

- (1) Konzept Windenergie Schweiz, BFE, 2003.
- (2) CORE is the Federal commission of energy research activities in Switzerland.

Author: Robert Horbaty, Swiss Wind Energy Program, Switzerland.



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CHAPTER 28
UNITED KINGDOM

1.0 INTRODUCTION

Following the table of summary statistics below, this section provides an overview of the UK energy market characteristics followed by a brief summary of some highlights in the wind energy sector for 2005. UK renewable energy statistics can be found at http://www.dti.gov.uk/energy/inform/energy_stats/renewables/index.shtml.

1.1 OVERVIEW OF THE UK ENERGY MARKET CHARACTERISTICS

UK primary energy supply comes from a range of sources: natural gas (40%); petroleum (33%); coal (17%); nuclear electricity (8%), and renewables and other sources (2%). Electricity plays a key role in this energy system. It is not a fuel, but rather a conduit of energy generated from a mixture of coal (33%), gas (40%), nuclear (19%), and renew-

ables (4%) with the remaining 4% coming from electricity imports and oil.

The UK's energy sector has a framework that combines competition where it is desirable and regulation when it is necessary. Consumers, business and households are able to choose between competing suppliers of electricity and gas, and a number of companies operate in the electricity generation market. The electricity and gas networks are privately owned and operated, but 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).

In terms of indigenous resources, the UK has reserves of coal, oil, and natural gas. Large-scale extraction of oil and gas from the UK Continental Shelf (UKCS) began in the late 1970s. Production of both, however, has been declining and on current trends the UK will become a regular net importer of oil by around 2010. The UK was a net importer of gas on an annual basis in 2004 and 2005.

The UK is still, however, one of the global top 10 producers of oil and gas and will remain a major player for many years. So far, 34 billion barrels

Table 1 Key Statistics 2005: United Kingdom	
Total installed wind generation	1,380.0 MW estimated (2005) (1) 933.2 MW (2004)
New wind generation installed	447 MW (2005) 241 MW (2004)
Total electrical output from wind	2.394 TWh estimated (2005) 1.935 TWh (2004)
Wind sector turnover	500 million € (2005) (2)
Wind generation as % of national electric demand	0.48% (2004)
Target:	10% renewables by 2010

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 UKCS 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 instead of just 10%.

The UK is, in the most recent available figures, a net importer of around 7% of its gas. 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 12.7% of total demand for gas 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.

In terms of renewable energy, the UK has some of the best wind resources in Europe, substantial marine energy resources, and also useful potential in solar and bioenergy.

1.2 GENERAL SUMMARY OF 2005

In June 2005, the UK passed a significant landmark of 1 GW of installed wind and in 2005 as a whole, more than 446 MW of new capacity was commissioned, an increase of 85% on the capacity installed in 2004, and another record for the UK wind industry. Included in this new capacity was one offshore wind farm at Kentish Flats in the Thames Estuary just off the east coast of England. This wind farm is the UK's fourth offshore wind farm and at 90 MW it has both the largest UK offshore wind farm capacity and its 3-MW turbines are also the largest capacity turbines in the UK. This brought the total installed offshore wind capacity at the end of 2005 to 214 MW.

The contribution from wind energy was 1,935 GWh (2004) or 0.48% of the total demand for

the UK. This contribution from wind is set to rise dramatically over the next few years with predictions that wind energy will meet between 7 to 8% of the total demand in 2010. The average load factor for onshore wind has been estimated as 26.6% during 2005. The first large offshore wind farm, the 60-MW North Hoyle Offshore Wind Farm, began operation in November 2003. In the year from July 2004 to June 2005, it had an overall availability of 84% and an overall capacity factor of 36%.

The Renewables Obligation (RO), the key support mechanism for renewable energy in the UK, was extended such that electricity suppliers will be required to meet a growing proportion of their generation from eligible renewables reaching 15.4% by 2015/16. The RO was also extended to Northern Ireland where by Northern Ireland Renewables Obligation Certificates (NIROCs) can be gained on the same basis as GB ROCs.

2.0 PROGRESS TOWARD NATIONAL OBJECTIVES

2.1 POLICY BACKGROUND

The UK government's energy policy is detailed in the Energy White Paper 'Our energy future – creating a low carbon economy' – released in February 2003. The Energy White Paper 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. There were four key goals set by the 2003 Energy White Paper:

- to put ourselves on a path to cut the UK's carbon dioxide emissions by some 60% by about 2050 with real progress by 2020;
- to maintain the reliability of energy supplies;
- to promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve our productivity; and
- to ensure that every home is adequately and affordably heated.

In July 2005, the second annual report on the Implementation of the Energy White Paper was published jointly by the Department of Trade and Industry (DTI) and the Department for Environment, Food and Rural Affairs (DEFRA). The report sets out progress made to date and summarises the way ahead to achieving the four goals of energy policy. The second 12 months has seen continued progress against the short term goals. However the second year has also been about setting in place more of the foundations for the 50-year energy strategy, plotting the route to meet the government's targets and putting place plans for the long term. The report can be found at <http://www.dti.gov.uk/energy/sepn/secondannualreport.shtml>

On 29 November 2005 the Prime Minister and Secretary of State for Trade and Industry, announced a Review of UK energy policy with a view to bringing forward policy proposals in 2006. The Terms of Reference of the Review are broad in scope, including aspects of both energy supply and demand and will focus on policy measures to help deliver UK objectives beyond 2010. The Review will aim to ensure the UK is on track to meet the goals of the 2003 Energy White Paper in the medium and long term. On 23 January 2006 the Secretary of State and the Minister for Energy launched the consultation document "Our Energy Challenge: securing clean, affordable energy for the long term" to stimulate a wide-ranging and informed debate on energy policy issues both over the 12-week consultation period and beyond. Further details of the review can be found at: <http://www.dti.gov.uk/energy/review/>

The Energy Act (July 2004) is an important part of the legal framework within which wind energy developments are undertaken in the UK. The Offshore Production of Energy part of the Energy Act 2004 puts in place a comprehensive legal framework for offshore renewable energy projects (wind and wave and tidal) and extends the boundary for such projects beyond the UK's territorial waters to the 200 mile point. The Act establishes a Renewable Energy Zone (REZ), ad-

acent to the UK's territorial waters, within which renewable energy installations can be established.

The Act also provides a framework for the implementation of the British Electricity Trading and Transmission Arrangements (BETTA). These went live in April 2005. BETTA provides a common set of trading rules so that electricity can be freely traded across Britain and a common set of rules for access to and charging for the transmission network.

In addition to the policy framework already in place, a number of strategically important reviews were initiated during the reporting period, in particular the Energy Review, and a review of the Renewables Obligation. These are described in the following paragraphs. The Renewable Obligation (RO) remains the key support mechanism for renewable energy in the UK whereby a number of qualifying technologies receive price support.

2.2 KEY ISSUES

2.2.1 DEFENCE AND CIVIL AVIATION INTERESTS

One of the key constraints in meeting renewable energy targets is related to restrictions in developing wind farms near civil and military radar installations because wind turbines have the potential to interfere with radar and navigational systems. The Wind Energy, Defence and Civil Aviation Interests project was set up by the DTI in 2000 to understand these issues and investigate appropriate mitigation solutions and to ensure that a clear strategic view on mitigation activities relating to issues surrounding wind farm development/radar interference is achieved. As part of this project, a Steering Group (and several Sub-Groups) were formed, comprising a cross-section of stakeholders, including representatives from the British Wind Energy Association (BWEA), the UK Ministry of Defence (MoD), the Civil Aviation Authority (CAA), National Air Traffic Services (NATS), the British Airport Association (BAA) and the Department of Trade and Industry

(DTI) assisted by Future Energy Solutions (FES). The Scottish Executive and Welsh Assembly also provide guidance on their respective issues.

A strategic view paper has been prepared listing priority developments for both civil and military communities. It is anticipated that this document will form the basis of an agreed program of UK activities, which are more clearly focused on developing mitigation solutions and which enable the aviation industry to increase the proportion of consents given to future wind farm developments while maintaining air safety standards and air defence.

The DTI are sponsoring 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, which will further develop the system/s to make them suitable for commercial application, will be undertaken during 2006.

As part of the DTI's Technology Programme, two projects are being supported investigating materials and methods (stealth technology) that will assist in the mitigation of radar interference from wind turbines. These projects are scheduled for completion in 2007.

DTI prepared the introductory note for the IEA Topical Expert Meeting 46, hosted by the DTI. The meeting covered Radar, Radio and Wind Turbines, and took place on 17th-18th March 2005.

The MoD has been active in conducting a series of trials to provide a better understanding of the impact of wind turbines on their radar systems. Air Defence (AD) trials were undertaken and the data captured will enable a greater understanding of wind farm issues associated with AD radar and, in doing so, direct the MoD's policy on wind turbine farm developments. Air Traffic Control (ATC) trials have also been completed.

2.2.2 GRID ISSUES

BETTA Grid issues were dominated in 2005 by the regulatory reforms of the new British Electricity Transmission and Trading Arrangements (BETTA), and by investment proposals by the electricity regulator, Ofgem, for the transmission network upgrade to accommodate large renewable generation seeking to connect to the system. BETTA came into effect on the 1 April 2005 and is essentially the 'roll out' of the preceding transmission and trading agreement, NETA, to include Scotland thus enabling one Great Britain (GB) market. BETTA was designed to bring a number of important benefits for Scottish consumers giving them more choice of supplier, and to enable Scottish generators to have access to the wider Great Britain (GB) market. This will significantly increase competition for their output to include suppliers operating in England and Wales. Without BETTA, the upgrades to the transmission system needed in Scotland to accommodate the growth in renewable generation would have been charged only to Scottish users. Under BETTA the cost will now be spread across all transmission users in GB. This is important as some of the UK's best wind resource is in the north and west of Scotland and its development relies on increased transmission capacity.

Ofgem has approved investment of £560 million for strengthening the transmission system in Scotland and Northern England to accommodate the growth in renewable generation and enable its delivery to points of demand, for example, in the southern parts of GB.

Offshore Transmission Offshore renewable energy is going to be critical to the delivery of the government's target of 10% renewable energy by 2010. Currently there is no regulatory regime in place covering connection of the second round of offshore wind farms (and the marine renewables that follow them) to the onshore electricity grid. However, the Energy Act 2004 gives the Secretary of State for Trade and Industry various

powers to set up a regulatory regime for offshore transmission. The government's aim is that the regulatory regime facilitates the connection of a proportion of Round 2 (R2) projects in time to contribute to the 2010 target. The objectives are to ensure efficiency of connections and to allow fair and open access for potential offshore generators. Grid connections are likely to constitute 10-15% of capital costs for R2 projects given the considerable cable lengths involved. Certainty about how the grid connection costs will be funded, and the regulation that controls them, is a key factor that developers need in preparing their business models.

The DTI and Ofgem issued a joint consultation document – "Regulation of Offshore Electricity Transmission" – on 19 July which sought views from stakeholders on the high level options for this offshore regime.

The main options set out were:

- Extension of arrangements broadly similar to the existing onshore regulated price control approach offshore. Under this model the cost of building the electricity transmission line connecting the offshore wind farm to the onshore electricity grid would be met by a licensed Transmission Owner (TO). The funding would need to be approved by Ofgem. Under this approach, the bulk of the connection costs would be recovered from developers through annual transmission charges levied by the GB System Operator (GSO) who would refund the TO.
- Extension of the existing onshore system offshore but with the addition of some limitation of the highest transmission charges. This would involve some proportion of the extra costs of offshore transmission being recovered from other users of the system.
- A light touch regulatory approach with developers directly responsible for funding upfront the construction of cable connections to the onshore system.

The consultation period closed on 19 October 2005. Copies of the responses received are available on the DTI web-site: http://www.dti.gov.uk/renewables/renew_whatsnew.htm

Transmission Charges Section 185 of the Energy Act 2004 gives the Secretary of State the power to adjust transmission charges for renewable generation in an area of GB with significant potential for renewable development, where that development would otherwise be deterred by the high level of transmission charges that would apply.

In March 2005, the government announced that it intended to put in place a scheme to adjust transmission charges for renewable projects in the Western Isles, the Shetlands, and the Orkneys. These islands have the potential to generate enough renewable energy to power the cities of Aberdeen, Glasgow, and Edinburgh combined. But, a report commissioned by the DTI showed that no renewable development was likely to take place on the islands unless transmission charges were adjusted. The DTI is considering the details of how it should implement a scheme in light of responses to the consultation. The DTI expects to publish its response in Spring of 2006. The response will set out the further work that needs to be done before a scheme can be put in place. There will be further consultation before a scheme is established including an assessment of the costs.

The bulk of the costs of island connections will be met by projects themselves, in the normal way that generators pay to use the transmission system in GB. The cost of the scheme to adjust these charges will be met by a slight increase in the charges paid by all electricity suppliers in GB, which will be passed on to electricity consumers. Any price rises will be very small – perhaps around 0.50£ a year for the average domestic customer while the scheme is running.

2.2.3 COMMUNITY BENEFITS

A study reported in 2005 on the Community Benefits from Wind Power (Wind Power – A

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study of UK practice & comparison with leading European countries, Report to the Renewables Advisory Board & the DTI, URN number 05/1363, Centre for Sustainable Energy with Garrad Hassan).

This study was designed to establish a firmer evidence base about the scale and nature of community benefits being offered in the UK, to increase understanding of how the whole process of community engagement plays out in the planning decision-making process and to enable comparison with common practices in other leading European countries, specifically: Denmark, Germany, Spain, and Ireland. The study assessed all opportunities for local communities to benefit from the wind power project – from direct financial contributions into ‘community funds’ and opportunities for local ownership to payment of local taxes and jobs and construction and component manufacturing contracts.

The study had six recommendations based on the assumption that there will not be a wholesale change of UK policy on supporting renewables through market mechanisms and also following a strict interpretation of EU procurement rules namely:

- a good practice ‘toolkit’ on community benefits
- planning best practice guidelines to legitimise community benefits within planning process
- guidance on community engagement
- a review of the potential for local taxes to accrue locally
- research into the impact of new planning policy framework
- establish bankable models for community ownership

2.3 PROGRESS TOWARD NATIONAL TARGETS

2.3.1 GENERAL

The latest available figures for the total electricity demand in the UK are for 2004 and show that

it was 401,811 GWh, an increase of 0.56% over 2003. The contribution from wind was 1,935 GWh during 2004, which is 0.48% of the total demand. Achieving the 10% renewable generation target will require a step change in the level of renewable generation and depends amongst other things on five key factors: the planning system, timely reinforcement of the grid network, wholesale electricity prices, stability of government renewable energy policy, and required additional support for some technologies.

More than 446 MW of new capacity was commissioned in 2005 in the UK, an increase of 85% on the capacity installed in 2004 and another record for the UK wind industry. As a result, the installed capacity increased by 50% compared to the total installed at the end 2004. Figures from the British Wind Energy Association (BWEA) show that during 2005 a total of 19 new projects came on stream representing over 446 MW of new capacity, an increase of 85% on the capacity installed in 2004. This raised the total capacity in the UK to over 1,337 MW, an increase of 50% of the total capacity at the end of 2004 and a record for the UK wind industry. Table 2 details the projects that were commissioned in 2005.

Of particular note was the commissioning of Kentish Flats, the UK’s third and currently largest offshore wind farm with a capacity of 90MW pictured in Figure 1. Situated in the Thames Estuary just off the east coast of England, this wind farm is the UK’s fourth offshore wind farm and at 90MW it has both the largest UK offshore wind farm capacity and its 3 MW turbines are also the largest capacity turbines in the UK. It brings the total UK offshore wind capacity to 214 MW.

Figure 2 shows the history of wind capacity growth in the UK. Figure 3 shows all the wind projects built in the UK by Country, and Figure 4 shows the wind projects built in 2005 by Country. Figure 5 shows projects under construction at the end of 2005 by country.

In 2005, a total of 34 new projects were approved through the planning system, totalling over 767

Table 2 Wind Projects commissioned in the UK in 2005

Wind farm	MW Capacity	Turbines	Location	Country	Online
Nissan Motors Plant	3.96	6	Tyne & Wear	England	November 2005
Coldham	16.00	8	Cambridgeshire	England	November 2005
Green Park	2.00	1	Berkshire	England	November 2005
Kentish Flats	90.00	30	Kent	England	October 2005
Boulfruich	13.00	15	Highland	Scotland	October 2005
Tir Mostyn & Foel Goch	21.25	25	Denbighshire	Scotland	September 2005
Black Law A	97.00	42	South Lanarkshire	Scotland	September 2005
Glens of Foudland	26.00	20	Aberdeenshire	Scotland	July 2005
Artfield Fell	19.50	15	Dumfries & Galloway	Scotland	July 2005
Rothes (Cairn Uish)	50.60	22	Moray	Scotland	May 2005
Cefn Croes (inc Devils Bridge, Bryn Du)	58.50	39	Ceredigion	Wales	April 2005
Longhill	2.00	1	Cambridgeshire	England	March 2005
Forest Moor	2.70	3	Devon	England	March 2005
Haverigg III	3.40	4	Cumbria	England	March 2005
Tappaghan Mountain	19.50	13	Co Fermanagh	Northern Ireland	March 2005
Winscales extension	6.80	8	Cumbria	England	February 2005
Burray	0.85	1	Orkney	Scotland	February 2005
Ness Point	2.75	1	Suffolk	England	January 2005
Spurness Wind Farm	11.00	4	Orkney	Scotland	January 2005
Total New Capacity	446.81	258			
Average Turbine Size	1.73				

Source: BWEA

MW, which brought the total UK capacity approved but not yet under construction to 2,133 MW whose spread by country is shown in Figure 6. Figure 7 summarises all the approved capacity in the UK.

The 767 MW of new capacity approvals in 2005 represented a capacity approval rate of 59.6%

which is very similar to the 58.8% rate during 2004 but well down on the 75% approval rate in 2003. The overall approval rate is 65.3%. Figures 8 and 9 show the wind farm planning application success and failure rates from 1991 to 2005. On 12 July 2005, the largest UK onshore wind farm (the 164-MW extension to the Crystal Rig farm giving a total farm capacity of 214 MW) received



Figure 1 One of the thirty 3-MW turbines at Kentish Flats Offshore Wind Farm (Photo courtesy of Elsam A/S).

consent from the Scottish Executive under Section 36 of the Electricity Act.

2.3.2 OFFSHORE

The first phase of development of the UK offshore wind industry (known as Round 1), consists of a total of 18 sites, limited to 30 turbines per site, grouped at 13 locations around the UK. Three of these projects are now generating electricity, including the newly completed Kentish Flats, with a fourth, Barrow Offshore, expected to be commissioned in early 2006. More information is reported under the capital grants in section 4.

The second phase of development of the UK offshore wind industry, Round 2, comprises 15 sites, totalling as much 7,200 MW, being developed in three strategic areas around the UK coastline, the Thames Estuary, the Greater Wash - off the East of England coast, and the North West - including the Liverpool Bay area. Visible progress on the Offshore Round 2 projects was first seen with 4 applications for consent:

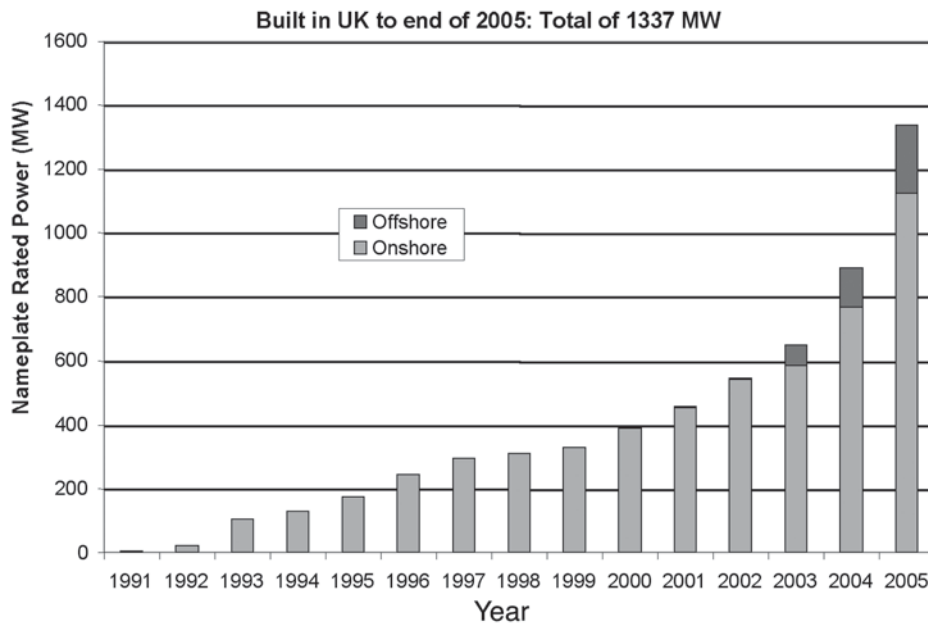


Figure 2 UK wind capacity (3) built in the UK to the end of 2005: Total 1,337 MW.

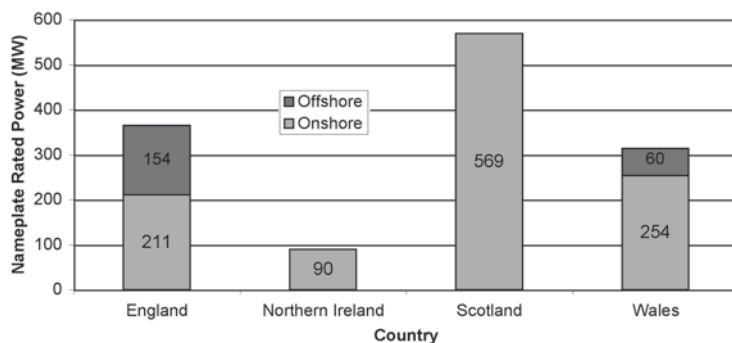


Figure 3 UK wind capacity built to the end of 2005 by Country (England 365 MW, Northern Ireland 90 MW, Scotland 569 MW and Wales 314 MW).

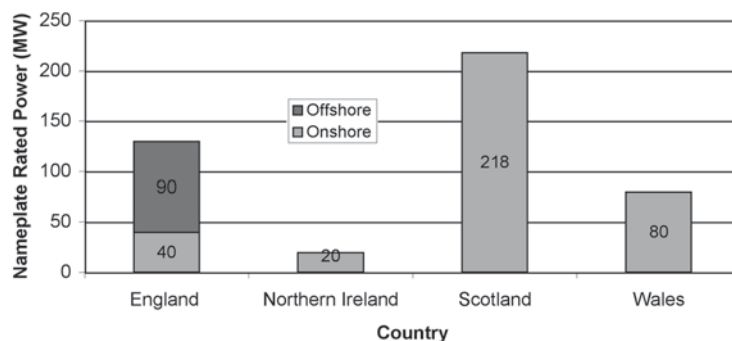


Figure 4 UK wind capacity built in 2005 by country: Total 449 MW.

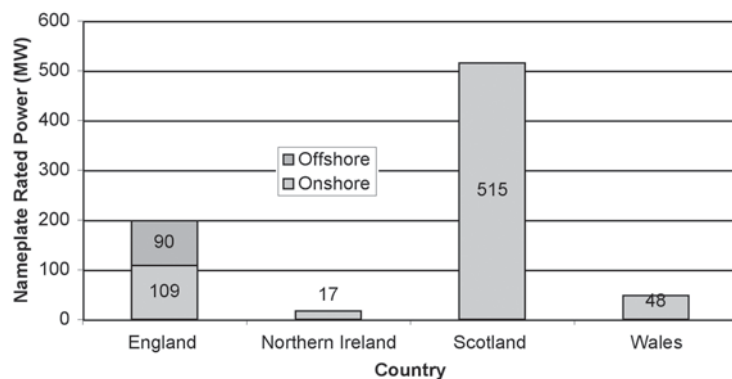


Figure 5 UK wind capacity under construction: Total 778 MW.

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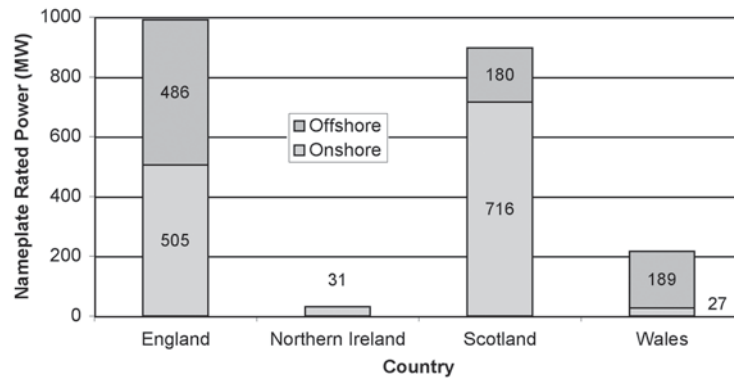


Figure 6 UK capacity approved but not yet under construction: Total 2,133 MW.

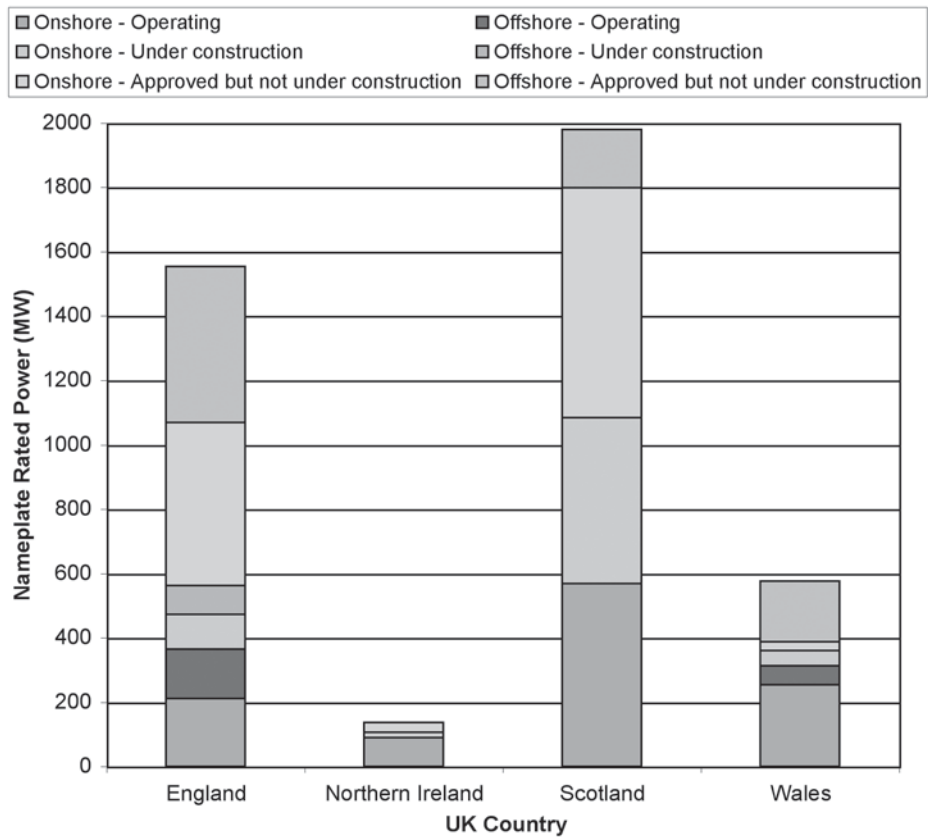


Figure 7 All UK approved projects at the end of 2005: Total 4,248 MW.

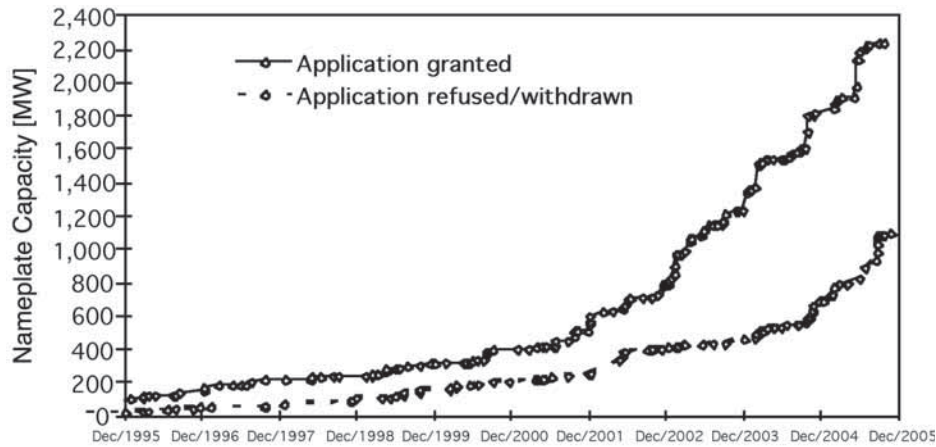


Figure 8 Wind farm planning application success and failure by capacity.

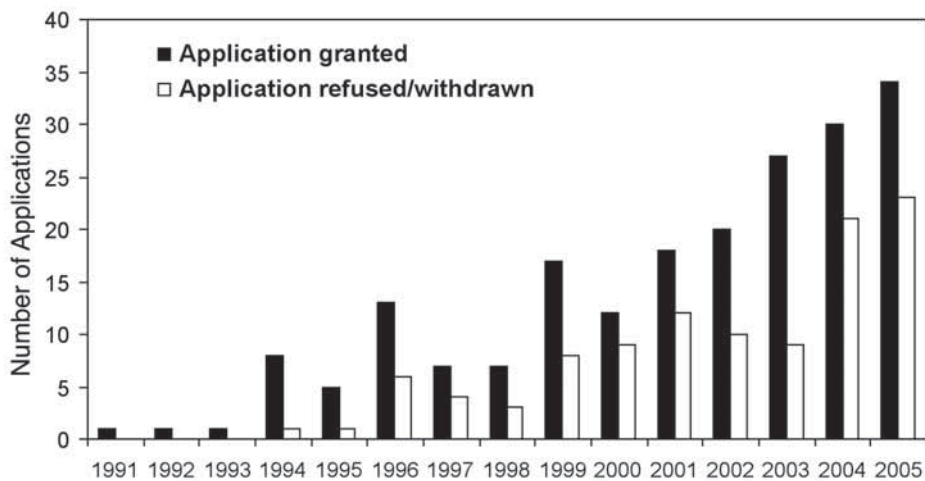


Figure 9 UK number of wind farm planning application successes and failures.

- The London Array project developed by London Array Limited submitted its application for consent in June 2005. If successful, construction could start on this site in 2007, and if built to its full extent it will comprise 1,000 MW – capable of powering a quarter of all the homes in London.
- The 500 MW Greater Gabbard project, developed by Airtricity and Fluor, submit-

ted its application in October 2005. This project is unique as it is the first offshore wind farm to seek consent outside UK territorial waters, enabled by the Energy Act 2004 under which a Renewable Energy Zone has been declared for the UK continental shelf.

- The 300 MW Thanet project submitted its application in November 2005, noting the high level of public support received local-

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ly for their project with 73% of people who attended the public exhibitions about the scheme in June 2005 saying they were supportive, with only 7% against.

- The 750 MW Gwynt y Mor project, developed by Npower renewables, submitted its application in November 2005.

3.0 BENEFITS TO NATIONAL ECONOMY

3.1 MARKET CHARACTERISTICS

Wind energy remains one of the fastest growing energy sectors in the UK. Statistics from 2004, showed that around 4,000 jobs are sustained by companies working in the wind sector and this is projected to increase as the industry grows. Around 1,500 of these jobs are in Scotland, with the balance located in the rest of the UK. The DTI has estimated that Round 2 of offshore wind developments alone could bring a further 20,000 jobs for Britain.

There are no indigenous UK manufacturers of large wind turbines, but there are a number of small and micro turbine UK manufactures e.g. Brumac (50 kW), Gazelle Wind Turbines (20 kW), Proven (0.6 to 15 kW), Iskra (5 kW), Marlec (0.06 to 0.72 kW) and Ampair (0.1 kW).

Several international companies have invested in UK facilities. Vestas, the world's largest leading large turbine suppliers has invested in the UK but made some of its staff at its Machrihanish factory redundant in 2005 citing a drop in orders. REpower UK Ltd, the joint venture between specialist engineering company Peter Brotherhood Ltd and wind turbine company REpower Systems AG set up in 2004 still continues.

FKI sold its Wind Turbine business DeWind GmbH ("DeWind") to EU Energy Shriram Ltd ("EU Energy") for Euro 75,000 in May 2005 removing the UK manufacturing link.

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, consultants, supply chain manufactures covering all major elements of a wind turbine, including blade manufacture, foundations, seabed survey, logistics and port storage, installation, cable laying, connections, standards/certification and O&M services.

Significant entry to the turbine supply chain market is currently limited because UK suppliers and turbine suppliers obtain the bulk of their components outside the UK. A project to encourage, support, and promote UK businesses to enter the supply chain for wind energy components through innovation and product development is being supported by the DTI and a number of UK Regional Development Agencies. The 'WindSupply' project has developed an open marketing database containing full details of UK companies and their products and services for the international wind energy market. It is targeted at international purchasers needing further suppliers for existing components or wanting to develop innovative new components and sub-assemblies. Further details can be obtained from <http://www.windsupply.co.uk>

At the small turbine end of the spectrum, a number of Building Mounted Wind Turbines (BUWTS) are either on or are very close to appearing on the UK market e.g. Proven's 2.5-kW WT 2500, Renewable Devices' 1.5-kW Swift, Windsave's 1-kW WS-1000, Eclectic Energy's 400-W D400, and Powertech Solar's Wind Tech-400. Others are undergoing testing e.g. Wind Dam's WD3 and XCO₂'s Quietrevolution. (Figure 10)

3.2 ECONOMIC DETAILS

Finance for wind farms is obtained largely from corporate investors and banks, though there is a small amount of private investment. Since the announcement of the Renewables Obligation, utilities and conventional power generators have

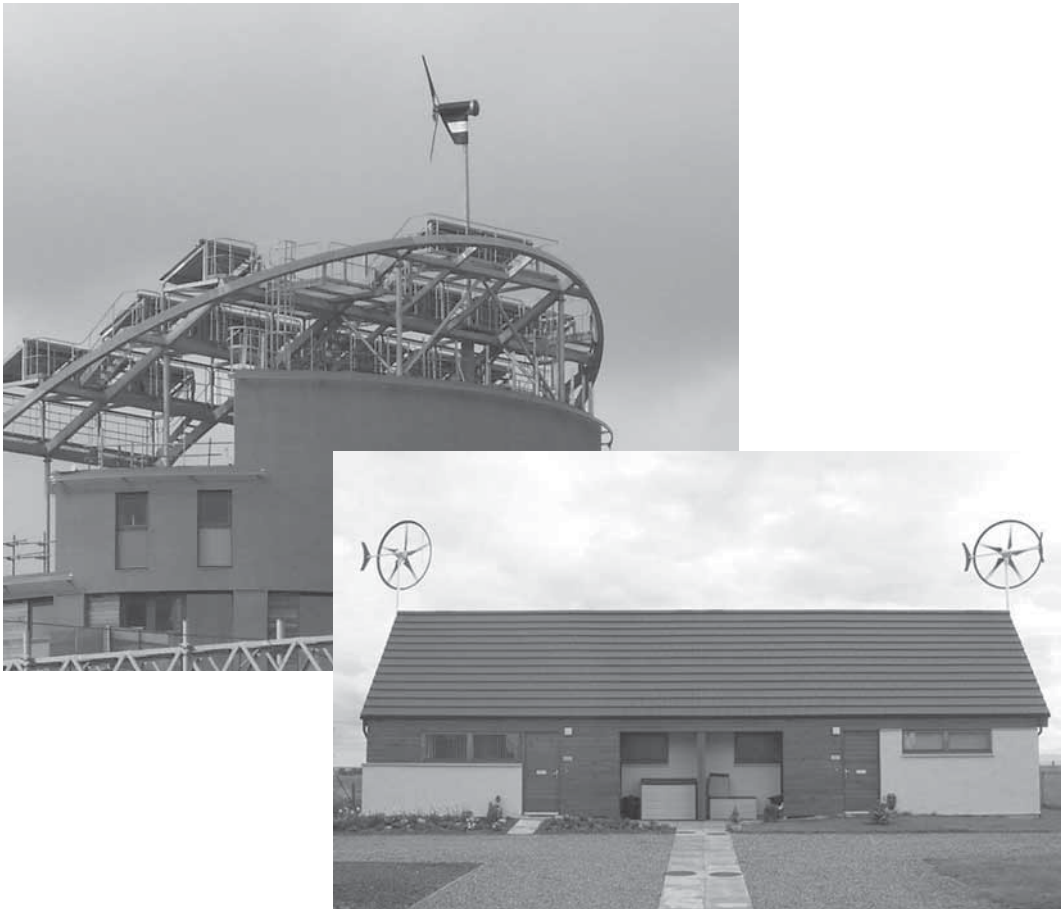


Figure 10 Proven's 2.5-kW WT 2500 installed on the Manchester Green Building (left), and Renewable Devices' 1.5-kW Swift installed on a Berwickshire Housing Association building in Whitsome, Berwickshire (right) (Photos courtesy of Proven & Renewable Devices).

become increasingly involved in wind farm development. Because of the high value the obligation places on renewables, corporate investment will yield good returns through an expansion of the core business whilst reducing their exposure to penalty payments. Wind has found particular favor because of its economics, maturity, and ability to deliver relatively quickly. As has already been stated, the investment case for wind has been boosted by the announcement of the increase in the level of the RO and of the review of the RO with input already given by the stakeholders on the draft terms of reference.

The present-day costs of installing wind energy in the UK are from 585 to 800£/kW onshore rising to 970 to 1430£/kW offshore. The additional costs of offshore installation include around 100£/kW for the electrical connection to shore and 150£/kW for inter-turbine cabling.

For offshore projects there is a move from EPC/turnkey contracts to multi-contract plant/design build contracts, which appears to be reducing the overall price of offshore development. There is some uncertainty due to the rise in the price of steel, turbine, and vessel availability as to how

much cheaper large installations now planned will be although studies in 2003 suggested that generating costs could fall by 30% or more. Price reductions will be achieved partly through economies of scale, partly through moving further offshore to higher wind speeds, and partly through 'learning curve' reductions.

Indications of power purchase prices come from published auction prices and trading prices from renewable energy certificates. Currently, the NFPA conducts green power auctions biannually. 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 NFPA power auction no.10, completed in August 2005, the price for wind was the highest to date at 90.5£/MWh. This compares to the February 2005 auction no.9 price of 62.60£/MWh and the prices in 2004 of 62.60£ and 73.10£/MWh for February and August respectively. The prices of ROCs traded quarterly in 2005 fell from 47.18£/MWh in January to 39.17£/MWh in October which had the opposite trend to the electricity only price. In 2004, the average prices were higher varying from 46.12£/MWh in October to a high of 52.07£/MWh in July.

4.0 NATIONAL INCENTIVE PROGRAMS

4.1 RENEWABLES OBLIGATION

The key support mechanism to enable the UK to meet its 10% target in 2010 remains the Renewables Obligation (RO). The RO requires licensed electricity suppliers to derive a specified proportion of the electricity they supply to their customers from renewables. The cost to consumers is limited by a price cap, and the obligation is guaranteed in law until 2027. The RO percentage

target is set to increase each year from its level of 5.5% in 2005/06 to reach 15.4% by 2015/16.

The RO and associated Renewables (Scotland) Obligation came into force in April 2002 as part of the Utilities Act (2000). The NI Renewables Obligations is similar and came into force in April 2005. The Renewables Obligation Order 2005 made changes to the Obligation resulting from a statutory consultation during 2004 and included an extension of the level of the Obligation to 15.4% by 2015/16; measures to secure the buyout fund; increased flexibility for small generators; and a single recycling mechanism and recognition of Northern Ireland Renewables Obligation Certificates (NIROCs) in Great Britain on the same basis as GB ROCs. Eligible renewable generators receive ROCs for each MWh of electricity generated. These certificates can then be sold to suppliers, in order to fulfil their obligation. Suppliers can either present enough certificates to cover the required percentage of their output, or they can pay a 'buyout' price of 30£/MWh for any shortfall. All proceeds from buyout payments are recycled to suppliers in proportion to the number of ROCs they present. ROCs can be freely traded and the price varies according to the ratio of ROCs to buy outs (which increase the overall value of the ROCs). ROCs have increased the viability of renewable energy generation and the certificates can currently sell for more than the power. This is especially true for wind energy generation, which can produce electricity at competitive prices.

The government undertook to review the Renewables Obligation in 2005/6. This Review was a focused look at certain specific issues where there might have been a strong case for change with a view to reducing the regulatory burdens on the companies who benefit from and/or are required to comply with the Obligation. This exercise has resulted in the Government making a number of specific measures to simplify the operation and administration of the Obligation in the following areas:

- Eligibility rules in the area of energy from mixed wastes – the changes here aim to deliver some additional renewable generation from biomass and mixed wastes without undermining the wider operation of the RO.
- Processes relating to the administration of the Obligation – the changes here aim to improve the administration of the Obligation and reduce regulatory burdens on companies that benefit from or are required to comply with the RO.

These changes enjoy the strong support of the renewables industry and subject to Parliamentary approval it is expected that they will come into force from 1 April 2006. Further details of the Review and the outcomes can be found at: http://www.dti.gov.uk/renewables/renew_2.2.5.htm

4.2 CLIMATE CHANGE LEVY

Running alongside the new RO is a drive for increased energy efficiency and the Climate Change Levy. Introduced on 1 April 2001, this is a new tax on energy use by both business and public sectors. The principal aim of the levy is to encourage non-domestic electricity users to become more energy efficient and so reduce carbon emissions. 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 PROGRAM

The Offshore Wind Capital Grants Programme was launched by the DTI and Big Lottery Fund in early 2002 in order to stimulate the early development of Round 1 offshore wind schemes. The 117 million £ Scheme provides the additional financial support required to get early projects started and should allow developers to gain experience and confidence to help reduce generation costs for subsequent future projects. The Capital Grant Scheme is a critical element of the government's overall policy to achieve 10% of electricity supplied by 2010 from renewable sources. The rate of deployment of projects has been slower than ini-

tial expectations. The increased costs of materials and services together with protracted contractual negotiations and a move to multi-contract arrangement have resulted in the build program of many Round 1 Offshore wind projects slipping, with the majority of projects now forecast to be commissioning in 2008. In 2006, Barrow should be commissioned, which is expected to be followed by Burbo in 2007; six of the remaining projects are anticipated to come on line in late 2008 and one in early 2009. Projects supported under the Capital Grant Scheme are shown in Table 3. Offshore wind will thus make a significant contribution to the government's target for 2010.

5.0 RD&D ACTIVITIES

5.1 National RD&D Efforts

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. The Technology Strategy Board, comprising mainly experienced business leaders, identifies the new and emerging technologies critical to the growth of the UK economy into which government funding and activities can be directed.

For the period 2005 to 2008 at least 20 million £/yr of Technology Programme funding is expected to support research and development into renewables and low carbon technologies, subject to high quality proposals coming forward and the ability of the sectors to demonstrate success from the support received. In 2005, approximately 1.3 million £ was spent on the wind program to support cost-shared R&D with industry.

In 2005, the Technology Programme ran competitions for funding in April and November. However, wind energy was not included in the April competition, although it was included amongst the renewable technologies in the

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Table 3 Round 1 offshore wind farms information and their capital grant scheme support

Round 1 Offshore Wind Farm	Capacity (MW)	Status	Online	Grant Value (M£)
North Hoyle Offshore Wind Farm	60.0	Commissioned	Jul-04	10
Scroby Sand Offshore Wind Farm	60.0	Commissioned	Dec-04	10
Kentish Flats Offshore Wind Farm	90.0	Commissioned	Nov-05	10
Barrow Offshore Wind Farm (Barrow)	90.0	Constructing	Apr-06	10
Burbo Offshore Wind Farm*	90.0		Dec-07	10
Norfolk Offshore Wind Farm	100.0		Apr-08	10
Rhyl Flats Offshore Wind Farm	100.0		Aug-08	10
Robin Rigg Offshore Wind Farm (Solway)	Up to 108.0		Dec-08	9
Inner Dowsing Offshore Wind Farm	97.2		Dec-08	10
Lynn Offshore Wind Farm	97.2		Dec-08	10
Gunfleet Sands Offshore Wind Farm	108.0		Dec-08	9
Robin Rigg Offshore Wind Farm (OERL)	Up to 108.0		Apr-09	9
Total	Up to 1,108.0			117

* Funded by the Big Lottery

autumn 'Low Carbon Energy Technologies' competition, with invitations for proposals sought on Offshore Wind technology.

5.1.1 R&D PRIORITIES

The autumn call recognized offshore wind as one of the key technologies with the potential to contribute to the UK's 2010 and 2020 generation targets. Specifically, the call identified the need to reduce the costs of offshore wind projects as one of the key factors in improving the economics of this technology and is essential to drive forward future investment in this sector.

Innovative proposals were invited that would reduce costs in the following areas:

- Marine foundations and the high cost of transporting and installing;
- Installation methods and Operation & Maintenance costs – including remote control and monitoring solutions;
- Weight saving, speed of installation, performance and reliability – in recognition that the move to larger machines offshore using existing scaling-up of technology will increase the weight of machines.

In addition, the call recognized that the interaction of wind turbines and radar remains a key barrier to both onshore and offshore development and proposals were sought to mitigate this problem, including air traffic mitigation solutions.

Proposals that address the above technology areas were sought for collaborative R&D projects that involve science-to-business and business-to-business interactions. Projects should tackle critical development issues, thereby offering significant prospects for improving understanding of the technology and improving their economic attractiveness. Projects can range from small, highly-focused basic research aimed at establishing technical feasibility, through to applied research and experimental development projects configured to produce technology demonstrators. In particular, projects were encouraged that could demonstrate benefits to a number of business sectors, and ideally should include at least one partner with defined end-user needs. Typically, a project would have a 2 to 3-year duration and require DTI support in the range 1 to 2 million £, although larger projects would be considered. Projects would generally aim to implement significant business change in a 5 to 7-year time frame. Further details of the Technology Programme can be found at http://www.dti.gov.uk/renewables/renew_2.2.5.htm

5.1.2 COMPLETED R&D PROJECTS

Two R&D projects concerning foundations for offshore wind turbines completed during the year. The FINPILE project aimed to improve the lateral stability of monopole foundations and establish potential for cost savings over alternative foundation types. Extensive laboratory and large scale testing was completed on finned piles and the results of the work complimented by numerical modelling using 3D finite element techniques and conventional pile design software techniques. Based on this fourteen month duration study, cost savings of between 55,000£ and 230,00 £ have

been estimated for an individual foundation depending on overall pile size.

The project 'Application of Suction Caisson Technology to Offshore Wind Turbines' was completed over 35 months. The main objectives were to develop suction caisson technology to the point at which it can be applied to the design of foundations for wind farms. The project developed existing mathematical models and validated/calibrated these using laboratory and large scale testing. The project demonstrated that suction caisson foundations are a feasible option for wind farms. The next stage in the development of the concept would be to install a full scale foundation for a wind turbine or for a meteorological mast. Further details on completed R&D projects can be found at <http://www.dti.gov.uk/publications>

5.2 COLLABORATIVE RESEARCH

During 2005, the UK was involved in several important collaborative research projects and initiatives. The Distant Offshore Windfarms with No Visual Impact in Deepwater (DOWNVIND) project is the world's first deep water wind farm and is due to be constructed 25km off the east coast of Scotland by late 2006. Two 5-MW wind turbines with a hub height of 90m a.s.l. will be installed in 44-m water in the Moray Firth adjacent to the Beatrice field oil platform. The project consists of two elements – the first is a Research and Technological Development (RTD) project funded by the European Commission (EC) together with support from more than a dozen participants. The second element is the 'Demonstrator project' which will receive funding from UK government authorities, the EC, together with contributions from the two project partners. The total project budget for both elements is around 28 million £.

The Concerted Action for Offshore Wind Energy Deployment (COD) project is a co-operation of energy agencies, energy departments and key par-

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ticipants. The aim of the project was to accelerate the deployment of offshore wind energy within the European Community by streamlining legislation, consenting procedures; environmental impact assessment; and grid integration. Information was exchanged between the national energy agencies of most sea-bordering member states in the EC including Belgium, Denmark, Germany, Ireland, the Netherlands, Poland, Sweden, and the UK. This represents 90% of the offshore wind energy potential within the EU. Garrad Hassan and Partners produced the Principal Findings Reporting.

COD's findings concerning legal and administrative issues concluded that it is not yet possible to determine best practices for national consent schemes. There is no need for harmonized approaches to trigger further or faster development of offshore wind energy activities. Further work on this issue does not seem necessary other than co-ordination through the regular channels especially beyond the 12-mile zone and notifying changes in regulation.

COD's findings concerning grid integration were that the main points of concern are transmission bottlenecks, power system stability, offshore transmission infrastructures and grid access, pricing and balancing. The project described the European electricity grid, and then focused on grid reinforcements, requirements from Grid Codes, aspects related to bundling of cables and the relationship between grid access, prices and balancing. Further international co-operation between the industry and Union for the Coordination of Transmission of Electricity (UCTE) and European Transmission System Operators (ETSO) is required.

COD's findings concerning the environment were that the knowledge of impacts are primarily based on 1-2 years of research at two offshore wind projects, so generalisation should be done with the greatest possible care. Substantial negative environmental impact has not, so far, been demonstrated but sites studies are limited. Further

work needs to be done to fill the knowledge gap and common definitions and approaches will need to be established in impact assessments. Further details on COD can be found at http://www.offshorewindenergy.org/index_cod.php

The UK worked with Denmark, Germany, and the Netherlands to prepare the Copenhagen Strategy on Offshore Wind Power Deployment which was finalised at the European Policy Seminar in Copenhagen 27 October 2005.

In addition to these projects, the UK participates in the following IEA annexes:

Annex XI - Base Technology Information Exchange

Annex XXI - Dynamic models of wind power farms for power system studies

Annex XXIII - Offshore wind energy technology development

Annex XXV - Power system operation with large amounts of wind power.

6.0 THE NEXT TERM

For the next year, there will be a continued push to deliver the Renewable Obligation targets for energy production with the government continuing 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, 778 MW are under construction and a further 2,133 MW of capacity is approved but not yet under construction. The Offshore Round 1 is expected to add 1,108 MW capacity by April 2009 and the Offshore Round 2 is expected to start construction in 2007 probably with the 300 MW Thanet Offshore Wind Farm.

In terms of R&D focus, as identified in the Technology Programme Autumn 2005 call, R&D activities will focus on those 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.

Expected trends for future offshore developments is a sizing-up of turbines with machine capacities increasing to 5 MW and larger.

REFERENCES

(1) Estimated from the sum of the Digest of UK Energy Statistics (DUKES 2005) figure for 2004 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 of 1,337.15 MW 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.

(2) Based on the price of installed capacity

(3) Figures from BWEA

Authors: Mark Thomas, Mike Blanch, Henry Parkinson and Aaron Stevens, Future Energy Solutions, United Kingdom.



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CHAPTER 29 UNITED STATES

1.0 INTRODUCTION (1)

The U.S. wind energy industry's prediction that 2005 would be a record-breaking year for new installations came to fruition at year's end with new installations totaling 2,431 MW. The capacity growth in 2005 broke the previous record set in 2001 of 1,697 MW. The new additions, worth more than 3 billion USD in generating equipment, brought the total national wind energy capacity to 9,149 MW. According to the American Wind Energy Association (AWEA) based in Washington, D.C., industry expects this unprecedented growth to continue in 2006 with installations topping 3,000 MW.

In 2005, wind power facilities generated approximately 28,000 MWh of electricity (Table 1) – enough to power 2.3 million average U.S. households. AWEA estimates that the 9,149

MW of installed wind power capacity will save more than half a billion cubic feet (Bcf) of natural gas per day in 2006. The United States currently burns about 13 Bcf/day for electricity generation, which means during 2006, wind power will reduce natural gas use for power generation by approximately 5%.

As of October 2005, renewable energy resources comprised approximately 2% of the total electricity generation sources in the United States. Wind energy comprises approximately 15% of the renewable generation sources (does not include hydroelectric) and approximately 0.3% of the total generation sources (Figure 1).

According to the U.S. Energy Information Administration, weather conditions and continuing economic growth are expected to increase electricity demand by 0.5% in 2006 and an additional 2.0% in 2007. Projected regional 2006 electricity prices, to the residential sector, range from 0.079 USD/kWh, in the East South Central region, to 0.139 USD/kWh, in New England.

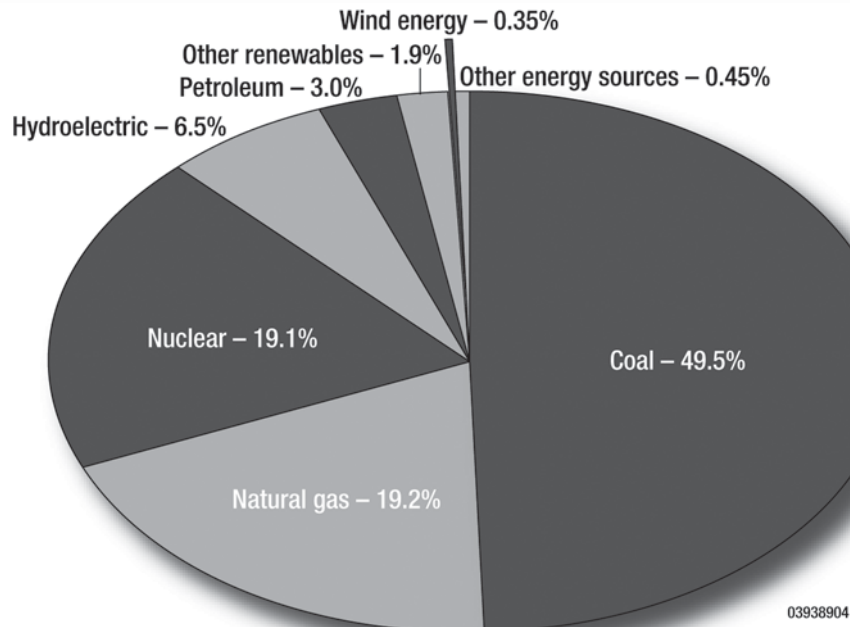
2.0 NATIONAL OBJECTIVES

In February 2006, U.S. President George W. Bush launched an Advanced Energy Initiative that provides for a 22% increase in funding for

Table 1 Key Statistics 2005: United States

Total installed wind generation	9,149 MW
New wind generation installed	2,431 MW
Total electrical output from wind	28,051 MWh
Wind sector turnover	NDA
Wind generation as % of national electric demand	<1%
Target:	

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U.S. Department of Energy, Energy Information Administration
 Figure 1 Net generation shares by energy sources, YTD October 2005.

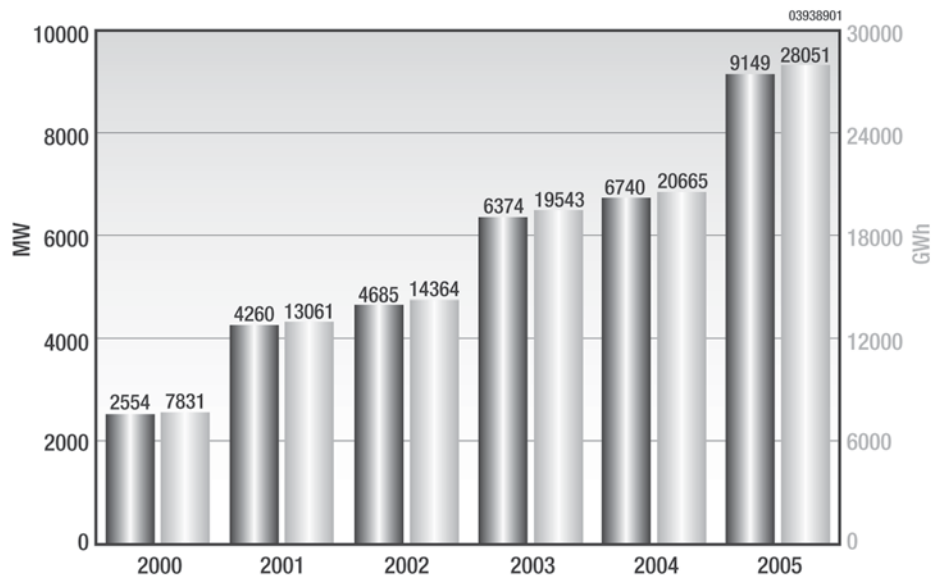


Figure 2 U.S. Capacity/generation history, 2000-2005.

United States - 2005 Year End Wind Power Capacity (MW)

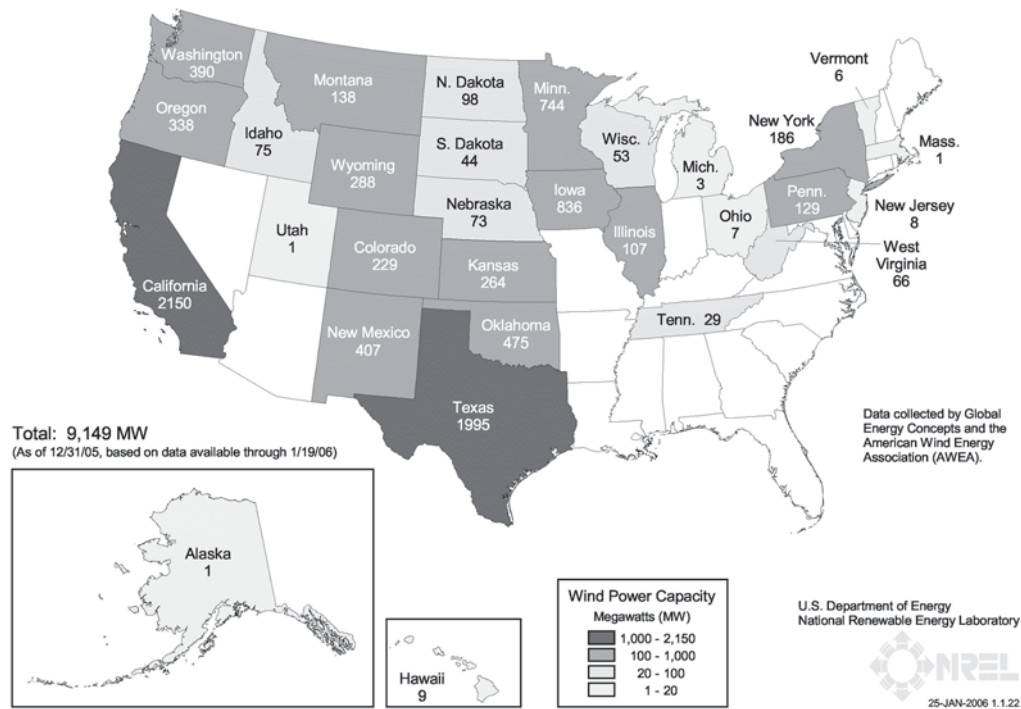


Figure 3 Wind power capacity map.

clean-energy technology research. According to the Initiative, areas with good wind resources have the potential to supply up to 20% of the electricity consumption in the United States.

As the fastest growing energy source in the United States, wind energy has enjoyed an annual average growth rate of 26% in the past six years; the largest growth occurred in 2005 (Figure 2). In 2005, capacity growth jumped from 6,740 MW to 9,149 MW, an increase of 36%.

The goal of the U.S. Department of Energy’s (DOE) Wind Powering America project is to have 30 states with more than 100 MW of generating capacity by 2010. Although there are currently commercial wind power facilities in 30 states, only 15 have more than 100 MW (Figure 3). The five states with the most generating capacity are:

- California with 2,150 MW
- Texas with 1,995 MW
- Iowa with 836 MW
- Minnesota with 744 MW
- Oklahoma with 475 MW.

In 2005, approximately 52 new projects were installed in 22 states that commissioned more than 1,600 turbines. The average size of the turbines is 1.5 MW. The five largest wind farms operating in the United States are:

- Stateline in Oregon/Washington with 300 MW
- King Mountain in Texas with 278 MW
- Horse Hollow in Texas with 210 MW
- New Mexico Wind Energy Center in New Mexico with 204 MW
- Storm Lake in Iowa with 193 MW.

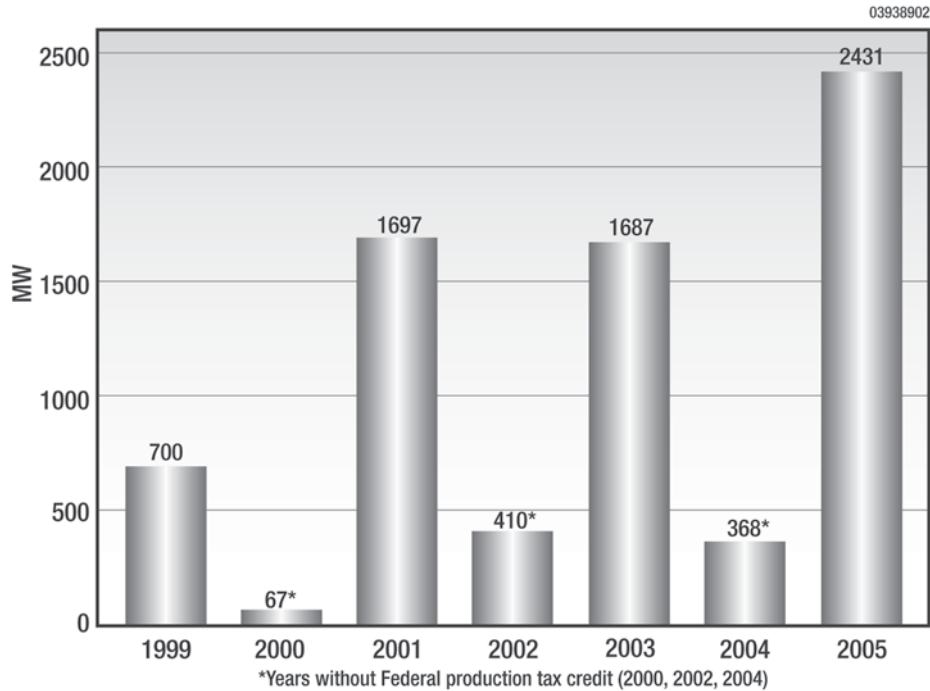


Figure 4 Effects of PTC expiration on capacity.

The record growth in 2005 is attributed to the passage of the Federal production tax credit (PTC) in October 2004. The PTC provides a 0.019 USD/kWh credit for the first 10 years of production. Originally enacted in 1992, the PTC has expired three times in the past six years. Industry growth slowed between each expiration and re-enactment, as shown in Figure 4. The PTC is set to expire again at the end of 2007.

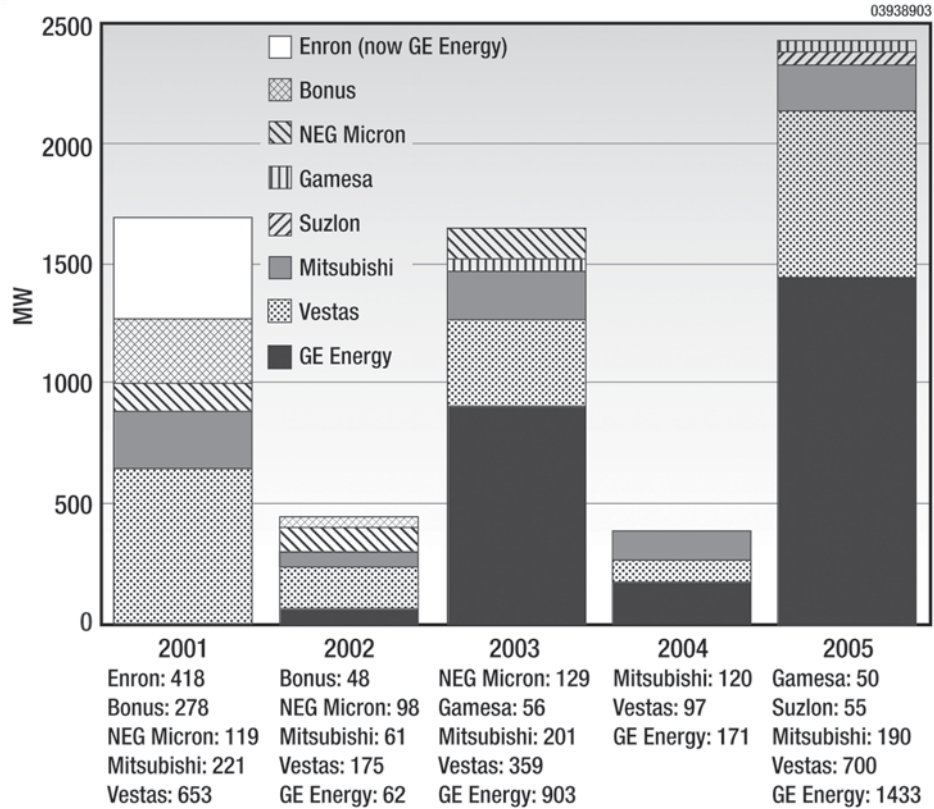
Although wind energy accounts for less than 1% of the electricity generated in the United States today, AWEA believes that by 2020, with consistent policy support, wind can provide at least 6% of U.S. electricity, or about the same amount that hydropower provides today.

At the current capacity of 9,149 MW, wind energy will displace emissions of more than 15 million tons of carbon dioxide annually. If wind energy

achieves the industry goal of 6%, it will displace about 3 quads (quadrillion Btu) of primary energy per year, and 65 million metric tons of carbon equivalent per year.

3.0 BENEFITS TO THE NATIONAL ECONOMY

In addition to cleaner air and more electricity for homes and businesses, wind energy development is boosting economic activity and providing new high-tech jobs and additional income to farms and rural communities. According to AWEA, the capacity added in 2005 provides clean power to the equivalent of 700,000 homes, approximately 3 billion USD investment in power generating equipment, an estimated 10,000 new job-years nationwide (10,000 one-year jobs or 1,000 long-term, 10-year jobs), and 5 million USD in annual payments to landowners.



U.S. Wind Energy Industry Rankings, American Wind Energy Association

Figure 5 U.S. wind energy industry rankings.

3.1 MARKET CHARACTERISTICS

The U.S. wind industry is composed of many small- to medium-sized companies that range from manufacturing facilities to companies that provide project development services, construction, operation and maintenance, and financing. A few of the larger firms, such as, GE Energy and Goldman Sachs are divisions of Fortune 500 companies. According to the Renewable Energy Policy Project, approximately 90 companies in 25 states currently manufacture wind turbine components.

In 2005, U.S.-based GE Energy claimed the largest portion of wind turbine manufacturing shares with 1,433 MW. Vestas, based in Denmark, came in second with 700 MW, and

Mitsubishi Power Systems, with a headquarters in Lake Mary, Florida, was third with 190 MW. Figure 5 shows the industry rankings for the top eight turbine manufacturers that supply capacity in the United States. Of the project developers responsible for adding the new generation, the top three were FPL Energy with 500 MW, PPM Energy with 394 MW, and Horizon Wind Energy with 220 MW.

The market for small wind systems is also experiencing significant growth. According to the first Small Wind Industry Market Study (2) published by AWEA's small wind turbine committee in August, nearly 43,000 small wind turbines with a total of approximately 30 MW are currently

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installed in the United States. Almost 4,700 turbines totaling 5 MW were sold in the United States in 2004, and industry expected that to increase to 8,300 turbines with an installed capacity of approximately 9.5 MW in 2005.

The U.S. small turbine manufacturers also play a leading role in the global small wind turbine market. According to the study, four U.S. manufacturers supply about one third of the global market.

3.2 INDUSTRIAL DEVELOPMENT

General Electric Energy (GE) delivered 1,346 wind turbines worldwide during 2005, generating more than 2 billion USD in revenue for the year. GE also conducted extensive testing on its new line of 2.5- and 3-MW machines in 2005 and plans to start serial production in 2006. The company is also moving ahead with its 3.6-MW offshore model that was first deployed at the offshore Arklow Bank Wind Park in Ireland. GE Energy Financial Services announced that it is forming an alliance with Starwood Energy Group Global, LLC to fund power generation development projects that include wind power projects. The alliance will initially focus on mid- to late-stage development projects with long-term equity investment potential in the United States and Canada.

Clipper Windpower, Inc., based in Carpinteria, California, opened a new wind turbine manufacturing plant in Cedar Rapids, Iowa. Clipper invested 22 million USD in the 300,000 ft² facility and plans to initially use 60,000 ft² of the facility to assemble the giant components for its new 2.5-MW Liberty wind turbine. The new facility will create 140 jobs by the fall of 2006 and Clipper plans to add manufacturing to the plant's activities. To develop funding, Clipper completed an initial public offering on London's AIM exchange and has developed a business strategy that includes wind turbine manufacturing and wind farm development.

Northern Power Systems (NPS) of Waitsfield, Vermont, was awarded a contract in October to install and commission three additional NorthWind 100 wind turbines for Anchorage-based Alaska Village Electric Cooperative (AVEC). Working with the generators at Toksook Bay, the three new turbines will produce approximately 675,000 kWh annually. They will replace more than 30% of the energy normally generated by diesel and, at current fuel prices, provide an estimated annual fuel cost saving of approximately \$100,000. The contract brings the total number of turbines AVEC has purchased from NPS to 10. The wind turbines will generate electric power for four of the 52 remote communities served by AVEC, including the communities of Toksook Bay, Savoonga, Gambell, and Kasigluk, located in western Alaska.

In September 2005, Xantrex Technology, Inc., of Carpinteria, California, agreed to supply converters for Clipper's new 2.5-MW Liberty wind turbine. The deal will generate more than 10 million USD in revenue for Xantrex over the next two years.

Gamesa Corporation based in Vitoria, Spain, plans to open a blade manufacturing plant at the South Park Industrial Complex in Cambria County, Pennsylvania. The plant is expected to create as many as 500 construction and operation jobs, including 236 permanent high-paying manufacturing positions.

Aerisyn, LLC, a wind turbine tower manufacturer founded in 2004 in Marshfield, Wisconsin, began operating the first automated wind tower production facility in North America in Chattanooga, Tennessee. Aerisyn invested more than 7 million USD in equipment and capital and expects to manufacture up to 200 utility-scale towers during its first year of operation. The company currently employs 70 people and plans to employ 150–200 people by the end of 2006.

In April 2005, LM Glasfiber, which has hired 100 new employees since October 2004, announced

plans to hire 40—50 employees to ramp up the production of its blade manufacturing plant in Grand Forks, North Dakota. The company, which supplies fiberglass blades for GE Energy wind turbines, also announced plans to open a new manufacturing facility in Gaspé, Quebec, Canada, to provide blades for 990 MW of new capacity in Canada and 1,400 MW of additional capacity in North America.

Suzlon, based in Pune, India, broke ground for a 14-million USD assembly plant in Pipestone, Minnesota, in October. The plant will employ 100—200 people to build blades and nose cones for 400 MW of turbines to be installed in the United States in 2006.

DMI Industries of West Fargo, North Dakota, announced that it is expanding its heavy steel wind tower fabrication operations into Canada with the purchase of a manufacturing plant in Fort Erie, Ontario. The plant, which expects to begin making deliveries in the summer of 2006, will employ 100 people during the first year.

4.0 NATIONAL INCENTIVE PROGRAMS

4.1 FEDERAL INCENTIVE PROGRAMS

The Federal Energy Policy Act (EPAct), enacted in 2005 (3), contains a number of provisions that benefit the wind energy industry including the extension of the Federal PTC through 2007. 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. As a production-based incentive, project developers and owners are the primary benefactors of the credit, and equipment manufacturers benefit from an active market. In addition to the PTC, the Act 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) – Businesses can recover investments in wind energy property through depreciation deductions.
- Renewable Energy and Energy Efficiency Improvements Program – 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 – Financial and technical assistance to tribes for feasibility studies and installations on tribal lands.
- Renewable Energy Production Incentive – Renewed under the 2005 EPAct, this incentive provides annual payments of 0.015 USD/kWh for electricity produced by new wind generation facilities for the first 10-year period of their operations.

4.2 STATE INCENTIVE PROGRAMS

Of the state programs offered to wind energy developers, the renewable energy purchase mandates, or renewable portfolio standards (RPS), have had the largest impact on industry growth. RPS requires utilities to purchase a percentage of their overall generating capacity from renewable resources. By the end of 2005, 20 states and the District of Columbia had adopted RPS and almost half of the 2,431 MW installed in 2005 resulted directly from state RPS policies.

Green power marketing programs have also had a significant impact on wind industry growth. Retail sales of renewable energy through green power marketing programs such as green pricing, competitive markets, and renewable energy certificates (RECs), increased by more than 60% to 6.2 billion kWh annually in 2004.

Through utility green power or “green pricing” programs, utility customers may choose to purchase green power for a premium to support a

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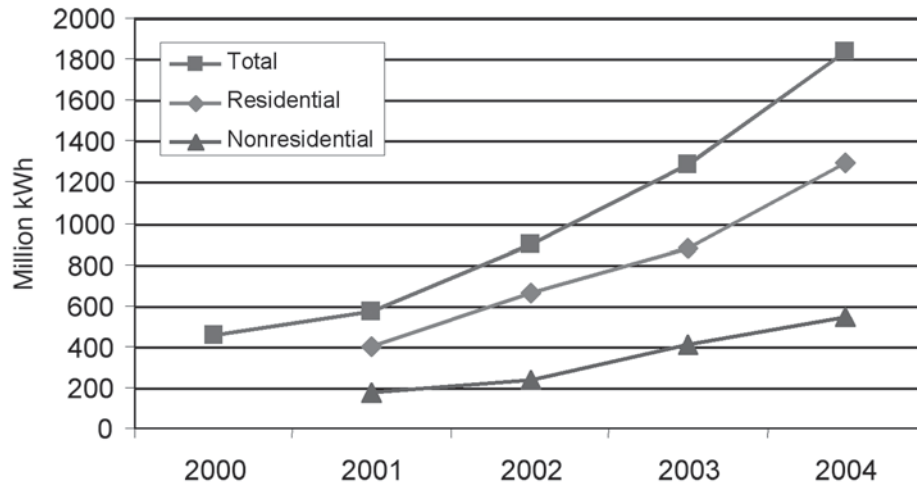


Figure 6 Utility green pricing sales, 2000 - 2004.

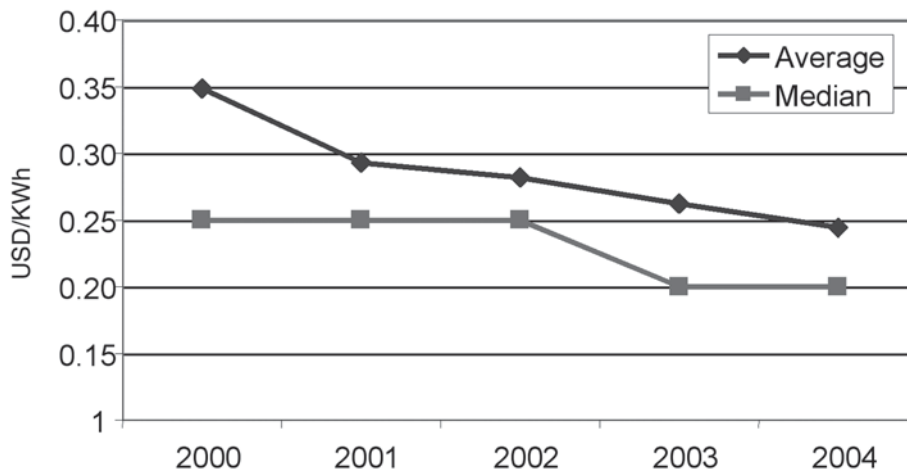


Figure 7 Trend in green pricing premiums, 2000 - 2004.

greater level of utility company investment in renewable energy technologies. To date, nearly 600 utilities in 34 states, including investor-owned, municipal utilities, and cooperatives, have either implemented or announced plans to offer a green pricing option. According to a study published by the National Renewable Energy Laboratory (NREL) in October 2005, by the end of 2004, more than 330,000 customers were participating in utility green pricing programs nationwide. Participation in green pricing programs increased

by an annual average rate of 38% from 1999 through 2004, and sales to participants totaled more than 1.8 billion USD in 2004 (Figure 6). Although participation numbers have increased, green power premium prices dropped during this time frame by an annual average rate of 8% (Figure 7).

Consumers may also purchase power generated by renewable resources through competitive markets and RECs. About one-third of the states have

restructured their electricity markets to introduce retail service competition that allows consumers to purchase their electricity from alternative electricity suppliers that offer green power.

As an alternative to switching electricity suppliers, consumers may support the development of renewable energy resources by purchasing 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. Residential and nonresidential consumers can purchase RECs from more than two dozen suppliers nationwide via the Internet. By the end of 2004, approximately 200,000 consumers had purchased green power or RECs from competitive suppliers.

Other state programs that provide stimulus for market growth include:

- **Production Incentives** – Usually funded by a small surcharge on electricity rates (USD/kWh), 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 net metering, investment incentives, tax incentives, and low-interest loan funds. Investment incentives and net metering are considered to be the most important programs.

- **Investment Incentives** – Often administered by renewable energy funds, 24 states offer direct rebates or grants to small wind

electric systems that sometimes cover more than half of the installed cost of the systems.

- **Net Metering** – Net metering encourages direct customer investment in renewable energy. Under this policy, electric customers who install their own grid-connected wind turbines would be 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 September 2004, 41 of the 52 states and territories offered some form of net metering policy.

5.0 RD&D ACTIVITIES

5.1 NATIONAL RD&D EFFORTS

To ensure the future growth of the wind industry, DOE’s Wind Energy Program conducts R&D on wind energy technologies that will operate cost effectively at lower wind speed sites. Although competitive COE levels have been achieved at higher wind speed sites with average wind speeds of 6.7 m/s at a height of 10 m (15 mph at a height of 33 ft), as the industry continues to grow, the number of easily accessible prime high-wind-speed sites is dwindling. Lower wind speed sites with average wind speeds of 5.8 m/s at a height of 10 m (13 mph at 33 ft) cover vast areas of the Great Plains from central and northern Texas to the Canadian border and are found along many coastal areas in the Great Lakes and along shallow coastal areas of the eastern United States.

To develop technologies that will work cost effectively in these regions, program researchers at NREL’s National Wind Technology Center (NWTC) near Boulder, Colorado, and at Sandia National Laboratories (SNL) in Albuquerque,

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New Mexico, work with industry through cost-shared partnerships. The level of cost-sharing required depends on the size of the procurement and the accompanying technical risk. The industry partners lead new technology designs and make commercial decisions while the laboratories provide theoretical and technical support through applied research and performance testing.

5.1.1 FUNDING

Funding for wind energy technology R&D that was conducted under DOE's Wind and Hydropower Technologies Program was 39.8 million USD for fiscal year (FY) 2004. The funding increased slightly in FY 2005 to 40.6 million USD.

5.1.2 TECHNOLOGY VIABILITY

Solicitations for low wind speed turbine (LWST) partnerships were completed in 2001 and 2004. A third solicitation is envisioned for early 2007. Solicitations offer bidders an opportunity to participate in one of three technical areas: concept and scaling studies, component development, or LWST prototype development.

In 2005, three U.S. manufacturers worked with DOE to develop low wind speed multi-megawatt prototypes. Clipper Windpower completed the fabrication of its 2.5-MW Liberty prototype turbine in 2004 and began field testing it at a site in Medicine Bow, Wyoming (Figure 8), in 2005. Clipper's new design uses a highly innovative



Figure 8 Clipper Windpower's 2.5-MW Liberty prototype turbine at a site in Medicine Bow, Wyoming.

multiple-drive path gearbox feeding four advanced permanent magnet generators. The multiple-drive path design radically decreases individual gearbox component loads, which reduces gearbox weight and size. Clipper began commercial production of the new machine at the end of 2005. GE Energy completed the preliminary design for a land-based multi-megawatt prototype turbine in 2005 that includes advanced controls, a more efficient drivetrain, an innovative rotor, and a taller tower. In 2006, GE will begin work on the design for a new multi-megawatt turbine for offshore applications. NPS began a multi-megawatt prototype development that incorporates a permanent-magnet, direct-drive generator, and optimized power electronics.

DOE is also working with several small wind turbine companies to develop more efficient, cost-effective machines. NPS is developing a design to modify its 100-kW cold weather turbine for farm and community applications. Southwest Windpower is currently conducting acoustic, performance, and load tests on its new 1.8-kW prototype at NREL. Abundant Renewable Energy is working on a concept design for a 10-kW system that will produce electricity for 0.11 USD/kWh in moderate wind resources. Wetzel Engineering is working on a concept design for a 6-kW system that will produce electricity for 0.08 USD/kWh in low wind speed resource areas. Both companies completed preliminary design reviews in 2005.

In addition to prototype turbines, DOE is working with several companies to develop components for utility-scale and small, distributed wind turbines. Genesis Partners LLP is working on a new gear tooth form that analytically promises major improvements in the power density of gears, especially as applied to wind turbines, while lowering the cost of these devices. NPS completed the fabrication of a new design for a 1.5-MW, direct-drive, permanent-magnet generator, with a novel power converter to allow variable-speed operation. NPS is also developing a multi-megawatt

advanced power converter configuration that will optimize the operation of its generator.

Small wind turbine component development includes a project with Windward Engineering to develop a unique overspeed control system. The system will undergo field tests in 2005 on a 5-kW machine developed specifically to test the control system. Princeton Power Systems developed a 50-kW AC-AC converter prototype that was tested by SNL in 2005, and Composite Engineering is developing a 7.5-m, reaction injection molded, variable-pitch blade for 50–100-kW machines.

Seven land-based concept studies were underway or completed in 2005. Two of the studies explored alternative approaches to power conversion. Peregrine Power Technologies is exploring the potential of replacing silicon with silicon carbide in electric switches, and Behnke, Erdman, and Whitaker Engineering completed a study on the use of medium voltage components. Voltages higher than the 575- and 690-volt designs that are currently in use may reduce the overall cost of converter systems as machines become larger than 1.5 MW. Another study conducted by Native American Technologies Company explores a method to form and fabricate towers on site to reduce fabrication and transportation costs. GE Global Research conducted a study that examined concepts for integrating reverse-osmosis desalination with wind energy that included cost of energy modeling. A study conducted by QinetiQ investigated the potential of LIDAR systems for sensing turbine inflows and attenuating adverse loads when integrated with appropriate controllers and actuators.

Global Energy Concepts is conducting two concept studies. The first study looks at operations and maintenance costs and developing a model to assist developers and operators in exploring innovative ways to improve designs and maintenance procedures. The second study is investigating ways to reduce the COE through active control of rotor aerodynamics and geometry.

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Three of the concept studies conducted under the Wind Program's LWST initiative investigated technologies for offshore applications. Massachusetts Institute of Technology is conducting a study that employs dynamic response simulations to evaluate at least two floating platform concepts for offshore wind turbines deployed in water depths of 50—200 m. Concept Marine Associates completed the evaluation of a semi-submersible platform and anchor foundation system that can support a 5-MW wind turbine, and AWS Truewind, LLC is conducting a study to characterize the offshore wind and wave environments of the Atlantic and Lower Great Lakes regions in which these turbines will operate.

5.1.3 TECHNOLOGY ACCEPTANCE

To address the non-technology barriers to the use of wind energy systems and facilitate equitable treatment of wind energy in the national grid, the U.S. Wind Energy Program conducts research in systems integration and technology acceptance. 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 address 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.

To gain a better understanding of systems integration issues, in 2005, NREL researchers worked to develop models that simulate the performance of wind power plants, their impacts on the transmission system, and the sources of disturbances that affect wind power quality. NREL worked with industry partners and utility groups to obtain the data needed to characterize wind power plants by instrumenting wind farm substation output, providing specialized data acquisition systems, and conducting specialized data processing and analyses of operating wind systems.

In addition to government-sponsored grid integration research, AWEA has been working with wind industry representatives (manufacturers, owners, developers, utilities, constructors) to establish grid codes that will provide developers with an improved process for interconnection and a uniform set of requirements that are known to all equipment vendors. If accepted, the codes will apply to wind generation projects 20 MW and larger that have not signed an interconnection agreement with the transmission owner or operator when the codes become effective. AWEA expects the Federal Energy Regulatory Commission to rule on its grid code proposal in 2006.

To gain technology acceptance on the state and regional levels, the program's Wind Powering America project works with Federal agencies, state and local energy offices, Native American agencies, rural agencies, electrical cooperatives, and utilities. WPA project activities include exploring wind applications for investor- and consumer-owned utilities, enhancing rural economic development tools and outreach, supporting the formation and maintenance of working groups to advance the use of wind energy in each state, and providing general technical assistance and outreach.

The goal of the WPA project is that "By 2010, at least 30 states will have 100 MW of wind installed." In 2005, WPA convened a nationwide state wind working group summit and provided technical and outreach support on wind technology for public power, multi-state, and agricultural events. By the end of 2005, 32 states had more than 20 MW of installed wind capacity and 16 states had at least 100 MW of installed capacity.

The Wind Program also works to resolve environmental issues that may hinder technology acceptance and deployment for both land-based and offshore wind energy technologies. To gain a better understanding of the environmental issues, NREL is working with the National Wind

Coordinating Committee to provide technical and strategic analysis support for Wildlife Working Group activities; the Bat Conservation International and the wind industry to investigate bat kills at a wind farm in Maryland; and the Bureau of Land Management on preliminary environmental impact statements. For offshore siting issues, DOE is working with the Minerals Management Service (MMS) within the Department of Interior. Under the 2005 Energy Policy Act, the MMS, which has regulated the offshore oil and gas industry and other mineral extraction activities in Federal waters for 40 years, was granted the authority to evaluate the potential impacts of compatible uses of the Outer Continental Shelf, such as wind energy development, to marine resources. The Wind Program also provides technical support and presentations to industry and environmental groups about wind facilities and wildlife impacts.

5.1.4 TESTING AND CERTIFICATION FACILITIES

To accomplish the U.S. research, development, and demonstration goals, NREL and SNL work with private industry partners and researchers from universities nationwide to develop advanced wind energy technologies. Each laboratory is extensively equipped with a unique set of skills and capabilities to meet industry needs. SNL conducts research in advanced manufacturing, component reliability, aerodynamics, structural analysis, material fatigue, and control systems. NREL's NWTC conducts research across the complete spectrum of engineering disciplines that are applicable to wind energy. It is designated as the lead research facility for the U.S. Wind Energy Program. NWTC researchers provide technical support in the form of design review and analysis; dynamometer, field, and blade testing services; and field verification and certification services for wind turbines that range in size from 400 watts to 2.5 MW.

NWTC's industry partners can use the Center's facilities to conduct atmospheric, static-strength,

and fatigue tests on turbine components, and its 2.5-MW dynamometer to conduct lifetime endurance tests on a wide range of wind turbine drive trains and gearboxes. In addition, the NWTC has two permanently installed advanced wind turbines to test new control schemes and equipment, test pads for manufacturers that need to test their prototype machines, and a hybrid systems test bed to test systems that integrate wind energy, solar cells, fuel cells, and diesel or gas generators.

As part of its certification services, in 2005 NWTC researchers worked with Germanischer Lloyd of Hamburg, Germany, to approve NREL's wind turbine design codes for calculating onshore wind turbine loads for design and certification. Although many U.S. wind turbine manufacturers have relied on these design codes to estimate the design loads of their turbines in the past, until recently the codes were not accepted by certifying agencies in Europe.

5.2 COLLABORATIVE RESEARCH

In addition to working with industry partners, universities, and special interest groups, DOE supports the IEA Wind Energy Annexes by attending executive committee meetings and is the operating agent for several of the Annexes.

The objective of Annex XX – HAWT Aerodynamics and Models from Wind Tunnel Measurements, is to increase understanding of the aerodynamics of horizontal axis wind turbines (HAWT) by using new data from a full-scale wind tunnel experiment conducted in 2000 to develop and validate model subcomponents that can then be used to improve comprehensive aerodynamic models. During 2005, participants continued research activities previously proposed and the research results were presented and discussed at the Task XX Annual Progress Meeting, which was held in May at the Centro Nacional de Energías Renovables (CENER), in Pamplona, Spain. As in previous years, the Task XX meeting was held in conjunction with the Task XI Aerodynamics of Wind Turbines meeting.

Annex XXI – Dynamic Models of Wind Farms for Power Systems Studies coordinates the development and validation of wind farm models that are suitable for evaluating power system dynamics and transient stability. In 2005, NREL contributed to a study on Dynamic Models of Wind Farms for Power System Studies. The report provides an overview of the available wind farm models and presents a systematic approach for model benchmark testing.

The objective of Annex XXIII – Offshore Wind Energy Technology and Deployment is to give participants an overview of the technical and environmental assessment challenges encountered in offshore applications and help them to understand the areas of further R&D needed. As one of its operating agents, the United States supports this Annex by leading a research effort in wind turbine technologies for applications in water deeper than 30 m (Figure 9). The goal of this research is to develop better computer models for analyzing and evaluating offshore wind turbines on various types of foundations. Current offshore technologies are based on designs that were adopted from marine industries for shallow water applications. For offshore technologies to advance to deeper water and become economical, design uncertainties like those associated with load prediction, must be reduced so that appropriate safety margins can be applied.

At a workshop held at RISØ National Laboratory in January 2005, participants formed a working group named Offshore Code Comparison Collaboration (OC³) to focus on coupled turbine/substructure dynamic modeling. The working group determined that at least six structural dynamic codes are under development or modification for more accurate prediction of support structure load modeling. Model comparison is the first step in quantifying and reducing load prediction uncertainties. The objectives OC³ include:

1. Identify and verify model capabilities and limitations
2. Establish confidence in predictive capabilities
3. Establish analysis methodologies

4. Identify areas needing further research and testing.

As part of its research into the potential benefits of combining wind and hydropower to provide a stable supply of electricity to the grid, the United States is also the operating agent for Annex XXIV – Integration of Wind and Hydropower. The two purposes of this annex are to conduct cooperative research concerning the generation, transmission, and economics of integrating wind and hydropower systems and to provide a forum for information exchange. As part of its contribution to the R&D conducted under Annex XXIV in 2005–2006, the United States is developing at least three case studies, the Missouri River Case Study, the Lower Colorado River Case Study, and the Grant County Public Utility District Case Study, to analyze the grid integration issues and costs related to combining wind and hydropower resources. The case studies selected represent some of the diversity found in hydro facilities and control areas throughout the western United States.

The Missouri River Case Study will analyze the potential for, and impact of, integrating wind power in the Western Area Power Administration (WAPA) control area that is supplied in part by electricity from six large hydro facilities on the Missouri River, with a large amount of hydro impoundment (water storage). The objectives of this project are to create a realistic wind generation scenario for North and South Dakota in wind development “zones” identified by WAPA, and to determine the incremental impacts of varying levels of wind generation on operation and scheduling in the WAPA control area. Project completion is expected in 2006.

For the Lower Colorado River Case Study, the Arizona Power Authority will work with Northern Arizona University and NREL to examine ways to make the best use of its federal hydropower allocation and transmission rights and the potential to combine hydropower generation with renewable energy generation, in particular wind energy, in Arizona. The partners

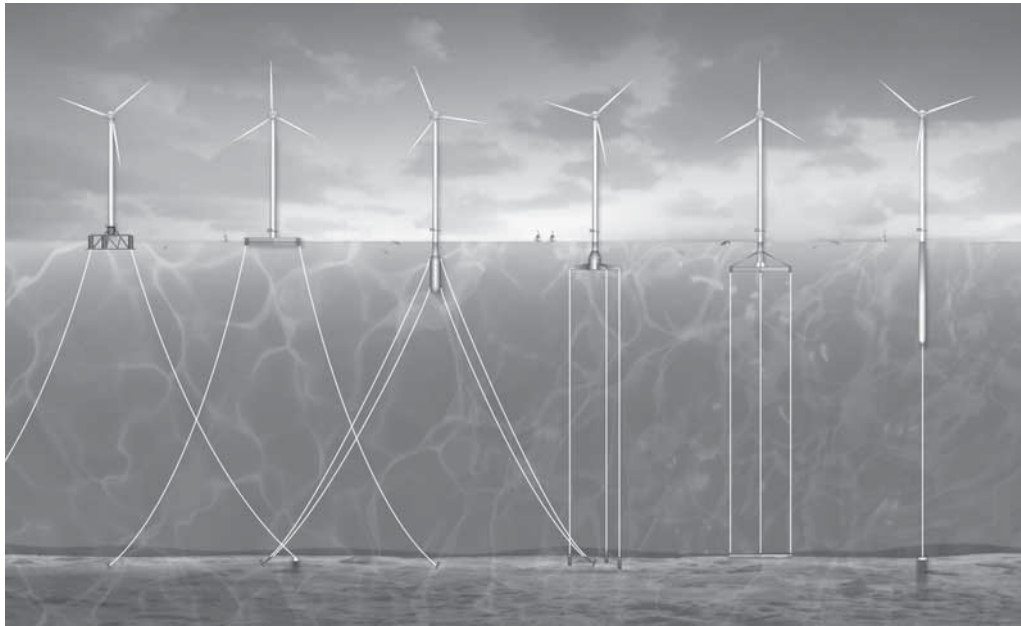


Figure 9 A wide range of platform architectures are being considered for floating offshore platforms in water deeper than 30 m.

in this project include the Bureau of Reclamation, Western Area Power Administration, along with Arizona utilities and Native American Tribes.

The Grant County Public Utility District Case Study will study ways to expand the district's wind energy generation through effective integration with its hydropower operations. The district owns and operates the two-dam Priest Rapids Project on the Columbia River in central Washington. Together, Priest Rapids and Wanapum hydroelectric dams make up one of the nation's largest hydropower developments, with the capacity to produce approximately 2,000 megawatts of electricity. In addition to its hydropower generation, the District also purchases 12 MW (18.88% share) of the 63.7 MW Nine Canyon Wind Project. The district integrates the wind output via a dynamic signal into the district's control area, essentially putting the output in the Priest Rapids Project's pond. The ability to combine hydropower with wind power beyond the current level offers potential benefits to the district's customers and possibly

to other interconnected parties. The two primary goals of this study are to understand the impacts and costs of the district's current efforts at integrating wind and hydropower and to study the potential for future expansion of wind integration.

Preliminary results showed that at wind energy penetration levels of 3.5% (12 MW), 18.5% (63.7 MW), and 44% (150 MW), the impact upon regulation is quite small. The Grant County Case Study results will be presented at the next Annex XXIV R&D meeting to be held in Hobart, Tasmania, Australia, in September 2006.

The ultimate objective of Annex XXV – Power System Operation with Large Amounts of Wind Power is to provide information to facilitate the highest economically feasible wind energy penetration within electricity power systems worldwide. The annex 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 will

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review the U.S. methodology/studies completed to date, which include:

- Xcel North Study (Minnesota Department of Commerce), EnerNex/Windlogics
- The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations, prepared by GE Energy, Energy Consulting for the New York State Energy Research and Development Authority, February 2005
- A 15% penetration study to be performed by EnerNEX with DOE support on Sacramento Municipal Utility District. This study will use the AREVA dispatch simulator used for training utility operators that allows for simulation of the power system response to the variable wind energy generation. Issues of accuracy of wind forecasting will be addressed. DOE/NREL also plans to coordinate with the Irish TSO, which also uses the AREVA simulator.
- NREL is investigating the use of GE MARS, a model of the transmission system and wind plant locations, to address the ability to move wind and power system reserves where they are needed.

6.0 THE NEXT TERM

As the U.S. Wind Energy Program looks to the future of large-scale wind technology, it appears that the technology will take three development paths: land-based, offshore, and emerging applications (Figure 10). Each path will present its own set of technology challenges and unique non-technology barriers.

The land-based electricity path, which is an important focus of the current U.S. Wind Energy Program, is expected to result in very cost-competitive 2- to 5-MW turbine technology. The program's goal is to reduce the COE for multi-megawatt wind systems to 0.036 USD/kWh in Class 4 wind resources (average wind speeds of 5.8 m/s at a height of 10 m) by 2012. In 2006,

the program will continue to work with industry partners to develop turbine architectures that can achieve the program's goal by providing technical support, funding, and project management for on-going prototype and component development and conceptual design studies.

The land-based electricity path will also include continued support for the small wind industry. In 2006, the U.S. Wind Energy Program will continue to work with its industry partners to develop advanced small wind systems (turbines up to 100 kW) that operate cost effectively in many regions of the country and for a wide variety of applications. Similar to the utility-scale activities, the small wind activities will continue to focus on technological innovations that will reduce the COE in lower wind speed regions. The program's goal is by 2007, to reduce the COE from distributed wind systems to 0.10–0.15 USD/kWh in Class 3 (5.3 m/s) wind resources, the same level that is currently achievable in Class 5 (6.2 m/s) wind resources.

The offshore electricity path envisions a migration of current technology to offshore sites, first into relatively shallow waters and then later into deeper waters. Higher quality wind resources (reduced turbulence and increased wind speed), proximity to loads (many demand centers are near the coast), increased transmission options, potential for reducing land use and aesthetic concerns, and the easing of turbine size constraints due to transportation and installation are a few of the advantages that have drawn attention to offshore wind energy development. Recent studies show significant offshore wind resources in regions that are close to major urban areas in the mid-Atlantic and Northeast. Preliminary estimates conducted at NREL indicate there is more than 1,000 GW of offshore wind energy potential in the United States between five and 50 nautical miles off the coastlines, including the Great Lakes, with approximately 810 GW over waters that are 30 m and deeper.

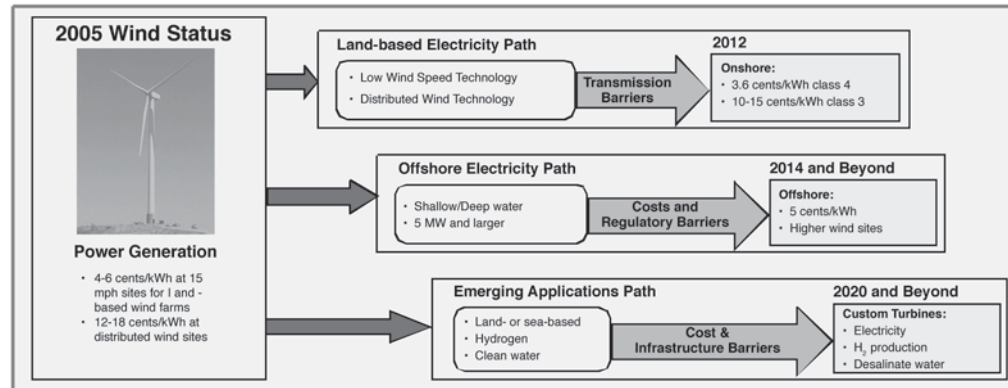
Wind Energy Pathways
DOE View

Figure 10 Future technologies will follow three development pathways.

The U.S. Wind Energy Program has identified a multiyear three-phase strategy for developing the technologies that will allow the United States to harness the offshore wind resource base: near-term/shallow water, mid-term/transitional depth, and long-term deepwater. Near-term/shallow water technologies will focus on water depths of 30 m or less that are generally near the shore with relatively benign external conditions. For this pathway, the program is committed to a goal of 0.05 USD/kWh in Class 6 (6.7 m/s at a 10 m height) winds by 2014. Mid-term/transitional depth technology development will focus on turbine support structures for installations at depths up to approximately 60 m and technologies to offset inherent adversities such as increased distance from shore, decreased accessibility, and more severe environmental conditions. This technology development pathway is planned to begin in FY 2007 with a goal of 0.05 USD/kWh in Class 6 winds by 2016. Long-term/deepwater technology development will focus on turbine support structures (primarily floating systems) that are suitable for waters as deep as 900 m, integrated design of wind turbines for floating platforms, and improvement of operation and maintenance costs.

In 2006, the U.S. Wind Energy Program will launch a new initiative called SeaCon (sea-based

concept studies), which is the first major step in its multiyear offshore research efforts. The SeaCon studies will define the requirements for offshore wind infrastructure and technology development, and identify technology improvement opportunities for offshore wind technologies.

The emerging applications pathway leads toward the design of wind energy technologies that are tailored for emerging applications like hydrogen production, the production and delivery of clean water, and integration with other energy technologies such as hydropower.

Using wind to produce hydrogen may offer wind technologies an opportunity to provide low-cost, clean energy for the transportation sector. In addition, co-producing electricity and hydrogen for the power and transportation markets may significantly reduce the total wind-hydrogen system cost. Production of hydrogen may also offer opportunity to better balance variable energy production from wind farms with electricity demand in some regions, through coordinated co-located operation, or delivery of wind-generated electricity via the grid to distant electrolyzers serving population centers. In 2006, the U.S. Wind Energy Program will conduct research to identify the most appropriate ways to link wind turbines and electrolyzers

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and identify technical and market barriers that need to be better understood for wind-hydrogen applications to progress.

Another emerging application is the combination of wind and hydropower technologies. To examine the potential benefits of combining wind with hydropower technologies to provide a stable supply of electricity to the grid and relieve some of the stress placed on finite water supplies, DOE hosted a Wind Water Nexus Workshop at NREL in November 2005. The workshop was originally planned in conjunction with the IEA Annex XI – Base Technology Information Exchange meeting, but the IEA meeting was cancelled. Presentations at the workshop were made by experts in the areas of wastewater treatment, municipal water supply, coal bed methane production, desalination, and irrigation. As a result of participant recommendations, the Wind Program decided to focus its 2006 research on analysis of the technical and policy issues and opportunities for wind in the natural gas driven irrigation market and municipal water supplies. The Wind Program will also continue to monitor the desalination technology developments while expanding the GIS mapping of wind-desalination opportunities.

Municipal water and wastewater operations are energy intensive industries. Energy used by water systems accounts for more than 3% of total electric demand in the United States. Eight of the 10 states with the largest public water supply withdrawals and 9 of the 10 states with the highest per capita water consumption have good to excellent wind resources. The use of wind energy to help provide power for municipal water supplies in these regions will also help reduce the amount of water needed for hydroelectric supplies. For more

information on the research conducted by NREL on wind/municipal water supply applications see Wind Energy Applications for Municipal Water Services: Opportunities, Situation Analyses, and Case Studies; <http://www.nrel.gov/docs/fy06osti/39178.pdf>.

Irrigation, which is the second largest water user after thermoelectric power in the United States, has traditionally used systems powered by diesel, gasoline, electricity, propane, or natural gas. Nine of the top 10 irrigation states are in regions with good to excellent wind resources, which is another excellent opportunity for wind energy to provide a clean renewable source of energy for irrigation.

NOTES AND REFERENCES

- (1) This work has been authored by an employee of the Midwest Research Institute under Contract No. DE-AC36-99GO10337 with the U.S. Department of Energy. The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for United States Government purposes.
- (2) Small Wind Industry Market Study, American Wind Energy Association, http://www.awea.org/AWEA_SWT_Market_Study_6-05.pdf
- (3) Energy Policy Act, 2005 http://www.electricity.doe.gov/program/electric_oa_policy_energy_epacthome.cfm?section=divisions&level2=oandm_policy_energy

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APPENDIX A



Attendees of the 55th Executive Committee in Porto, Portugal



APPENDIX B

Appendix B IEA WIND EXECUTIVE COMMITTEE 2005

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APPENDIX C

Currency Conversion Rates IEA Wind Annual Report 2005			
Country	Currency	1 Euro	1 USD
Australia	AUD	1.613	1.362
Austria	Euro	1.000	0.844
Canada	CAD	1.380	1.165
Denmark	DKK	7.461	6.299
Finland	Euro	1.000	0.844
Germany	Euro	1.000	0.844
Greece	Euro	1.000	0.844
Ireland	Euro	1.000	0.844
Italy	Euro	1.000	0.844
Japan	JPY	139.593	117.880
Korea	KRW	1196.040	1010.000
Mexico	MXP	12.585	10.628
Netherlands	Euro	1.000	0.844
New Zealand	NZD	1.880	1.388
Norway	NOK	7.987	6.744
Portugal	Euro	1.000	0.844
Spain	Euro	1.000	0.844
Sweden	SEK	9.3999	7.937
Switzerland	CHF	1.557	1.315
United Kingdom	GBP	0.689	0.582
United States	USD	1.184	1.000
Source: Federal Reserve Bank of New York (www.x-rates.com) 30 December 2005			

APPENDIX D

Glossary of terms and abbreviations.

AUD	Australian dollar	GHG	greenhouse gas
CEN/CENELEC	European Committee for Standardization/ European Committee for Electrotechnical Standardization (the original language is French); similar to ISO/IEC	GW	gigawatts
CHP	combined heating and power or cogeneration of heat and power	GWh	gigawatt hour
CIGRE	International Council on Large Electric Systems	HAWT	horizontal axis wind turbine
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	hydro	hydroelectric power
COE	cost of energy	IEA	International Energy Agency
DKK	Danish Kroner	IEC	International Electro-Technical Commission
DFIG	doubly fed induction generator	IEEE	Institute of Electrical and Electronics Engineers
DG	distributed generation	IPP	independent power producer
DNV	certifying organization (Danish)	ISO	international standards organization
DSM	Demand-side management	IT	information technology; Italy
EC	European Commission	kW	kilowatt
EEZ	Exclusive Economic Zone	kWh	kilowatt hour
EIA	Environmental impact assessment	£	United Kingdom pound
EU	European Union	m	meter
ExCo	Executive Committee of IEA Wind	m a.g.	meters above ground
FY	fiscal year	Mtoe	million tonnes of oil equivalent
GEF	Global Environment Facility	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

APPENDIX D

repowering	taking down old turbines at a site and installing newer ones with more generating capacity	UK	United Kingdom
		UN	United Nations
		UNDP	United Nations Development Programme
RPS	renewables portfolio standard	U.S.	United States
S.A.	Sociedad Anonima	USD	U.S. dollar
tCO ₂ -e per capita	tonnes of carbon dioxide emissions per person	VAWT	vertical axis wind turbine
TNO	transmission network operator	wind index	describes the energy in the wind for the year, compared with a normal year
TSO	transmission system operators	WT	wind turbine
TW	terawatt	yr	year
TWh	terawatt hour		

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