IEA
Wind Energy
Annual Report
2003

International Energy Agency
Executive Committee for the

Implementing Agreement
for Co-operation in the
Research and Development
of Wind Turbine Systems

April 2004

Front cover photo: The Arklow Bank offshore windfarm, Ireland, uses 3.6-MW turbines for an installed capacity in 2003 of 25 MW. Photo Courtesy Airtricity.

Back cover photo: Atlantic Wind Test Site, Prince Edward Island, Canada's national wind test site.

Foreword

The twenty-sixth IEA Wind Energy Annual Report reviews the progress during 2003 of the activities in the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems under the auspices of the International Energy Agency (IEA). The agreement and its program, which is known as IEA R&D Wind, is a collaborative venture among 23 contracting parties from 20 IEA member countries and the European Commission.

The IEA, founded in 1974 within the framework of the Organization for Economic Co-operation and Development (OECD) to collaborate on international energy programs, carries out a comprehensive program about energy among 26 member countries. IEA R&D Wind was one of more than 40 implementing agreements of IEA in 2003.

This report is published by PWT Communications in Boulder, Colorado, United States, on behalf of the IEA R&D Wind Executive Committee. It was edited by P. Weis-Taylor, with contributions from experts in participating organizations from Australia, Canada, Denmark, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Mexico, the Netherlands, Norway, (two contracting parties, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

Jørgen LEMMING
Chair of the Executive Committee
(2003-2003)

Patricia WEIS-TAYLOR
Secretary to the Executive Committee

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

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Message from the Chair

This year has been a significant one for the development of wind energy. The world's wind generating capacity grew by more than 8.3 gigawatts (GW) in 2003 to a total of about 40 GW by the close of the year. Of this world capacity, a full 90% is installed in the countries that participate in the IEA R&D Wind agreement. By the end of 2003, the total installed capacity in the IEA R&D Wind countries reached 35 GW and included 493 MW of offshore generation, about 1.4% of the total.

Jørgen Lemming, Chair 2002-2003

We are pleased to report that the energy production from wind turbines in the IEA R&D Wind member countries is making an impact. The total production in 2003 was equivalent to more than the entire energy needs of Switzerland or nearly twice the needs of Denmark. In some countries, a significant portion of national electricity demand is being met by wind generation. For example, Denmark now meets more than 20% of its electricity demand from wind energy.

In addition to the widely recognized environmental and energy benefits of wind-generated electricity, many countries see that wind energy can offer economic and social benefits as well. In countries with a strong market for wind energy generation, there is also a great opportunity for commerce and employment, which can be especially welcome in rural areas. The value of the global market for wind turbines in 2003 was estimated at over 7 billion US dollars (USD). On top of this, the value of related services for the operation of installed plants was estimated at an additional 1 billion USD. So an expansion of the wind sector is accompanied by opportunities for industry. This is well demonstrated by Denmark, Germany, Spain, and the United States, which have developed strong national industries and have become exporters of turbines and components.

Along with benefits, the growth of the wind energy sector has generated new issues and challenges. To address these challenges, the IEA R&D Wind agreement brings experts together and conducts collaborative research (Annexes) to maximize the benefits of the member countries' national activities. For example, grid integration issues are a challenge to the expansion of wind power in some countries. The IEA Wind Annex XXI *Dynamic models of wind farms for* *power system studies* builds on current research and is accelerating the learning process for participating countries. The member countries of IEA R&D Wind are always considering new opportunities for international collaboration to increase knowledge and understanding to meet challenges as they arise.

I hope you will find this IEA Wind Energy Annual Report both interesting and informative. We report in Chapter 2 on the work of our cooperative research (Annexes), on the activities of the Executive Committee (ExCo) of the IEA R&D Wind agreement, and on selected news about the International Energy Agency. Chapter 3 provides an overview of national activities and highlights the key issues and changes at the national level. This compressed analysis is designed for decision makers in any country. Finally, chapters 4 through 21 present detailed information about wind energy research, development, and demonstration, (R,D&D) in each of the member countries.

For additional information about our activities or to send us comments about this report, please visit our Web site at http://www.ieawind.org

Jørgen Lemming, Chair of the Executive Committee, 2002 to 2003

Chapter 1

Executive Summary

The continuous progress of wind energy brings with it many new challenges. To meet these challenges the IEA R&D Wind Implementing Agreement provides a vehicle for conducting cooperative research activities and exchanging information. In 2003, the IEA R&D Wind Agreement was extended for another five years to encourage and support the technological development and global deployment of wind energy technology. To guide the activities of the ember countries, a strategic plan was developed and approved by consensus.

> The Wind Implementing Agreement's mission is to stimulate co-operation on wind energy research and development and to provide high quality information and analysis to member governments and commercial sector leaders by addressing technology development and deployment and its benefits, markets, and policy instruments.—
>
> ***Strategic Plan of IEA R&D Wind for 2003-2008***

Tackling Grid Issues

Approved in 2002, Annex XXI *Dynamic models of wind farms for power system studies* demonstrates the very real benefits of effective international co-operation. A diversity of views have been aired on the levels of confidence that can be placed in models simulating the interaction of wind installations with the grid, especially for very large projects under grid fault conditions. For example, the Irish Utilities have halted progress on two large wind farms because of worries about grid interaction. On the other hand, participants heard at the first Annex meeting, that dynamic models have been used with confidence in the United States to accept large wind farms in Texas.

By facilitating a coordinated effort to develop wind farm models suitable for evaluating power system dynamic and transient stability, participants in Annex XXI hope to assist the planning and design of wind farms. Time domain turbine response data is being put onto a database for the use of participants and bench-mark tests will enable participants to compare model performance. One early consequence of this work may be an update of IEC standard 61400-21, to include turbine response to given fault conditions; thus enabling the direct measurement of fault conditions rather than relying on models.

Cold Climate Activity Warming Up

The IEA R&D Wind work on wind turbines in cold climates (Annex XIX) has produced some hard results in 2003. Wind energy is increasingly being used in cold climates, and technology has been adapted to meet these challenges. Annex XIX was initiated in 2002 to supply much needed information on the operation of wind turbines in cold climates. In 2003, Participants in the task published a report titled *The State-of-the-art of Wind Energy in Cold Climates*. This report summarizes information on available wind turbine technologies that are intended to be used in low temperatures and icing climates. The report can be downloaded in a pdf format from the project Internet pages at http://articwind.vtt.fi.This link also leads to a discussion forum launched in 2003, enabling more people to share their expertise and experiences about wind turbines operating in cold climates. Continuing with the Annex work plan, participants began drafting guidelines in 2003 for applying wind energy in cold climates.

Developing Improved Load Data and Models for Turbines

Improving wind turbine design and continuing the trend toward lower-cost wind energy, will require aerodynamics models of greater accuracy and reliability than those currently in use. To achieve this, theoretical and computational models must evolve alongside high-quality experimental measurements. Continuing work completed in previous years, several member countries of IEA R&D Wind initiated Annex XX *HAWT Aerodynamics and Models from Wind Tunnel Measurements*.

This cooperative research activity began with wind turbine test data from the NASA Ames wind tunnel and data collected during previous IEA R&D Wind work under Annexes XIV and XVIII. The first meeting was held in May 2003, at NREL's National Wind Technology Center, near Boulder, Colorado. The participants began work to acquire accurate, reliable, high-resolution experimental aerodynamic and structural loads data for turbines representative of full-scale machines. They will then go on to analyze the data and to formalize the understanding of models and their computational efficiency. The final step will integrate model sub-components into comprehensive models.

Wind Characteristics Database on the Internet

A unique database of wind characteristics has been developed under Annex XVII at Risø National Laboratory, Denmark for the benefit of wind turbine designers, researchers, planners, and the international wind engineering community. The database contains vigorously controlled wind field data (time series and resource data) observed in a wide range of different wind climates and terrain types; and all available through the Internet. (Link posted on www.ieawind.org)

Completed at the end of 2003, the database has seen progressive expansion and improvement since its inception in 1996. The database has 215 registered uses and contains more than 175,000 hours of high-sample-rate data. A wide variety of wind climates, terrain types, and wind turbine wake situations are available from 58 sites in Europe, Egypt, U.S.A., and Japan. For three of the sites, the meteorological time series are complemented by structural time series from nearby turbines. The work has also made a fundamental contribution to international standardization by calibrating wind field parameters and quantifying rare events of crucial importance to turbine structural integrity.

Comparison of Testing Facilities Complete

To validate wind turbine testing procedures, analyze and resolve sources of discrepancies, and so improve testing methods and procedures, IEA R&D Wind work under Annex XVI was completed in 2003. A series of round-robin tests were conducted at participating national laboratories using identical machines and comparable test instrumentation and data acquisition equipment. The tests showed that commonly used anemometers produce differences in readings in complex terrain of up to 2%. They also showed that the measurement of blade pitch settings is more difficult and uncertain than previously assumed. The full final report has been approved by the participants for public release and can be downloaded from the Website

Offshore Wind Approaching Deep Water

Participants in the IEA R&D Wind agreement recognize the importance of developing more collaboration on R&D issues of offshore wind energy deployment. A Topical Expert Meeting on the subject scheduled for early 2004 may result in a proposal for cooperative research through a new annex dedicated to offshore.

One aspect of offshore of great interest to some participating countries is the development of suitable structures for wind turbines in deep water (more than 30 meters). The United States sponsored a meeting October 2003 to review the technical status of offshore wind turbine systems in water depths greater than 30 meters. Lessons learned from the offshore oil and gas industry were reviewed. Wind sites in deeper water offshore may have distinct advantages over conventional land-based and near-shore wind sites. Resource studies indicate that wind speeds increase with the distance from shore, and the number of possible deep-water sites is enormous.

New Activity in Integrating Wind Generation and Hydropower

As wind generation has become a mainstream technology, issues of power variability and scheduling have produced a keen interest in the potential for combining wind generation and hydropower systems. In 2003, a Topical Experts Meeting on this subject was held in Portland, Oregon, USA. Participants concluded that future collaboration on wind/hydro integration would be beneficial for countries participating in both the wind energy and hydropower implementing agreements of IEA. Future activities will focus on the sharing of information on experience, modeling, and educational outreach. There was a high level of interest and the subject will be taken forward through either the formation of a new annex to the IEA R&D Wind implementing agreement or through continued topical expert meetings.

Chapter 2

The Implementing Agreement and Active Annexes

2.1 THE IMPLEMENTING AGREEMENT

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 R&D Wind) began. The past 26 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 R&D Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

Every five years, the contracting parties have decided to extend the IEA R&D Wind implementing agreement. In 2003, the agreement was extended once again and a new Strategic Plan was adopted outlining objectives for the coming years. The mission of the IEA R&D 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 R&D 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 R&D Wind. Australia, Austria, Canada, Denmark, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Mexico, the Netherlands, New Zealand, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States are now members. (See Table 2.1.1)

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.

National Programs

The national wind energy programs of the participating countries are the basis for the IEA R&D Wind collaboration. These national programs are directed toward the evaluation, development, and promotion of wind energy technology. An overview of national program activities in 2003 is presented in Chapter 3 of this Annual report. Individual county activities are presented in Chapters 4 through 21.

Collaborative Research

Participants in the IEA R&D Wind Agreement are currently working on six cooperative

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 Technical Research Centre of Finland (VTT Energy)
Germany	Forschungszentrum Jülich GmbH
Greece	The Ministry of Industry/Energy and Technology (CRES)
Ireland	The Irish Energy Center
Italy	CESI S.p.A. and ENEA Cassaccia
Japan	National Institute of Advanced Industrial Science and Technology (AIST)
Mexico	Instituto de Investigaciones Electricas (IIE)
Netherlands	The Netherlands Agency for Energy and the Environment (NOVEM)
New Zealand	Pending
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	Energimyndigheten
Switzerland	The Swiss Federal Office of Energy
United Kingdom	Department of Trade and Industry
United States	The U.S. Department of Energy

Table 2.1.1 Contracting parties to the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems in 2003

research tasks, which are approved by the Executive Committee as Annexes to the original Implementing Agreement. Progress in cooperative research is described later in this chapter. Tasks are sometimes 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. Countries choose to participate in tasks that are relevant to their current national research and development programs. Several additional tasks are planned when new areas for cooperative research are identified by Members. (See Table 2.1.2)

Member countries benefit from sharing the effort and expense of research performed in the Annexes. The level of effort on a task is typically the equivalent of several people working for a period of three years or longer. The projects are either cost-shared and carried out in a lead country, or task-shared,

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 XI	**Base technology information exchange OA: FFA, Sweden. (1987 to present)**
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 XIX	**Wind energy in cold climates OA: Technical Research Centre of Finland - VTT Energy. (2000 to 2003)**
Task XX	**HAWT Aerodynamics and models from wind tunnel tests and measurements. OA: NREL, the United States. (2003 to 2005)**
Task XXI	**Dynamic models of winf farms for power system studies. OA: Sintef Energy Research, Norway. (2003 to 2005)**
Task XXII	**Market development for wind turbines. On hold.**

Table 2.1.2 Cooperative research tasks defined in Annexes to the IEA R&D Wind implementing agreement

when the participants contribute in-kind effort, usually in their home organizations, to a joint program coordinated by an Operating Agent. To date, 14 tasks have been successfully completed and two tasks have been deferred indefinitely. (See Table 2.1.3)

To obtain more information about the cooperative research activities, contact the Operating Agent Representative for each task listed in Appendix B.

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 from 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. 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 2003, Mr. J. Lemming (Denmark) served as Chair, Mr. P. Goldman (United States) served as Vice-Chair and Mr. S-E Thor (Sweden) served as Vice-Chair. At the 52nd Executive Committee (ExCo) meeting, Mr. Goldman was elected Chair beginning in 2004 and Mr. S-E Thor was re-elected Vice-Chair for 2004.

Participants
In 2003, Portugal accepted the invitation to join the agreement bringing total membership to 20 participating countries and the European Commission. Germany withdrew from the IEA R&D Wind implementing agreement effective 1 January 2004. (See Appendix B for an updated list of Members, Alternate Members, and Operating Agent representatives.) During the year, the Executive Committee invited representatives from Korea who attended the ExCo meeting as observers.

Meetings
The ExCo normally meets twice a year for Members to review ongoing tasks; plan and manage cooperative actions under the Agreement; and report on national wind energy research, development, and deployment activities (R,D&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 51st ExCo meeting was hosted by Sustainable Energy Ireland, in Dublin, Ireland, 29 April to 1 May 2003. There were 25 participants from 14 of the contracting parties and three operating agent representatives of the tasks. The ExCo reviewed and approved technical progress reports of ongoing tasks XI, XVI, XVII, and XIX; and approved progress on new annexes contingent on several steps being completed within one year. The new tasks are XX, Horizontal Axis Wind Turbine (HAWT) Aerodynamics and Models from Wind Tunnel Measurements, operating agent, NREL, the United States; XXI, Dynamic Models of Wind Farms for Power System Studies, operating agent, Sintef Energy Research, Norway. Task XXII, Wind Energy Market Acceleration remained on hold pending decisions at IEA. The audit report of 2002 accounts of the Common Fund was approved. On 1 May 2003, the ExCo visited the Corneen Wind Farm operated by Airtricity.

The 52nd ExCo meeting was hosted by Natural Resources Canada, at Charlottetown, Prince Edward Island, Canada on 8 October to 9 October, 2003. There were 26 participants from 16 of the contracting parties, three operating agent representatives of tasks, and several observers, including two observers from the Republic of Korea.

The ExCo invited the Republic of Korea to become a member and welcomed Portugal, which formally joined the agreement. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2004. *The Strategic Plan of IEA R&D Wind for 2003 Through 2008* was approved by email ballot. On 10 October 2003, the ExCo visited the Atlantic Wind Test site, the national wind energy test site of Canada.

	XI	XVI	XVII	XIX	XX	XXI	XXII
Country	**Base Technology Information Exchange**	**Round Robin Test (Completed)**	**Database of Wind Charac-teristics**	**Wind Energy in Cold Climates**	**HAWT Aero-dynamics and Models from Wind Tunnel Tests**	**Models for Wind Farm Power Systems**	**Market Develop-ment for Wind Turbines (on hold)**
Australia							
Austria							
Canada	x	x		x	x		
Denmark	x	x	OA		x	x	x
European Commission	x						
Finland	x			OA		x	
Germany	x						
Greece	x	x			x		
Ireland	x					x	
Italy	x						
Japan	x		x				
Mexico	x						
Netherlands	x		x		x	x	
New Zealand							
Norway	x		x	x	x	OA	
Portugal						x	
Spain	x				x		
Sweden	OA		x	x	x	x	
Switzerland				x			
United Kingdom	x						
United States	x	OA	x	x	OA	x	x
Start Date	1987	1995	1999	2001	2003	2003	2003
End Date	Ongoing	2004	2004	2004	2005	2005	On hold

Table 2.1.3 Participation of member countries in Annexes during 2003. (OA indicates operating agent, which manages the task)

The 25th issue of the *IEA R&D Wind Annual Report* was published in April 2003 along with a poster commemorating 25 years of international cooperation.

2.2 TASK XI - BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this task is to promote wind turbine technology by co-operative activities and information exchange on R&D topics of common interest. These particular activities have been part of the IEA Wind Implementing Agreement since 1978. The annex was extended in 2003 for the years 2004 and 2005.

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 that requires recommended practices. In the series of Recommended Practices, 11 documents have been published. Five of these have appeared in revised editions (Table 2.2.1). Due to high demand, the documents on noise emission and cup anemometry were reprinted during 2003. Many of the documents have served as the basis for both national and international standards.

The second sub-task is to conduct joint actions in specific research areas designated by the IEA R&D Wind ExCo. So far, Joint Actions have been initiated in aerodynamics of wind turbines, wind turbine fatigue, wind characteristics, offshore wind systems, and wind forecasting techniques. Symposia and conferences have been held on each of these topics. In addition to Joint Action Symposia, Topical Expert Meetings are arranged on topics decided by the IEA R&D Wind ExCo.

Over the 24 years since these activities were initiated, 41 volumes of proceedings from Expert Meetings (Table 2.2.2) and 25 volumes of proceedings from Joint Action Symposia (Table 2.2.3) have been published.

The following activities were conducted in 2003:

- Joint Action Symposium 16 on Aerodynamics of Wind Turbines
- Joint Action Symposium 3 on Wind Conditions for Wind Turbine Design
- Topical Expert Meeting 41 on Integration of Wind and Hydropower Systems
- A pending meeting on Critical Issues Regarding Offshore Technology and Deployment will be arranged early 2004

Joint Action Symposium 16 on Aerodynamics of Wind Turbines

This meeting was held in the United States at NREL in Boulder, Colorado, and gathered 21 participants representing nine different countries. The meeting was held on 5-6 May 2003, immediately followed by the kick-off meeting for the new Task XX, HAWT Aerodynamics models from Wind Tunnel Measurements. From this meeting, the following topics-of-interest list was gathered:

- Vortex wake model development
- Near, far, and prescribed wake models
- Rotational augmentation, 3-D effects
- Dirt and abrasion effects on transition, separation, and performance
- Turbulent inflow and CFD methods
- Atmospheric boundary layer modeling and low-level jets
- CFD experiments with extraction of angle of attack, CL, CD, and Cm for Beam Element Methods (BEM) modeling
- Simulations and comparison with actual behavior (Task XX)
- Dynamic stall modeling and unsteady aerodynamics
- Basic studies of yawed wakes
- Tower shadow
- BEMs in aero-elastic simulation (instead of modal formulation)
- Improvement of engineering models
- More NASA tests; a second project may be within reach

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

Table 2.2.1 List of Recommended Practices

- 3-D actuator disc model development
- Aerodynamics of parked rotors; background data are lacking
- Aero-acoustics

A discussion was held on the subject of how to continue the exchange of aerodynamic knowledge in the future, especially in the light of the fact that Task XX has started "aero-mining" activities. It was considered to be a duplication of efforts to run both Task XX and Task XI aero meetings during the time frame when Task XX is in operation. It was proposed that Task XI aero meetings are co-arranged with Task XX in the future.

Joint Action Symposium 3 on Wind Conditions for Wind Turbine Design

Design of wind turbine structures requires a broad spectrum of external load situations to be addressed, including both ultimate- and fatigue-type loading. As turbine size increases, the importance of ultimate loading also increases.

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 2.2.2 List of Topical Expert Meetings held since 1990. For a complete list of meetings see www.ieawind.org.

A fatigue load analysis requires the consideration of wind load components of both periodic deterministic and stochastic character. The wind contribution to the periodic deterministic load component basically arises from (horizontal/vertical) mean wind field shear (and yaw errors). Contrary to onshore sites, surface roughness (and thus wind shear) associated with off-shore sites depends on the mean wind speed through the wave characteristics. The stochastic wind loading, caused by turbulence, is traditionally being modeled by means of synthetic stochastic wind fields with prescribed turbulence characteristics. Gaussian statistics is conventionally assumed for simple terrain categories, whereas non-Gaussian statistics may be required for more complex types of terrain. In addition to traditional turbulence loading, caused by the "undisturbed" turbulence in the atmospheric boundary layer, the stochastic loading in wind farms, caused by meandering wakes, poses a particular challenge.

The extreme loading to be considered in an ultimate limit state analysis of a wind turbine structure may result from a variety of extreme load events, among which are the extreme wind events. Extreme wind events include peak (mean) wind speeds (typically imposed on a wind turbine during stand-still) as well as peak (short-term) changes in wind speed, wind direction, and wind shear (typically to be imposed on a wind turbine during normal operation). In analogy with the fatigue load case, the extreme loading of stand-alone turbines usually differs from the extreme loading imposed on turbines situated in wind farms.

During the symposium, at Risø National Laboratory in Denmark, 13 presentations were given. The presentations covered a broad spectrum of external wind turbine load situations, encompassing low cycle fatigue loading; the impact of atmospheric stability on offshore wind characteristics; simulation of Gaussian/non-Gaussian turbulence fatigue loading; simulation of dynamic loading caused by wake meandering; combined wind and wave loading; determination of peak factors in ultimate loading; simulation of (extreme) wind gusts using constrained simulation; description of an existing extreme wind climate; variability in design load prediction caused by variability in code and

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				
1	**2002**	**SMHI**	**Norrköping**	**Sweden**

Table 2.2.3 List of Joint Action Symposia
***Meetings prior to 1994 not listed here.**

recommendation prescriptions; and rational calibration of code prescriptions based on the *Database on Wind Characteristics*. In addition, the content and potential of *Database on Wind Characteristics* as a source of a large number of high-quality representative full-scale site wind field measurements accompanied by a selection of analysis tools, were demonstrated.

Topical Expert Meeting 41 on Integration of Wind and Hydropower Systems

The meeting, held in Portland, Oregon, the United States, gathered 28 people from four different countries (Canada, Norway, Sweden, and the United States). Six of the participants came from outside of the United States. Participants came mainly from utilities in the United States and had a hydro-power background.

Wind power is an intermittent, variable power output technology. Because of these characteristics, wind power is typically not controlled, or dispatched, by utilities. This operational mode imposes unique challenges on integrated utility grid operations. When low amounts of wind are added to an interconnected grid system, changes to grid operations are minor or negligible. However, as wind penetration increases, operations of other generators may require modification, resulting in increased costs. Although these additional costs do not occur only with wind-generation additions, the nature of these additional requirements associated with wind is of considerable interest. The imposed additional system costs are a function of grid characteristics and increasing wind penetration, and are not well characterized at this time. These additional system costs are becoming a prime concern in some countries because the lifecycle costs of wind-generation equipment have decreased to levels competitive with conventional fossil-based generation, and are expected to create strong interest in wind power capacity additions. In other countries, wind is considered as a benefit, not associated with extra system costs.

All documents produced under Task XI are available from the Operating Agent representative (listed in Appendix B). More information can be found on the Internet at http://www.windenergy.foi.se/IEA_Annex_XI/ieaannex.html.

Author: Sven-Erik Thor, FOI, Sweden

2.3 TASK XVI - WIND TURBINE ROUND ROBIN TEST PROGRAM

IEA is developing international recommended practices for development and testing wind turbines, and the International Electrotechnical Commission Technical Committee 88 (IEC-TC88) and other agencies are developing international norms and standards. When countries adopt these new standards, a mechanism should be in place to ensure that turbines are tested and certified to common criteria. Common criteria could enable different countries to accept foreign certification in lieu of their own. However, countries have found that there can be discrepancies between tests conducted in different locations using different test equipment. A round robin test of anemometers demonstrated that even simple wind speed measurements could be significantly affected by different anemometer calibration procedures. Power curve, noise, and load tests of full turbines for certification programs in different countries may reveal important differences. A basis for exchanging test reports should be established to demonstrate that these tests could be reliably conducted in different locations by different testing agencies and achieve similar results. Results from this demonstration would facilitate international certification harmonization efforts.

A series of round robin comparison tests at participating national laboratories and other interested test stations have been suggested as a means of validating test procedures and establishing reciprocity between different certification testing laboratories. All participating laboratories will test identical machines at their own facilities, using comparable test instrumentation and data acquisition equipment. Discrepancies in the test data will be resolved and serve as the basis for improvements in testing procedures and calibration methods. This effort could also serve as justification for mutual recognition of foreign certification.

Objectives

The objectives of this program are to (1) validate wind turbine testing procedures, (2) analyze and resolve sources of discrepancies, and (3) improve testing methods and procedures.

Task descriptions

The main components of Task XVI are the (1) development of test and analysis plan, (2) procurement and installation of test turbines, (3) preparation of test sites, and (4) testing of standard turbines and data analysis.

Participants

The participating organizations in Task XVI are the (1) Risø Test Station for Wind Turbines, Denmark; (2) Center for Renewable Energy Sources (CRES), Greece; (3) Atlantic Wind Test Site (AWTS), Canada; and (4) National Renewable Energy Laboratory (NREL), the United States. NREL is also the Operating Agent for this task.

Status

All activities under this task have been completed with the exception of writing the final report, distributing remaining participation funds, and returning the 50-hertz wind turbine to the operating agent. The final report has been drafted and distributed for comments and editing. It will be completed by 31 March 2004. Remaining participation funds will be used to publish the final report and then distributed to the participants. CRES staff is preparing the 50-Hz wind turbine for shipment back to NREL.

Author: Hal Link, NREL, United States

2.4 TASK XVII - DATABASE ON WIND CHARACTERISTICS

In 1996, the EU-DG XII (JOULE) project, Database on Wind Characteristics, was started. The project was concluded at the end of 1998, and the project resulted in a unique database of quality controlled, documented wind field time series measurements supplemented with tools to enable easy access and simple analysis through an Internet connection.

As a follow-up to the JOULE project, Task XVII, within the auspices of the IEA R&D Wind, has been formulated with Sweden, Norway, the United States, the Netherlands, Japan, and Denmark as active participants. This task began on 1 January 1999, and an initial task period of two and a half years was successfully concluded on 30 June 2001. With the purpose of continuing the ongoing maintenance and dissemination, accomplishing the initiated extension of facilities and content, and furthering support for international wind turbine standardization efforts, IEA R&D Wind has agreed to run the task for an additional two and a half years. The continuation of Task XVII covers the period of 1 July 2001 to 31 December 2003.

The main purpose of the task has been to provide wind energy planners, designers, and researchers – as well as the international wind engineering community in general – with a source of actual wind field data (time series and resource data) observed in a wide range of different wind climates and terrain types. Connected to the extension of the initial task period, as described above, the scope was widened to include support for international wind turbine standardization efforts.

Objectives

Task XVII has five main objectives, as follows:

1. Assure that current and future users will have access to the database through the Internet
2. Accomplish the initiated globalization of the database, with the goal of collecting a limited, but representative, portion of existing wind data that reflects relevant wind turbine load situations
3. Attract more users by a continued effort on dissemination and development of the database facilities
4. Support international standardization efforts by contributing to calibration of load-critical wind field parameters as well as by identifying and quantifying rare events of crucial importance for the structural integrity of wind turbines
5. Investigate and promote the possibilities for running Database on Wind Characteristics on a commercial basis after the proposed prolongation has expired

The Operating Agent is Risø National Laboratory in Denmark, and the Database Operator is the Technical University of Denmark.

Status

Presently, the database contains more than 175,000 hours of high-sampled meteorological time series data from 58 sites in Europe, Egypt, the United States, and Japan that represent a wide variety of wind climates, terrain types, and wind turbine wake situations. For three of the sites, the meteorological time series data are supplemented by structural time series data recorded at nearby standing turbines. In addition to the time series data, more than 860,000 hours of resource data from 24 sites are included.

The time series are stored in a common file format, with the temporal resolution ranging between 1 Hz and 40 Hz and are mainly intended for investigations of design wind loads and phenomenological studies. In addition, an advanced data selection system is supplied that fully utilizes the interactive nature of the Internet. Tools for simple data analysis (e.g., analyses of wind-speed gusts, wind-direction gusts, and wind shear), data presentation (online plot facility), and download of time series for further processing are also provided.

The wind resource data are stored as ten-minute statistics. As with the time series measurements, emphasis has been given to ensure a high level of documentation of measurement setups.

The following sections summarize 2003 accomplishments within each of the defined work tasks.

Maintenance

The maintenance of the database includes both routine software updates and routine hardware updates. The new database software platform is now in full operation. This new platform includes queries, FTP access, the Wind Energy Document Database, the personal “Basket” function, the user management system, short-term access (fee), and the Online HelpDesk. Some minor modifications and adjustments were performed in 2003 in order to increase the functionality of the system, and the database is now in stable operation. All documents, except the user instructions, have been moved to the Wind Energy Document Database (WEDD).

As for the hardware platform, the database server has been updated to a 2.4 GHz Dell computer equipped with 1 GB of RAM and three hard discs with capacities of 40 GB, 80 GB, and 120 GB. The hardware update has resulted in a considerable reduction in access time.

Extension

This work task is comprised of the development of the database in a broad sense. It includes development of software facilities as well as implementation of meteorological data from new sites and extension of available data from existing sites. The database contains four basic data categories as illustrated in Figure 2.4.2.

The following is a description of the effort performed within upgrade of the database facilities as well as within extension of the amount of available wind field time series.

Database Utilities Implementation

The following database utilities have been implemented:

- Wind Energy Document Database (includes free text-search engine)
- Personal "Basket" queries function, which allows for re-use of previously specified user search profiles
- Online Help Desk
- Short-term access fee facility
- Several additional instruction documents as part of the "HOWTO" feature

Database Bank Implementation

New database bank information is as follows:

- Noerrekaer Enge site time series data (Denmark; coastal; flat; 213 hours)
- Oak Creek site additional time series data (California, U.S.A.; scrub; hilly; 1,936 hours)
- Petten site sonic anemometer time series data (the Netherlands; 670 hours)
- Petten site resource data (the Netherlands; costal; flat; 9,800 hours)
- Horns Rev site additional time series data (Denmark; offshore; flat; 4,600 hours)
- Näsudden site resource data (Sweden; coastal; flat; 28,000 hours)
- Sisimiut site resource data (Greenland; coastal; hill; 2,400 hours) ongoing measurement
- Cabauw site resource data (the Netherlands; pastoral; flat; measured with SODAR; 1,250 hours)
- Borglum site resource data (Denmark; pastoral; flat; 35,552 hours)
- Kegnaes site resource data (Denmark; coastal; flat; 96,432 hours)

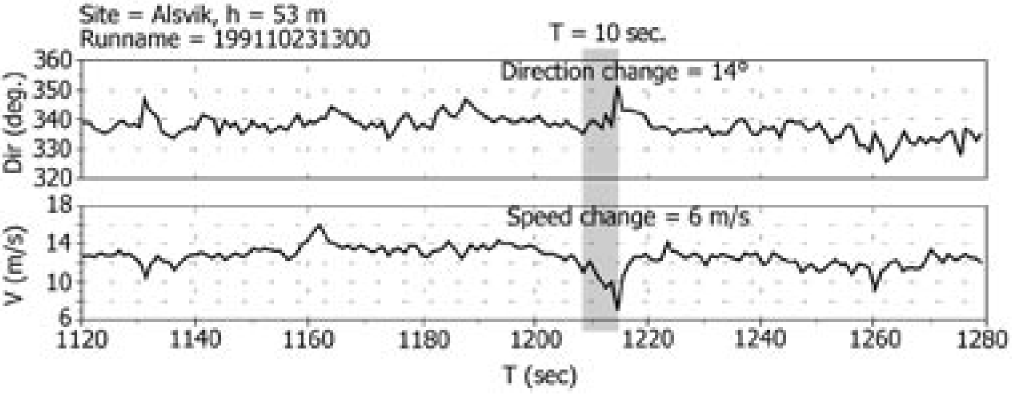

Figure 2.4.1 Example of simultaneously extreme wind speed (down) gust and wind direction change identified using database search and analysis tools

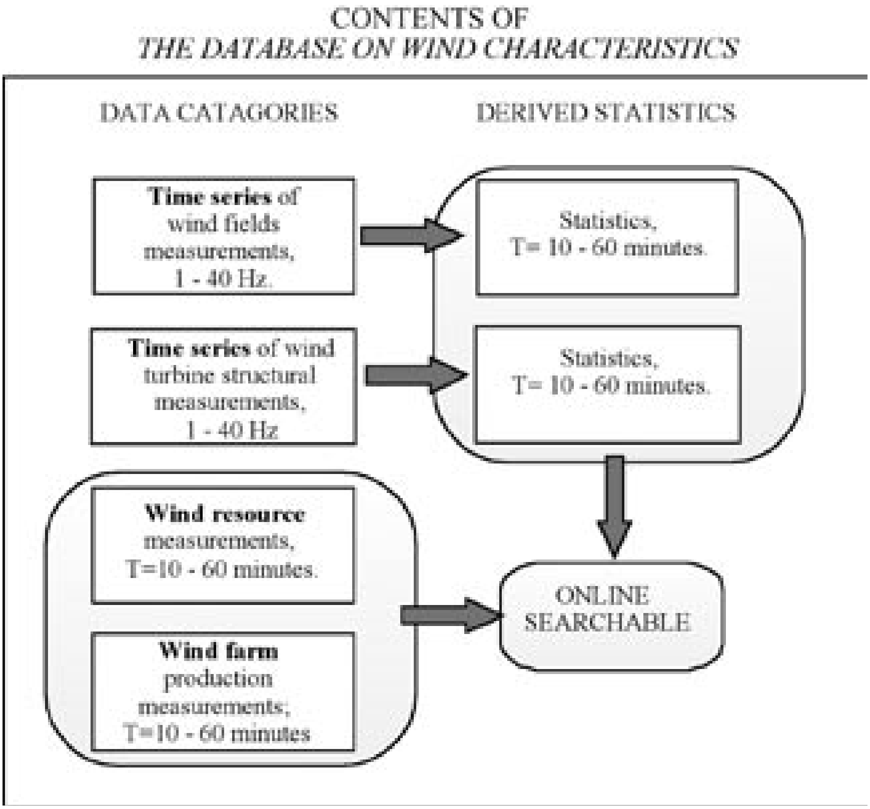

Figure 2.4.2 Data categories in the Database on Wind Characteristics

- Risø site resource data (Denmark; coastal; flat; 53,600 hours)
- Risø site additional resource data (Denmark; coastal; flat; 7.633 hours)
- Boulder Atmospheric Observation site resource data (the United States; pastoral; flat; 15,000 hours)
- Godhavn site resource data (Greenland; coastal; hill; 102,735 hours)
- Delabole site wind farm data (the United Kingdom; pastoral; flat; ten wind turbines; 8,038 hours)
- Noerre Kaer Enge site wind farm data (Denmark; coastal; flat; 42 wind turbines; 12,341 hours)
- Implementation of time series data from the TEJONA site (Costa Rica, scrub, mountain, 2,511 hours)

Dissemination

The value of the database is not only related to its technical quality and size, but is also highly correlated to the number of entities using it. Therefore, the dissemination aspect in Task XVII has a high priority. The following initiatives were taken in 2003:

- Four electronic newsletters were issued
- The database was demonstrated at the third IEA Joint Action Symposium on Wind Conditions for Wind Turbine Design at Risø, Denmark, in October 2003
- The Database on Wind Characteristics was used in a number of ongoing research projects (the JOULE project ENDOW and the Danish national project 3-D Wind Simulation for Extreme- and Fatigue Loads)

- The Database on Wind Characteristics was included in three new European Union proposals (TOPFARM, WICOLOLA, and FARMPERFECT)
- A paper was presented at the OWEMES 2003 Conference in Naples, Italy, 10-12 April 2003 (*Extreme Offshore Wind Shear* by K.S. Hansen and G.C. Larsen)
- Three papers by Hansen and Larsen were presented at the European Wind Energy Conference (EWEC) 2003 in Madrid, Spain, 16-19 June 2003, based on data originating from the database (*Parameterisation of Turbulence Intensity, Spatial Coherence of the Longitudinal Turbulence Component, On the Most Likely EOG Amplitudes*)
- Two papers will be presented at the special topic conference, The Science of Making Torque from Wind, in Delft, the Netherlands, 19-21 April 2004 (*Validation of Cup Anemometer Response Against 3-D Sonic Anemometer* by K.S. Hansen, G.C. Larsen, M.S. Courtney, M.S; and *Statistical Model of Extreme Shear* by K.S. Hansen and G.C. Larsen)
- Leaflets were distributed at OWEMES 2003, at EWEC 2003, at the Risø Vinddag, and along with mailed information material on WasP and WasP Engineering in general

The success criterion for the dissemination effort is the number of users attracted. At present, the database has approximately 215 registered users.

Support International Wind Turbine Standardization Efforts

This task comprises a rational calibration of load-critical parameters in existing design codes. Over time, the Database on Wind Characteristics has gradually become a more unique tool for rational calibration and improvement of design load cases (as specified in international codes) due to its broad spectrum of representative wind turbine site field measurements. During 2003, the focus has been on extreme shear load conditions and on the behavior of the spatial coherence (with special emphasis on vertical separation) in the longitudinal turbulence component.

Commercialization Of The Database

To ensure that the database will be online and available through the Internet for the benefit of a steadily increasing number of users, a need for funding of basic maintenance activities will occur. Two different categories of payment facilities are offered depending on the types of service requested: online payment and conventional payment by invoice. Online payment currently offers payment based on the (American) PAYPAL service for short-term access only (i.e., 24 hours of access for 20 euro or one week of access for 80 euro). The invoice payment facility currently includes a traditional annual fee payment for single users. This service is unrestricted in the sense that it covers all possible user segments.

Authors: Gunner C. Larsen, Risø National Laboratory, Denmark; and Kurt S. Hansen, Technical University of Denmark, Denmark

2.5 TASK XIX - WIND ENERGY IN COLD CLIMATES

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, Task XIX to the IEA R&D wind-implementing agreement was officially approved in 2001. The resulting task began in May 2001 and will continue for three years.

The following definition for the sites and turbines that are involved in this task has been agreed on as wind turbine sites that either have icing events or low temperatures outside the standard operational limits of wind turbines.

The participants will work to achieve the following four objectives:

1. Gather and share information on wind turbines operating in cold climates
2. Establish a site-classification formula, combining meteorological conditions and local needs
3. Monitor the reliability and availability of standard and adapted wind turbine technology that has been applied
4. Establish and present guidelines for applying wind energy in cold climates

Participants in the task include Canada, Finland (Operating Agent), Norway, Sweden, Switzerland, and the United States.

Means

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 main activities are divided to five subtasks, which follow.

Operational and Performance Experience

The project gathers operational and performance experience mainly through national wind turbine statistics and information available to the participants. For more widely spread information, project Internet pages have a form that can be used to report events.

The goal is to determine how much production loss and failure by icing and low-temperature events is caused to turbines at different sites. With the help of national statistics and reported information, the need and the scale of the need for adapted technology, as well as functionality and reliability of the cold climate modifications that are employed so far, is defined. Technical availability will provide information on reliability of turbines in cold climates.

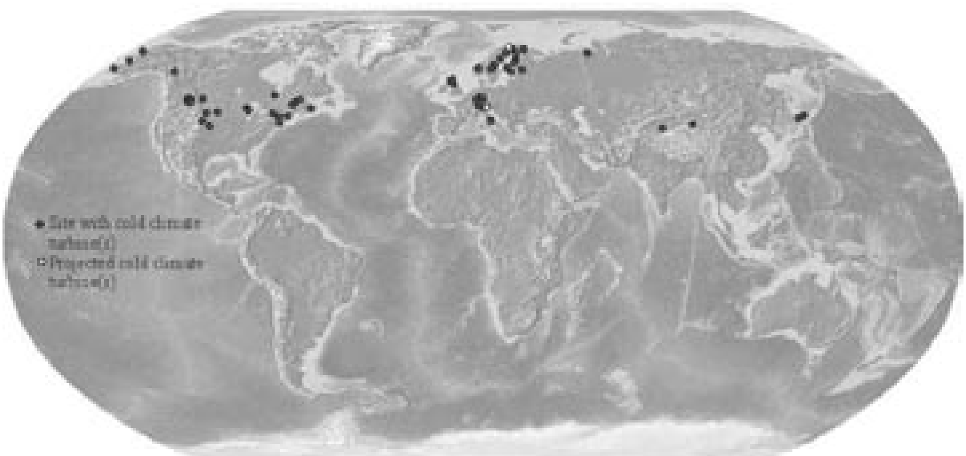

Figure 2.5.1 Wind turbines operating in low temperatures and/or in icing climate, totaling 500 MW

Figure 2.5.2 Long-term measurement campaign including monitoring of adapted technology suitable for severe icing climate has been carried out since 1999 at Olostunturi-fjeld wind farm

In addition to this, construction experience and operation and maintenance experience in cold climates are gathered. The reliability and power performance of wind turbines are often overestimated because the harsh conditions are not taken into account with appropriate seriousness, and not enough is known of the expected icing time and the persistency of icing.

The reliability of anemometers, ice detectors, and other sensors is also an issue for wind power utilization in cold climates. In addition to expected technical availability, the reliability of wind measurements plays an essential role at the time of investment decision. With unheated anemometers, wind resources may easily be underestimated in an icing climate.

Extraordinary Operational Events

In addition to general information gathered from several cold climate sites, the participants monitor in detail extraordinary events such as icing, storms, lightning strikes, and voltage losses on selected sites.

Site Assessment and Classification

Classification is needed due to different site requirements. In addition to the standard site assessment, low temperature and icing-related issues should also be considered.

This task uses a classification method and recommendations that take into account the following conditions:

- Climate (type and rate of icing, extremes and variations of temperatures, wind)

• Grid infrastructure and energy demand (energy system related matters)
• Geography (onshore, offshore, coastal, mountainous, elevated)
• Site accessibility (urban or sparsely populated area)

The development of the classification procedure will be based on existing information and measurement data.

Technology and Operations Classification

Proven technology, standard and adapted, will also be classified by the appropriateness of individual technology to specific climatic conditions. Finally, this classification of sites and technology will result in guidelines for turbine investors, manufacturers, and developers to be used during project planning. With this categorization, an estimate of the size of the markets of adapted wind turbine technology can also be formed.

Dissemination of Results

Internet pages have been created for the project in order to disseminate general information and operational experiences, as well as to gather more information (located at arcticwind.vtt.fi).

The operational experience and the final result, guidelines for wind turbine technology and operational strategies applied in cold climates, will be disseminated to developers and turbine manufacturers. This task also has an important connection to the standardization of wind turbines (i.e., icing and low temperature related features that need to be recognized in standards).

Status

The *State-of-the-Art of Wind Energy in Cold Climate* report was finished and published in spring 2003. This report summarizes available wind turbine technologies intended for use in low temperatures and icing climate. The report can be downloaded in a PDF format from the project Internet pages (located at arcticwind.vtt.fi).

In fall 2003, a new discussion forum was launched to attract more people to share their cold climate expertise. A link to the discussion forum can be found from the project main page. By January 2004, approximately 30 people representing different fields of wind energy had registered.

An adequate amount of data and experience has been collected, and drafting of the guidelines for applying wind energy in cold climate began in 2003.

First steps have been taken to establish a site-classification formula. Tests against measurement data are underway. The first recommended method for ice measurements in connection to site assessment and turbine operation has been established.

There remains a need to verify the guidelines and the recommendations of Task XIX. Continuation of Task XIX will be planned in the next meeting, which will take place in Switzerland on 16-17 March 2004.

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

2.6 TASK XX - HAWT AERODYNAMICS AND MODELS FROM WIND TUNNEL MEASUREMENTS

Continued innovation in wind turbine technology will require aerodynamics models of greater accuracy and reliability than those currently in use. 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 R&D Wind Task XIV, *Field Rotor Aerodynamics*, and Task XVIII, *Enhanced Field Rotor Aerodynamics Database*.

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

Figure 2.6.1 NREL UAE in NASA Ames 80-foot by 120-foot wind tunnel

To acquire aerodynamics data representative of full-scale turbines, under conditions of steady uniform inflow, the NREL Unsteady Aerodynamics Experiment (UAE) 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 with high spatial and temporal resolution for realistic rotating blade geometries under closely matched Reynolds number conditions in the presence of strictly controlled inflows. Completed in 2000, the test included 22 turbine configurations and produced more than 2,100 data files containing nearly 100 GB of high-quality data.

Shortly after test completion, select data were employed as a reference standard in a blind comparison designed to evaluate wind turbine aerodynamics code fidelity and robustness. In this exercise, participants were given the UAE geometry and structural properties, and then attempted to predict aerodynamic response for a modest number of test cases representing diverse aerodynamic regimes. Code comparison participants did not have access to the experimental aerodynamics data until well after their model predictions were completed and submitted to NREL. Blade element momentum models, prescribed wake models, free wake models, and Navier-Stokes codes were represented in the field of models. Results generally showed unexpectedly large margins of disagreement between the predicted and measured data. Notably, neither the magnitudes nor the directions of these deviations showed consistent trends.

Thus, the need for improved wind turbine aerodynamics models is clear, and the potential benefits are readily apparent. This research task is being established to capitalize on high-quality experimental aerodynamics data from the NREL UAE wind tunnel test, as well as comparable data from other sources. Appropriately analyzed, these data will yield unique and unprecedented findings regarding turbine aerodynamics. This information can be exploited to formulate and validate new wind turbine aerodynamics models. Improved models will improve wind energy machine design and continue the trend toward lower cost wind energy.

Task Organization

Objectives and Work Areas

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. They are as follows:

1. Acquire accurate, reliable, high-resolution experimental aerodynamic and structural loads data for horizontal axis wind turbines representative of full-scale machines
2. Analyze these data using methodologies designed to reveal the flow physics responsible for phenomena observed on horizontal axis turbines
3. Formalize this understanding in hierarchically structured, physics-based model subcomponents, with appropriate consideration for computational efficiency
4. 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

At present, ten organizations representing eight IEA member countries are participating in Task XX. They are as follows:

1. Center for Renewable Energy Systems (CRES), Greece
2. Energieonderzoek Centrum Nederland (ECN), The Netherlands
3. Institutt for Energiteknikk, Norway
4. National Center for Renewable Energy (CENER), Spain
5. National Renewable Energy Laboratory (NREL), United States
6. National Technical University of Athens, Greece
7. Risø National Laboratory, Denmark
8. Swedish Defence Research Agency Aeronautics Division (FFA), Sweden
9. Technical University of Delft, the Netherlands
10. University of Quebec, Canada

Task Status

During 2003, formal commitments and documentation were received from all countries intending to participate in Task XX. Subsequently, the IEA legal office completed review of the task document, and the Operating Agent accomplished directed revisions. With all administrative requirements fulfilled, Task XX was formally approved by the Wind R&D Executive Committee in April 2003, at ExCo Meeting 51. To provide convenient access to the database acquired during the NASA Ames wind tunnel test, a website was constructed to archive, document, and distribute these data for Task XX participant utilization. Using these data, participants initiated research activities previously proposed under Task XX. Results and future efforts were discussed during the Task XX Kickoff Meeting, which was held at NREL in May 2003, in conjunction with the Task XI, *Aerodynamics of Wind Turbines*, meeting. Plans currently are being made to hold the next Task XX meeting at the École de Technologie Supérieure, in Montréal, Canada, in June 2004, again in collaboration with Task XI.

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

2.7 TASK XXI - DYNAMIC MODELS OF WIND FARMS FOR POWER SYSTEM STUDIES

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, the user is left to build his or her own wind farm model. This is not trivial and certainly not efficient. Rather, a coordinated effort is expected to enhance progress, and consequently, Task XXI under the IEA R&D Wind agreement was proposed and approved in April 2002 with SINTEF Energy Research of Norway as the Operating Agent.

Means And Objectives

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:

1. Establish an international forum for exchanging knowledge and experience within the field of wind farm modeling for power system studies
2. 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.)
3. 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.

Status

The task now 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 and electric utilities. In total, during more than three years of operation, participants in the task are expected to contribute with more than 20 labor-years of work effort.

Cooperation within the task is through sharing measurement data, model descriptions, and discussions at meetings. A total of three task meetings have been arranged with the last at NREL in the United States, including a full-day workshop with invited industry actors.

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). The following graphs show example results of dynamic simulations using the models.

An Internet "e-room" has been established for sharing documents and measurement data among the participants of the task. To date, the database part of the e-room contains measurements from fixed-speed wind turbines only, whereas measurements from variable-speed wind turbines are expected to be included during 2004.

Work to facilitate benchmark testing of models has begun. Such tests include both validation against measurements and model-to-model comparisons, and they consider dynamic operation during normal, fault-free conditions and response to grid fault.

The importance and relevance of Task XXI is highlighted by a current situation that has a varying level of confidence in, and knowl-

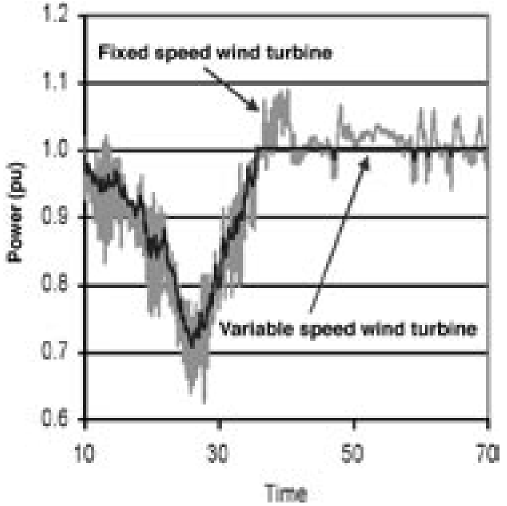

Figure 2.7.1 Simulated active output power from variable- and fixed-speed wind turbines subject to the same wind conditions

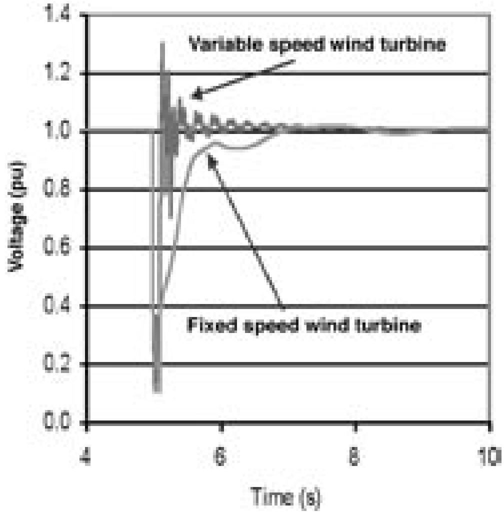

Figure 2.7.2 Simulated voltages at wind farm grid connection point, assuming a temporary, nearby, three-phase, short-circuit fault and variable- and fixed-speed wind turbine types

edge about, wind farm grid-interaction modeling with larger wind farm projects planned. Therefore, a key issue is dissemination of task results, which is performed by individual participants and through joint actions, such as arranging open workshops and maintaining public Internet information about the task.

A topic of high interest is the ability of wind turbines to ride through temporary grid faults, hence, contributing to grid stability. Detailed models may be used to assess such abilities, but an actual performance test may be required to provide confidence. A proposal emerging as a spin-off from this task work is to update IEC 61400-21 to specify requirements for such testing. Assuming this occurs, wind turbine manufacturers may in the future refer to standard test certificates for demonstrating performance under grid transients. These same data sheets may also be used for verifying dynamic models of wind farms for power system studies.

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

Author: John Olav Tande, SINTEF Energy Research, Norway

2.8 HIGHLIGHTS FROM ACROSS THE IEA

The International Energy Agency includes more than 40 implementing agreements (including IEA R&D Wind) to promote international cooperation in the field of energy research including renewable energy technologies. In 2003, one new implementing agreement was formed, 12 implementing agreements were extended for up to five years, and a new category of participation called Sponsors was created. In response to the new membership category, the IEA R&D Wind agreement is presently preparing the practical details for adding such participation. By the close of 2003, three Sponsors had joined other implementing agreements of IEA.

The legal and management structure within which the implementing agreements operate, has recently undergone an exhaustive review. The resulting "IEA Framework for International Energy Technology Co-operation" was approved in April 2003 by the governing board. It permits broader participation by countries outside OECD membership and by private-sector entities. It also simplifies international cooperation between national entities, business, and industry.

New Implementing Agreement

In 2003, the Climate Technology Initiative (CTI) gained a new status as an IEA implementing agreement. Its mission is to bring countries together to foster international cooperation in the accelerated development and diffusion of climate-friendly and environmentally sound technologies and practices. CTI participating countries will undertake a broad range of cooperative activities in partnership with developing and transition countries and other international bodies. For more information, visit their web-site at http://www.climatetech.net

New, Useful, and Free

Among the many useful publications that the IEA produces, two stand out as worth a look for those involved in renewables. The IEA *Renewables Information 2003* is the second edition of a new publication that is produced annually to provide reliable statistics on renewable energy. It is a comprehensive volume of basic statistics compiled by the IEA on electricity and heat production, supply and final consumption, and installed capacity of renewables and waste sources. The free 2003 report features a survey on renewables in Russia; where it says large-scale wind projects can compete in coastal areas of the Russian Far East, in the steppes along the Volga River, and in the North Caucuses. "The new is the well-forgotten old" is a Russian proverb that can well be applied to renewables.
http://library.iea.org/dbtw-wpd/Textbase/nppdf/free/2003/renew2003.pdf

Getting the energy framework to reflect the full and total costs of the environment and energy security is a challenge. However, doing so creates a framework where renewables can compete fairly with other technologies that are also needed in the energy mix, thus leading to a sustainable and vibrant energy sector. The REWP produced a report *Renewable Energy Policy... into the Mainstream (2003)* examining the issues and highlighting the benefits of renewables in IEA and non-OECD countries now and tomorrow. Download the pdf version at http://spider.iea.org/public/freepdfs/2003/binnenwerkiea2.pdf

To see all publications and activities follow easy links from http://www.iea.org/

Getting Renewables into Economies in Transition

The IEA recognizes the importance of renewable energy for economies in transition and the value of bringing IEA members' experience and opportunities for cooperation to the attention of regional policy makers and the public. The public information forum "Economies in Transition, the IEA and Renewable Energy" in Budapest on 13 October 2003 presented current views of policy regarding renewable energy markets and technology in selected countries.

New Policy Databases on the Internet

The IEA launched two policy information Websites. The "Dealing with Climate Change" Website features data on energy-related policies and measures taken or planned by the IEA's 26 member countries. It contains more than 800 records collected between 1999 and 2002. http://www.iea.org/dbtw-wpd/textbase/envissu/pamsdb/index.html

The "Renewable Energy Policies and Measures in IEA Countries," contains detailed references to some 160 pieces of legislation designed to encourage the development and market uptake of renewable energy sources. http://www.iea.org/dbtw-wpd/textbase/pamsdb/re_webquery.htm

The websites provide free access to the databases.

News from Other Renewables

The *Photovoltaic Power Systems (PVPS)* implementing agreement launched a new project: "Large Scale Deployment of PV in Urban Environments."

The *Hybrid and Electric Vehicles* agreement published a report analyzing more than 80 government programs to support market introduction of clean vehicles. Recommendations were made for choosing the optimum combination of promotion measures and regulations.

Within the program on *Energy Conservation through Energy Storage*, developments in 2002-2003 included approval of standards for underground thermal energy storage design and installation. In addition a workshop *Cooling in all Climates with Thermal Energy* was held. http://library.iea.org/dbtw-wpd/Textbase/techno/index.asp

New CADDET Super Center

The well-developed and popular CADDET information centers on renewables and energy efficiency have now merged and have an excellent Website. This well researched and internationally supported information network helps managers, engineers, architects, and researchers find out about renewable energy and energy-saving technologies. http://www.caddet.org

New Renewables Project Broker at GREENTIE

GREENTIE is an international directory of suppliers whose technologies and services help to reduce greenhouse gas emissions. It has more than 7,000 clean technology suppliers in its on-line directory.

A key development in 2002-2003 was the introduction of the Project Broker Facility that puts users and equipment manufacturers in contact via an on-line registration form. The Website can be found from CADDET under 'Suppliers Database' or by going directly to http://www.greentie.org/

Do You Need More Email?

Nobody needs more email, but….if you want to keep abreast of higher-level policies and keep updated on activities within the IEA's energy technology and R&D community, then try the IEA's *OPEN Energy Technology Bulletin*. Launched in 2002, this online newsletter has already acquired more than 3,000 subscribers world-wide. http://www.iea.org/Textbase/news/subscribe.asp

Chapter 3

2003 IEA Wind Energy Overview

3.1 INTRODUCTION

The basis of this overview chapter is the national reviews of the member countries of the IEA Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind). The individual national reviews are presented in Chapters 4 through to 21 of this Annual Report. This overview provides a compressed analysis of the national reviews, focusing on the most significant changes during 2003, together with a brief policy description for comparisons across all the countries.

3.2 GLOBAL CHALLENGE, GLOBAL MARKET, AND GLOBAL INDUSTRY

Countries are increasingly appreciating that wind energy can offer economic and social benefits in addition to its environmental value. Where the market goes, industry and employment follow. The countries with the highest deployment of wind energy, such as Denmark, Germany, the United States, and Spain, have developed strong national industries and have become exporters as well as importers.

Job creation is the most important benefit of wind energy to Spain, which estimates that this year around 7,000 jobs were dedicated to the wind industry with up to a further 20,000 jobs having an indirect input. Two Spanish companies, Gamesa Eólica and Ecotecnia, are now among the world's 10 largest manufacturers. Last year Germany alone reported some 35,000 people employed either directly or indirectly in wind energy, covering both manufacturing and servicing the then 12 GW of capacity (14.6 GW by the close of 2003).

Australia too is driving to achieve a national industrial benefit from the growth in its wind energy market. The market in Australia is quite new, but the favorable legislation and the associated growth in the last two years have already spawned local tower manufacture and a new Vestas factory. Towers are now also to be exported to New Zealand. Switzerland is aware of the down-side of this equation. It has recognized that because it does not as yet have a strong home market for wind energy, its national strengths in the electrical and mechanical industries are failing to realize their potential on the international wind energy market.

The value of new wind installations worldwide is estimated at 7 billion United States dollars (USD) for 2003. This figure is based on an average total project cost of 1,000 USD/kW installed. This excludes the operational costs of all the installed capacity; which is estimated at around a further 1 billion USD.

So wind energy now has demonstrated much more than the environmental benefits that have provided the initial momentum behind the sector. The other benefits have become increasingly apparent as the industry matures and countries are forming policies and measures aimed at maximizing these wider benefits. In summary, wind energy offers the following spectrum of potential benefits.

- Very low lifetime emissions of harmful gasses (especially carbon dioxide), per unit of electricity generated
- A large resource with a cost of energy approaching that of current thermal plant
- Increased diversity and security of electricity supply
- Removal of cost uncertainties caused by fuel supply price fluctuations
- Employment through turbine and component supply and assembly, the development and installation of turbines and infrastructure and ongoing plant servicing
- Supporting rural economies through additional income to land owners and local employment

3.3 POLICY UPDATE

Australia

The year 2003 began in the wake of a federal government report (the Parer Report) which recommended abolition of the most significant policy driver behind the recent strong wind sector growth, the Mandatory Renewable Energy Target (MRET). Originally based on 2% of electricity from renewables by 2010, the target is generally now taken as a fixed level of 9,500 GWh/year from renewables at the start of 2010. Implemented through a system of tradable certificates and capping penalties, it necessitates the installation of up to 900 MW of wind turbines.

A recent review committee report recommended that the current target for 2010 remain unchanged, but this, not surprisingly, caused concern in the industry, which thinks a higher target is needed to establish a robust manufacturing base in Australia. The government's response is still keenly awaited, because the outcome will undoubtedly have a significant impact on the Australian wind industry.

Canada

The government's recent 260 million Canadian dollar (CAD) program has been very effective in attracting new interest and an acceleration of wind energy development. This initiative is for projects commissioned between 2002 and 2007, boosting the economics and reducing the income risk by providing partial funding through fixed price payments for the first 10 years of production.

Other deployment support comes from accelerated capital write-off schemes and government contracts for green electricity. It is encouraging to see that 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 by-product of the federal program, wind power producers have built additional wind plants and green energy is being sold to private, provincial, and municipal consumers.

Denmark

Denmark continues to expect that a rising share of electricity consumption will be covered by renewables. In its 2003 climate strategy, the government again emphasized cost efficiency. Onshore wind will be supported through free market prices supplemented by environmental bonuses, and offshore wind will be supported through a tendering process. Renewable energy quotas announced in 1999 have realized their target of 20% of the electricity consumption being covered by renewables at the end of 2003.

For the duration of 2002, the main instrument for wind energy deployment on land was an incentive motivating owners to replace old, small turbines with larger and more efficient machines. The repowering scheme resulted in the replacement of 1,200 old turbines with 300 new. Over and above this, most new capacity in Denmark is expected to come from offshore. From the beginning of 2003, the price paid to private generators fell by between 16% and 38%, which has brought investment to a complete stop.

An action plan for wind produced in 1997 shows how a total capacity of 4,000 MW of offshore wind could be installed in Denmark by 2030. This would produce enough electricity to meet more than one third of the present demand. To date, two large offshore wind farms have been installed; one at Horns Rev in 2002 and one at Nysted in 2003. A third is to be announced in 2004. Further installations will be decided on economical grounds in the light of the government's future energy policy.

Finland

Finland sees a limited resource, which is predominantly offshore. The role of all the renewables is recognized, with the largest expectations from bioenergy. The action plan from 1999 strives to increase the share of renewables to 3 Mtoe/yr by 2010 and 6 Mtoe/yr by 2025. The corresponding targets for wind energy are 500 MW by 2010 and 2000 MW by 2025.

Germany

Germany has become increasingly concerned with the environment. It also seeks to maintain a strong technology position and to improve exports. In the short term, improvements in thermal power stations and energy efficiency measures are expected to produce reductions in carbon dioxide emissions, with renewables making a significant contribution in the medium to long term. Government targets for wind energy are not specified, but the two federal states of Lower Saxony and Schleswig-Holstein do publish targets. It is in these two states that most of the development to date has occurred.

Greece

Greece recognizes a high wind energy potential and the government wishes to exploit wind energy to replace expensive imported fuel and to actively involve Greek industry in creating new jobs. In spite of this, the deployment of wind energy technology has been slow. During recent years, new laws have liberalized the electricity market and established support for renewables within a competitive framework. There are also plans for a new high-voltage grid in the North, which will enable this windy area to be exploited.

Ireland

The final round of the principle renewables support mechanism, the Alternative Energy Requirement (AER), took place this year, and a government consultation exercise started to find its replacement. The AER started in 1996 and has had six rounds of competitive tendering for fixed price contracts of 15 years. The final round in 2003 generated contracts for 334 MW of new capacity and included the first offshore contracts, for two projects of 25 MW each. Whilst very effective in letting renewables contracts, it has been less effective at building projects, with only 12% having been realized to date, though this will increase with time.

Current targets are for an additional 500 MW of installed renewable electricity generating capacity between 2000 and 2005, with a further indicative target of increasing electricity consumption from renewable sources to 13.2% of total demand by 2010. Wind power is expected to contribute in excess of 90% toward these targets. The current consultation aims to set further targets for the period between 2010 and 2020.

Italy

Italy has followed up its pro renewables white paper of 1999, by approving the law which commits to an increase in the contribution of renewables from 16% of electricity, up to 22% by 2010. The law comes into force early in 2004, with the first deadline in 2005. Those that have not fulfilled their obligation, now at 2% of electricity sales, are likely to be fined with a penalty of 1.5 times the money for acquiring the corresponding number of green certificates.

Wind is expected to make a large contribution towards the 2010 goal, reaching around 2,500 MW of installed capacity. This equates to around 200 MW per year, with additional contributions from biomass, solar, and waste.

Japan

The situation in Japan has not changed much in the last year. The target for wind energy of 3,000 MW still stands, increased from just 300 MW in 2001. 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 required contribution of renewables to total primary energy is 3% in 2010; with Japan's utilities obliged to source 1.1% of their total electricity supply from renewables. Very positive national policy and capital subsidies from the New Energy and Industrial Technology Development Organization (NEDO) have been supported by the utilities offering private long-term electricity purchase contracts.

Mexico

The Mexican energy policy is aimed at securing enough electricity supply to allow expected economic development. This is in support of expectations of electricity demand increasing by an average of 5.6% over the years 2002 to 2011. This will require a projected 30 GW of new capacity, 15.6 GW of which will need to come from new projects not yet under construction. Wind energy has an opportunity to supply a proportion of this.

By the end of 2003, the Global Environmental Fund, through the United Nations Development Programme, approved the project *Action Plan for Removing Barriers to the Full Scale Implementation of Wind Power in Mexico*. The first phase of the project started in January 2004 and will systematically address barriers such as legal, regulatory, and wind resource evaluation. A Regional Wind Technology Centre will also be implemented to address educational barriers as well as wind turbine testing and technology transfer issues.

The Netherlands

The government policy for renewable energy was revised in 2001 with wind and biomass expected to give the greatest contributions to the target of a 10% contribution to energy demand by 2020. The realization of 6,000 MW installed wind capacity offshore is seen as a possible and necessary part of this expectation.

Measures for the support of renewables in the Netherlands remain dynamic. A set of step-wise measures was put in place this year that will come into force progressively up to the beginning of 2005. These measures aim to bring a change from an end-user, demand-lead stimulation to production stimulation through the MEP, which will increase national generation from renewables and so decrease green energy imports and the associated leaking of taxpayers' money abroad.

At the beginning of 2003, legislation was modified such that green energy attracted a reduced level of ecotax exemption, rather than being fully exempt as before. The exemption of ecotax is paid to the electricity retailers and it has enabled them to offer green electricity at the same price as conventional electricity, so creating a demand by the end user. Even with this lower energy taxation rate, the cost of green energy to end users in 2003 was the same as for conventional power, but with reduced margins, the retailers may increase prices in the future. The government proposes to further decrease demand stimulation by progressively reducing the ecotax exemption to zero by January 1, 2005. The production incentive, which improves the economics for the generator, was cancelled for imported wind electricity to encourage Dutch-based generation projects. At the same time, energy investments were no longer eligible for free depreciation.

From July 2003, the production incentive to generators was replaced by the Environmental Quality Electricity Production (known as the MEP). Under the MEP, producers of green electricity in the Netherlands get a fixed premium price per kWh for 10 years; up to a maximum of 18,000 full load hours in the case of wind. Only installations built from 1996 are eligible.

New Zealand

In New Zealand, renewable sources already provide 29% of total consumer energy, and around 70% of the electricity supply, mostly from hydro (63% of electricity supply). The electricity industry has undergone major structural reform in the past five years, which has kept the promotion of renewable energy at bay until July 2000, when the Energy Efficiency and Conservation Act came into force. In April 2002, the national government released a target for an increase of 30 Petajoules (PJ) of renewable energy by 2012. However, no quantifiable targets have been set for the electricity sector or for wind energy. It was just in December of 2002 that New Zealand signed the instrument of ratification for the Kyoto Protocol to the United Nations Framework Convention on Climate Change.

Norway

Wind energy has been supported through the combination of an investment grant of up to 10% and a small production subsidy. The production subsidy ceased at the end of this year. In the future, it is expected that the subsidies will be replaced by a green certificate market, which is under governmental deliberation. In the mean time a transition scheme for wind power development will come into force, the various options for which are currently being considered.

In a year with above average rainfall, Norway could be self sufficient with electricity from renewables, almost all of which is hydro. More typically now, with the increase in energy demand, Norway depends on importing some electricity, mainly from Sweden and Denmark. There are limited opportunities for new hydro projects and in 1998 the Norwegian government stated an overall goal to reach 3 TWh/yr of electricity from wind energy by 2010. This equates to approximately 1,000 MW of installed capacity operating with a capacity factor of at least 34%.

Portugal

The most significant government initiative in 2003 was the Cabinet Resolution, which reaffirmed the national objective of promoting the installation of 3,750 MW of wind capacity by 2010.

In April this year, the government published the Resolution of the Council of Ministries (RCM 63/2003) which approved the main energy policy objectives and their implementation. Key to the policy is an aim to reduce Portugal's dependency on external energy sources and to establish new objectives for renewable energy.

The supporting measures include financial incentives and feed-in tariffs. Applications for 7,000 MW of new wind capacity were received at the beginning of 2002 after the most recent fixed-price feed-in tariff law update in December of 2001. There is also personal tax relief for private investors investing in renewables.

Spain

Spain is notable for its success in both building wind farms and developing an indigenous wind turbine manufacturing industry. Spain has adopted the European target of 12% of the primary energy demand covered by renewable energies as the national target. To achieve this, the Spanish government set a target contribution of 21.5 TWh/year from wind by 2010, with a total power installed of around 9,000 MW. In 2002, the government recognized that, based on current progress, the target should be reached early. Taking into account the new plans for the different autonomous communities, the target has been increased to 13,000 MW by 2011 with a corresponding contribution to the electricity demands of 28.6 TWh/year.

Sweden

Considerable challenges face Sweden in the future. The decision to phase out nuclear power and limitations on further hydropower make renewables, and wind energy in particular, a crucial element of the future power system.

A new market-based system was introduced in May of 2003, with tradable electricity certificates (Elcertifikat) for renewable electricity generation replacing an investment subsidy. The system is driven by a compulsory renewables quota on electricity consumers and retailers. The quota starts at 7.4%, increasing each year up to around 17% in 2010. Heavy industry is exempt in the first two years. Those who do not meet their quota will pay a penalty of 150% of the average certificate price up to a cap, which for 2004 has been set at 0.240 SEK/kWh (0.033 USD).

In parallel with the introduction of Elcertifikat, the current "environmental bonus" will be ramped down from 0.181 SEK/kWh in 2003 (0.025 USD), to zero in 2009. During this time, the bonus for wind turbines offshore will be slightly higher than for onshore. The electricity and the certificates can be sold separately.

In the initial period, after the introduction of electricity certificates, wind generators have received an average total price of 0.721 SEK/kWh (0.10 USD); though the success of the new system and its impact on the development of the wind energy market can not be judged at this early stage.

Switzerland

The new Swiss Energy 10-year program set an objective to reduce the consumption of fossil fuels and the associated carbon dioxide emissions by 10% in the period 2000 to 2010. Additionally the growth of electricity demand must not exceed 5%, hydropower's contribution must not be reduced, and the contribution made by other forms of renewable energy must increase to 0.5 TWh. The Federal Department of the Environment, Transport, Energy and Communications (DETEC) has published a media report with a clearly positive statement concerning wind power generation in Switzerland aiming at an annual production of 50 to 100 GWh from wind power by 2010. This equals 10% of the goal for all renewable energies set by the federal Swiss Energy program.

United Kingdom

There have been two significant changes to the polices supporting renewable energy in the United Kingdom over the year. A white paper set out progressive and ambitious goals for increasing the contribution from renewables, and the renewables obligation (RO) was increased and extended.

Early in the year the Energy White Paper set out goals to work towards cutting the United Kingdom's carbon dioxide emissions by some 60% against 1990 levels by about 2050. It also stated an ambition to double the share of electricity from renewables by 2020. Much later in the year the government announced that it was increasing the level of the RO from 10% of electricity to be supplied from renewable sources by 2010, up to 15% by 2015. Most of this increase will come from wind energy. The increased certainty provided by the higher target will be vital in securing the necessary financing for building large-scale wind projects, particularly those proposed offshore.

Other policy elements include exemption of electricity generated from renewables from the Climate Change Levy (a tax on the business use of energy), development of a proactive strategic approach to planning in the regions through regional targets, and capital grants for early offshore wind and energy crops projects.

United States

The National Energy Policy, published in May 2001, contains recommendations to diversify the national energy supply, move toward clean affordable energy sources, and modernize the electricity grid and infrastructure. Wind energy and other renewable sources play a key role in this policy. The policy includes expansion of goal-oriented R&D focused on advanced technologies adapted to sites with lower wind speeds. There are no national targets for wind energy deployment. However, the goal of the U.S. wind industry is to generate 6% of the nation's electricity from 100,000 MW of wind by 2020.

In 2003, the Department of Energy released ambitious wind energy cost targets as a part of a multiyear technical plan for 2004 to 2010 and beyond. These goals are to reduce the cost of electricity from large wind systems in Class 4 (5.8 m/s at 10 m) wind resources to 0.03 USD/kWh for onshore systems or 0.05 USD/kWh for offshore systems by 2012. For distributed wind systems, the goal is to reduce the cost of electricity to 0.10 to 0.15 USD/kWh in class 3 (low wind) wind resources by 2007, the same level that is currently achievable in class 5 wind resources.

3.4 IMPLEMENTATION PROGRESS

High Sector Growth Sustained

Global growth in 2003 matched that of 2002 at 26%, sustaining the very high level seen over the last decade and more. Within the IEA R&D Wind reporting countries, growth reflected the global picture at 24.5%, which would be expected because these countries account for 90% of the world's installed capacity. This is a very strong performance and expectations for the coming years are of continued high growth; now sustained at around 30%/year since 1994. At the end of 2003, the global wind capacity reached 39 GW. The total installed capacity in the IEA R&D Wind countries reached 35 GW including 493 MW of offshore capacity, which is a 1.4% share.

The pattern changed a little over 2003, with the United States market beginning to show its promise, increasing its installed capacity by some 36%; whilst Spain and Germany throttled back in growth terms at

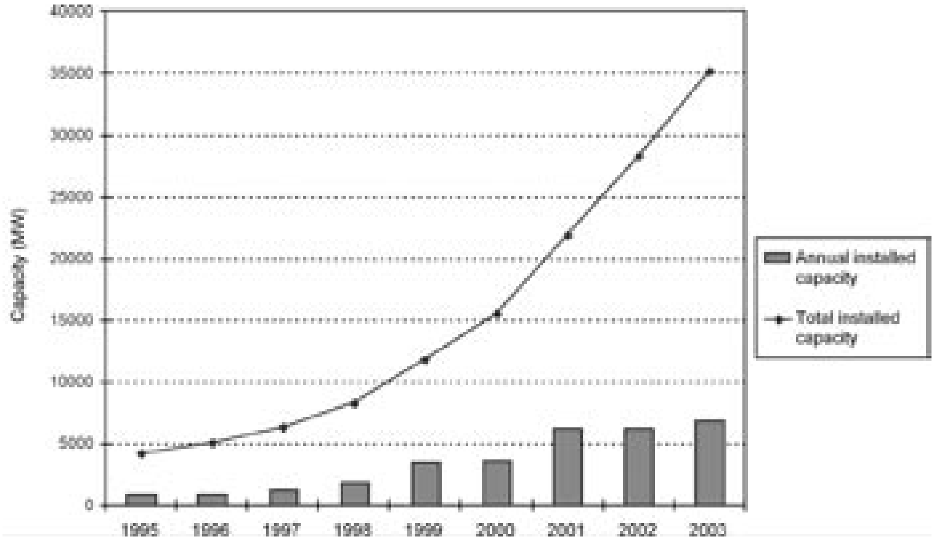

Figure 3.1 – Annual installed and cumulative installed capacity in the IEA R&D Wind member countries

27% and 22% respectively to match global performance rather than exceeding it. Spain attributes the slight reduction in growth to limitations in the electrical infrastructure. It is interesting to note that Spain and the United States are now very evenly matched with a little over 6 GW each, whilst Germany has nearer 15 GW and accounts for over one-third of global capacity.

It was another very positive year for the Netherlands and Japan with high growth also experienced by Australia, Portugal, Canada, and Ireland. The Netherlands had a record year, doubling its previous best year, 1995. Australia nearly doubled its installed capacity with Victoria now the home to almost half of all that installed. Both Japan and Portugal achieved a growth of close to 50%, Japan having increased capacity since 2000 by 7.5 times.

Growth was more steady and continuing the pattern set in 2002 for Italy, Greece, Sweden, and the United Kingdom. For Italy, growth was better than expected at the beginning of the year, aided by a rush of new installations at the end of the year, which will run through into 2004; but for the United Kingdom it was a disappointment against early expectations of over 300 MW, three times that actually achieved.

The changes in policy in Denmark kept new onshore capacity in 2003 to just 29 MW, but with a further 196 MW going in offshore. After such a good year in 2002 for Norway, only a single turbine was installed in 2003. Likewise New Zealand installed just two turbines but there were no new turbines for Mexico or Switzerland.

Offshore

Offshore wind farms were installed in Denmark, Ireland, and the United Kingdom in 2003. Denmark currently has 80% of global offshore capacity. Following on from the first major North Sea wind farm in Denmark at Horns Rev in 2002. This year a second 160 MW wind farm was installed at Nysted in the Baltic Sea. A smaller Danish

Country/region	Capacity at year end 2002	New capacity	Offshore capacity at year end 2003	Capacity at year end 2003
Australia	105.0	93		198.0
Canada	232.0	18		317.0
Denmark	2889.0	225	406	3,114.0
Finland	43.0	4		47.0
Germany	12,001.0	2608		14,609.0
Greece	355.4	69		424.4
Ireland	138.3	51.7		190.0
Italy	788.0	116		904.0
Japan	334.0	172	1.2	506.0
Mexico	2.2	-		2.2
Netherlands	678.0	227		905.0
New Zealand *	35.4	0.5		35.9
Norway	97.0	3		100.0
Portugal	193.8	94.8		288.6
Spain	4,879.0	1,323		6,202.0
Sweden	345.0	59	22.5	404.0
Switzerland	5.4	-		5.4
United Kingdom	552.0	95.6	63.8	647.6
United States	4,685.0	1,689		6,374.0
India*	1,702.0	418.0		2,120.0
China*	468.0	98.0		566.0
Austria*	115.0	276.0		391.0
Australia*	104.6	93.7		198.3
France*	147.0	51.0		198.0
Egypt*	69.0	-		69.0
Costa Rica*	71.0	-		71.0
Belgium*	34.5	33.1		67.6
Morocco*	54.0	-		54.0
Turkey*	19.0	1.0		20.0
Rest of world*	194.5	135.5		330.0
Grand Total	31,337.0	8,021.9	493.5	39,358.9
all figures in MW				
* Data from Windpower Monthly				

Table 3.1 Global installed wind capacity

wind farm of 23 MW south of Samsoe was also completed in 2003, owned partly by a utility and partly by private investors.

The United Kingdom's first major offshore wind farm at North Hoyle, off the Welsh coast, was just completed as the year turned. It comprises 30 Vestas 2-MW turbines. Capital grants have now been awarded for twelve offshore wind farms, with consents to build up to 1,163 MW of new offshore capacity. Late in 2003, the Crown Estate announced the successful bids for 15 new sites in their second round of leasing for offshore wind farms. The wind farms could provide between 5.4 and 7.2 GW of generating capacity, which would generate enough electricity for more than one in six UK households.

Construction of the first 25-MW phase of the Irish Arklow Bank project was completed in 2003. This is Ireland's first offshore wind farm, comprising seven General Electric Company (GE) 3.6-MW turbines, the largest turbines to go offshore to date.

Interest is increasing in offshore development in the United States too. Although there are no current offshore wind installations, there are several proposed applications for offshore projects along the east coast from New England to Virginia.

Greenpeace Spain completed a study of offshore potential (VIENTO EN POPA-June 2003), concluding that the Iberian Peninsula has a potential for 25,000 MW at less than 30 km from the coast and in depths of 30 m or less.

The Dutch 100-MW Egmond aan Zee near shore wind farm to be built 8 to 15 km from the coast, gained a draft building permit in November. The final permit is expected in March 2004. Environmental base-line measurements of birds, fish, sea-mammals, and sea bottom organisms have started.

Electricity Generated by Wind

In 2003, the combined output of all the turbines within the IEA R&D Wind member countries generated electricity equivalent to more than the entire needs of Switzerland or nearly twice that of Denmark. This was approximately 64 TWh, up 26% from last year. Globally, it is estimated that around 67 TWh of electricity were generated from wind in 2003.

How Windy Was It?

European wind speeds were reported as below average in 2003, at a slightly lower level than those experienced in 2002, which were also below average. The annual mean wind speed is often compared with the long-term mean wind speed by a wind index, which expresses the annual wind speed as a percentage of the expected long term. Wind indices of 92% and 84% were given by Sweden and Denmark respectively. Italy reported one of the worst wind years and Spain also reported wind speeds down by comparison with 2002.

3.5 TARGETS AND EXPECTATIONS

Overall, the picture is for wind energy to continue to show the very strong growth now experienced for many years. Wind energy is a global market place and whilst some well established markets like Germany are slowing, others like those in the United States, Asia, and Australia are stepping in to maintain a very positive picture.

Great Expectations

The annual average growth necessary for **Italy** to comply with its target is around 200 MW. With so many projects reaching the build stage at the end of last year and the beginning of this year, it now seems likely that this figure will be exceeded by some 100 MW in 2004. **Spain** too is on track to reach its target early. The current capacity is already close to the 2006 target in spite of some grid infrastructure issues; and the regional programs of the autonomies sum to more than 10,000 MW to be installed in the coming years. **Greece** can see up to 2,170 MW of wind capacity by 2010, based on an optimistic estimation of reaching a uniform 30% penetration of wind energy into the electricity network.

Large grid-connected wind in **Australia** also has a very positive outlook. At the end of 2003, more than 1,629 MW worth of projects had received planning approval, and more than 555 MW of capacity was already under tender or construction. In addition, four remote wind-diesel projects totaling 3.28 MW have received planning approval and will be built in 2004.

Increased electricity prices in **New Zealand** and the government managed carbon credit scheme have helped to invigorate their wind sector. Several new wind projects are underway and several others are being considered. In 2004, the installed capacity is expected to increase by 350%, from 36 to 163 MW. The lower than expected growth in **the United Kingdom** in 2003 has, if anything, increased expectations for 2004 because of the build up of projects with building permits. The industry association (BWEA) reports that a total of over 1,300 MW won planning permission in 2003, double the total amount that has been built over the previous 12 years. Of the 1,300 MW, some 943 MW, 75% of that consented, is for offshore wind farms.

In **Canada**, the amount of interest in the Wind Power Production Incentive in 2003 suggests that 2004 could be a watershed year. Applications were received for 5,300 MW of capacity, though funding is limited to supporting about 1,000 MW. Quebec in particular shows much promise with two 54-MW wind farms slated to be commissioned by the end of 2004 and the 1,000 MW RFP beginning installation in 2006.

Though **Ireland** had a relatively good year in 2003, a sharp increase in deployment is needed to reach the existing target of 500 MW of additional renewable generating capacity between 2002 and 2005.

In **Norway,** two projects with national grants are under construction and a further three have secured their grants. If all these projects are realized, Norway will reach approximately 50% of the national target of 3 TWh of wind power production. **Switzerland**'s small wind power capacity may double in 2004, if the projects with building permits totalling 4.35 MW are built as expected.

Raising the Bar

As the wind sector and policies mature, expectations and targets are becoming better founded and as a consequence more realistic. Denmark achieved its 2003 target, Spain expects to exceed its current target, and Italy sees development in 2004 exceeding the annual requirement to meet its target.

However, as more wind power goes in, capacity moves towards the target and as a consequence development can then slow. Investors need confidence for the economic life of a project, which can require that targets keep significantly ahead of time; the bar must keep being raised.

According to the Australian Bureau of Agriculture and Resource Economics, average annual growth in wind generated electricity is expected to exceed 25% until

2020. However, sustained growth requires an increased commitment beyond 2010. Over the past four years, Australia's wind capacity has undergone an averaged growth rate of 120%. This rapid growth rate is expected to continue until around 2007, but without an increased renewables target (MRET) beyond 2010, it is likely that the rate of investment will quickly drop off after 2007. The target was increased in the United Kingdom in 2002 for similar reasons.

Italy has become another country to employ targets at a regional level to help realize its national ambitions. Here it is thought that regional energy plans and their application, and in particular their acceptance by the local population, will play a decisive role. Sardinia and Tuscany have already completed this exercise, at the same time issuing guidelines for wind investors. All the other Italian regions are in the preparation and approval stages of their energy plans.

In Canada, provincial and territorial governments are being encouraged to provide additional support, and a number of provinces have begun to develop their own complementary programs. For example, Quebec has announced its own firm Request for Proposals for 1,000 MW to be built between 2006 and 2012. Ontario has also recently announced support for renewables including a Renewables Portfolio Standard.

There are no new or changed wind energy targets to report this year, though the Irish government has just initiated a consultation that should produce new targets to reach beyond the existing target for 2005. The Federal Government of Mexico has yet to state any specific national target for wind power, but officials are talking about a strategic goal of 1,000 MW to be completed within the next five years. About half of the national governments of the countries participating in IEA R&D Wind have announced formal targets for the amount of wind power capacity they wish to see installed, or the amount of wind electricity generated. Progress towards those targets is very uneven.

3.6 MARKET DEVELOPMENT

Bigger, Further, and Deeper Offshore

The sector has strong economic and visual drivers towards large, far offshore plant of gigawatt size. Given the early stage of development of the technology, the size of current offshore projects is moving quickly in this direction with recent installations of up to 160 MW. Denmark has built the two largest projects to date, each of 160 MW and in the case of Horns Rev 14 to 20 km out to sea. In reforming the electricity sector, Denmark has established the right to exploit wind both within its territorial waters and inside its economic zone, which stretches up to 200 nautical miles to sea. The most recent bid for offshore sites in the United Kingdom included three sites fully outside of territorial waters; i.e. more than 22 km off the coast. The largest of these is 30 to 40 km off the east coast and could have 250 or more turbines, providing up to 1,200 MW of generating capacity. The new Energy Bill, which is currently going through UK Parliament will enable developers to build wind farms beyond territorial waters.

The United States government has initiated a research effort to assess offshore wind resources. Initial estimates covering the area 20 to 50 nautical miles offshore, indicate that there is more than 800 GW of offshore wind resource in deeper water (30 to 100 m deep

Table 3.2 Wind and renewable electricity generation targets for the IEA R&D Wind Member countries

Country	National Target for Renewables	National Target for Wind Energy
Australia	An additional 2% of electricity from renewables by 2010 meeting the end target of 9,500 GWh/yr at the start of 2010.	No specific target but up to 900 MW of wind turbines anticipated by 2010.
Canada	None.	None.
Denmark	20% of electricity consumption by the end of 2003.	None.
Finland	To increase generation from renewables by 50% over 1995 levels, by 2010 (3 Mtoe/yr, up to 8.4 TWh).	Anticipate 3% of new renewables to be wind energy, giving 500 MW by 2010.
Germany	To reduce CO_2 emissions by 25% from 1990 levels by 2005.	No national targets. Lower Saxony has a target of 1,000 MW by 2000 and Schleswig-Holstein 1,200 MW by 2010.
Greece	None.	More than 1,500 MW by 2010.
Ireland	500 MW installed capacity by 2005; 13.2% of electricity generated from renewables by 2010.	None.
Italy	Double the renewables contribution to the energy balance by 2010.	3.4 million tons per year of avoided CO_2 emissions should come from wind power. This equates to about 2,500 MW by 2010 or 200 MW growth per year.
Japan	Reduce the output of greenhouse gases by 6% compared to 1990 levels by 2012. Renewable generation to increase its contribution to energy supply from 1.15% to 3.1%.	300 MW by 2012.
Mexico	None.	None.
Netherlands	5% of energy from renewables in 2010 (9% of electricity) rising to 10% of energy in 2020.	The government creates conditions for the installation of 1,500 MW by 2010 and 7,500 MW by 2020, of which 6,000 MW offshore.
New Zealand	An additional 30 PJ of renewable energy against the supply of consumer renewable energy in 2000.	None.
Norway	By 2010 to have 3 TWh/yr of electricity from wind energy plus 4 TWh/yr of energy from other renewables (and industrial waste heat), including fired central and district heating systems.	3 TWh/yr from wind energy in 2010 (approx. 1,000MW).
Portugal	4,951 MW by 2012, excluding large hydro	3,750 MW by 2010
Spain	Achieve 12% of primary energy demand from renewables by 2010.	13,000 MW installed capacity by 2011, yielding 28.6 TWh/year.

(Continued) Table 3.2 Wind and renewables electricity generation targets

Country	National Target for Renewables	National Target for Wind Energy
Sweden	Increase electricity production from renewables by 10 TWh by 2010, relative to 1990 levels.	10 TWh/year from wind by 2015.
Switzerland	To increase the electricity supplied from new renewables (without hydropower) by 0.5 TWh by 2010.	50 to 100 GWh by 2010.
United Kingdom	To increase the electricity supplied from renewables to 5% by 2003 and 10% by 2010, subject to the cost to the consumer being acceptable.	None.
United States	None.	None. The industry goal is to generate 6% of the nation's electricity from wind by 2020 (approximately 100,000 MW).

and greater) compared to less than 100 GW in shallow water (0 to 30 m deep).

The total number of large offshore wind farm projects in different planning and study phases in Sweden is very large. Discussions are ongoing with local and regional authorities, but the final concrete result will be very dependant on the results from the government initiatives. In the sound, Öresund, between Sweden and Denmark, the company Eurowind has received permission for an offshore project with 48 turbines of 1.5 MW each.

Two German offshore installations are expected. The "Buergerwindpark Butendiek" wind farm received approval in 2002, and building should start in 2005. It will be 35 km west of the island of Sylt and comprise 80 3-MW turbines. This is in addition to the "Borkum West" offshore installation, situated 45 km north of the island Borkum, with 12 turbines to be erected starting in 2004.

Connecting Offshore

A large component of the cost of offshore wind development is in the 'shallow' connection to the main grid, but also the 'deep connection' costs of integrating large offshore plant into the complete electricity network. This year, the Dutch Ministry of Economic Affairs funded a project called *Connect 6000*, the objective of which is to develop a vision on the integration of 6,000 MW of offshore wind power. The study will clarify responsibilities and address technical issues such as the implications for the land-based electricity grid and its possible extension to form an offshore grid. Studies have already considered the options of individual connections, an offshore grid, and both AC and DC. A lack of accurate cost data prevents firm conclusions as yet, but it seems that a grid at sea (bundling) is essential from the points of view of spatial planning and the environment.

In the United States, the development of offshore wind has a pronounced benefit in supplying electricity to coastal cities, where onshore wind would impose a large burden on the inland transmission system.

New Growth Through Replanting

Replanting is the word used by the wind sector to describe the process of replacing old turbines with new ones. Because wind turbines have grown in size so much, replanting a wind farm can increase its capacity by several times. So replanting is now becoming a common element of development for countries where wind energy has been established a long time and in particular where there is also pressure on land.

Denmark is the only country to date to specifically target replanting with its 2002 re-powering scheme. This scheme was very effective, resulting in the replacement of 1,200 old turbines with 300 new ones. This year, 186 small wind turbines were removed.

Turbines were also replanted this year in Australia, Germany, and the Netherlands. In Germany, 75 turbines were removed having a capacity of 37 MW, and in the Netherlands, 45 turbines with a total capacity of 7.3 MW were removed. One of the earliest Australian wind installations of six 60-kW Westwind turbines installed in 1988 has been replaced by six larger turbines.

3.7 ISSUES AFFECTING IMPLEMENTATION

Economics

Demand for wind has been created through a spectrum of capital grants, tax incentives, and market support mechanisms. There are now may instances of encouraging investment in wind (and other renewables) by providing a higher value for the electricity generated, enabling it to compete with conventional generation in the prevailing economic environment. It should be noted that the relative costs of different generation sources are complicated by historical policies and support and also that the real cost of impacts on the environment are not always fully passed on to the generators.

The level of support required to make wind energy competitive varies with the base cost of electricity. For several member countries of the IEA R&D Wind agreement, the base cost of electricity is low and in some cases compounded by an excess of capacity. New Zealand and Norway are dominated by low-cost long-established hydro electricity, and in Norway this is exacerbated by the import of low-cost electricity generated from coal and gas. Australia is dominated by low-cost coal-fired electricity. In Finland, despite quite substantial support, wind cannot compete with the low spot prices within this fully liberalized market.

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, with surplus generation rapidly declining in some provinces, such as Alberta and Ontario.

Market Stability

The high dependence of markets on government policies is an ever-present concern. The commercial and financial sectors need to have confidence that a market will remain favorable for long enough to warrant investment. Overall, the wind sector does have a degree of insulation from single market policy changes, because of the smoothing effect over the global market place.

Sweden has just changed to a green certificate-based system. It is currently uncertain what affect this will have on the larger investments and on offshore in particular. Such large-scale projects are expected to require project financing, which can only be financed against reasonable expectations in long-term revenue flow, i.e. the electricity and certificate prices. This suggests that some time may be needed to first establish confidence in the stability and prices delivered by the new market-based system with tradable green certificates.

Planning Policy

For several countries where the existing market stimuli make wind power attractive, the main constraint on the rate of development is the difficulty of obtaining building consent.

This is being addressed in many countries through evolving policies and planning guidance, which places increased importance on facilitating wind and other renewables. The United Kingdom this year published new draft Planning Policy (PPS22) in recognition of the threat planning difficulties pose to the realization of targets. It is also in response to the huge variation in planning success across different parts of England (50% average) and the much greater success in Scotland (greater than 90%).

Visual effects continue to generate strong opposition in Italy. This year the problem of local opposition has been exacerbated by difficulties in gaining consents for the high voltage lines providing grid connection. An unexpected addition to the league of objectors is the agricultural associations. Unexpected because the agricultural sector is one of the main beneficiaries of wind energy through payments to land owners and benefits to rural communities, usually including improved roads.

The rate of progress in Spain and Portugal has been constrained by lengthy bureaucracy and authorization procedures, which take four to five years from inception to the start of installation. Such delays increase development costs and in Spain many projects expected to go in this year were pushed back. Italy has suffered similarly, but has changed policies to emphasize that renewables are in the public interest, urgent, and not deferrable. Complete plant construction should now be authorized within 180 days by a single permitting act.

In the Netherlands, the low success rate in planning is being addressed at a provincial level by a requirement to designate locations for wind turbines before 2005. To enable Provinces and local councils to do this, Novem has formed a so called BLOW Expert Pool of certified independent consultants. Under the BLOW agreement each province has now submitted its action plan to designate locations for wind turbines for a total capacity of 1,500 MW.

The Swiss have tackled the very negative 2002 paper by the Foundation for Landscape Protection, by agreeing a set of criteria and plotting potential small wind sites. This should also reduce the uncertainties in the planning procedure.

It is hoped that defense and aviation interests may become less of a problem in Sweden soon. A research project is underway, modelling the disturbance wind turbines cause to microwave links, radar, and intelligence activities. The results so far show that the affects on radar have been overestimated. New rules will facilitate deployment nearer to military installations. Meanwhile the United Kingdom is looking into radar absorbent wind turbine blades.

Grid Limitations

Technically, the integration of large-scale wind energy into electricity networks can be done with existing technology, so long as there is the political will to make the investment in infrastructure. Denmark has already achieved a contribution of almost 20% from wind energy nationally, with no major technical problems. However, in most of the countries with high expectations from wind energy, large-scale integration into the electricity distribution system is seen as a potential, if not an immediate constraint (AU, DK, DE, GR, IR, IT, JP, NL, PO, ES, UK, US). Here, transmission constraints, operational policies, and a lack of understanding of the impacts of wind energy on utility grids are three of the toughest barriers facing future deployment. For many of these countries the problem arises because wind farms are located in relatively unpopulated areas, away from the main load centers. Consequently the local grids are weak and require reinforcement and improvement to enable significant power export. In the United States, the distances are large and so potential electrical losses are large.

Grid capacity and power quality has already become one of the most important issues in Japan. In the areas of Hokkaido and Tohoku, wind capacity has been limited to 250 MW and 150 MW respectively. Should this issue be not be resolved shortly, the national target for 2010 may well not be attained. The situation may be helped by NEDO demonstrations of power stabilization using battery-back-up.

Spain has already instigated some practical measures to maintain the stability of the system. At certain times, for example during the Christmas holidays, the production of wind farms has been voluntarily reduced, corresponding with low consumption periods and strong winds.

Denmark has a quite unique problem, arising from much of its generation capacity being weather dependent. It has roughly 50% of electricity from combined heat and power and 20% from renewables, mainly wind. This can lead to an electricity surplus on cold, windy nights. The surplus is generally exported, but if it is not physically possible to export the entire surplus a difficult situation arises. This is happening in the western part of Denmark with increasing frequency and may be seen in the eastern part in future. The response depends upon economics and the market value of the power and green credits, but stopping the wind turbines for a few hours may be a part of the solution.

Resource

The availability of good sites is becoming a significant constraint in a couple of cases. The Netherlands, Denmark, and parts of Germany have run into this problem. Many of the better sites are now taken up, and exploitation of lower wind speed sites is now also encouraged. Good locations in Switzerland all are at altitudes over 800 m in hilly or mountainous areas. This brings correspondingly difficult conditions such as cold climate, turbulent wind regimes, and difficult access. Experience shows that wind turbines can be operated even under these extreme conditions, although the economic viability may be poor.

Environmental Constraints

The benefit of low greenhouse gas emissions from renewable sources of electricity, including wind, continues to increase in importance as governments seek to limit climate change. Public opinion polls in several countries (UK, NL, DK, and ES) have shown that the environmental advantages of wind power are recognized, and the majority of the public are supportive of wind energy.

Concern remains about the possibility of bird strikes, although the incidences are low. The issue was highlighted by bird strikes at poorly sited wind farms in Spain and the United States in the early 1990's. There was some confusion at the time since these farms were on bird migratory routes, but the species involved were not migratory. Bird strikes since 1992 have been minimal and studies carried out in several countries suggest that turbines have a very small effect on bird life compared to other human activities. A bird study has just been completed at two Swedish offshore wind power plants. Radar was used to follow bird movement in intense bird migration areas, in order to evaluate possible effects on the eider duck in particular. The study shows that the birds fly 200 m or more from the nearest wind turbine, with an extremely low incidence of injury or fatality.

In the United Kingdom, a Strategic Environmental Assessment or SEA has been undertaken in planning the second round of site leasing for offshore wind farms. This comes ahead of the European Union SEA Directive, coming into force in 2004. The conclusions of the SEA resulted in the issue of guidance to the industry on the environmental restrictions that need to be adhered to for site selection within the nominated strategic areas.

3.8 NEW R&D DEVELOPMENTS

Turbines

The German-made 4.5-MW Enercon E-112 remains the world's largest operating turbine. It has now been under evaluation since October 2002. Its behaviour is reported to closely match computer simulations and the erection of two more E-112s has begun. These massive turbines are erected on a 120-m tower of part concrete and part steel construction.

The Norwegian/Swedish Company Scanwind Group AS has taken the unusual step of developing both a geared and gearless 3-MW turbine. The directly-driven version (no gearbox) was erected in Norway this year and the initial testing period showed very good results. The more conventional geared turbine will be erected in 2004. The Spanish company Ecotecnia has now also started the design of a 3-MW turbine, with a 100-m rotor. This is a big step from its current production models of up to 74-m rotor diameter, rated at 1,670 kW. NEG Micon's 2.75-MW, 92-m turbine has been erected at ECN's test site in the Netherlands, where it will be put to extensive testing before being used in the Dutch near-shore wind farm at Egmond aan Zee.

The U.S. company, GE Wind Energy, plans to develop a multi-megawatt machine that will incorporate pioneering features including multi-piece rotor blades, advanced controls, diagnostic systems, an innovative drive train, and taller towers with load reducing features. Clipper Windpower Inc., also a U.S. company, is developing a 1.5-MW to 2.5-MW Quantum prototype turbine that will incorporate advanced turbine components.

Three years of design at the Italian company Leitwind has lead to the installation of their 1.2-MW prototype in August 2003. The turbine, which is three-bladed and gearless, has exploited the lessons learned from the experimental 1990's Gamma 1.5-MW turbine.

Components

There is intense competition to supply the turbine manufacturers with components. Generally manufacturers seek to multi-source their major components to encourage competitiveness and flexibility. This is not always the case for blades or towers. Some manufacturers make their own blades and towers, which are often sourced within the project host country to bring local benefits.

With support from the United States government, Clipper Windpower developed an innovative multiple generator drive train that is 30% lighter than conventional drive trains and is designed to fit most 1.5-MW scale platforms. The new design includes eight generators, one gearbox, and variable-speed power electronics. They are also exploring a variable diameter rotor for improved performance in low wind speed areas and are considering including a self-erecting tower. The U.S. Company Global Energy Concepts finalized a new design for a single-stage, permanent-magnet drive train. Preliminary analysis shows high efficiency at low wind speeds and reduced capital costs, leading to a 10% improvement in cost of energy.

The National Renewable Energy Laboratory (NREL) in Colorado, United States, has installed its own hydraulic resonance blade test system. This test system uses a weight attached to the end of the blade, precisely controlled to excite the blade at its natural flap frequency. Other test methods push the blade up and down over a period of up to 4 months, but not at the blade's resonant frequency. The resonance approach has the advantage of using 1/3 of the energy of non-resonance methods and can cut testing time in half.

Grid Integration

Many countries are necessarily conducting research in this area, to tackle this immediate or looming problem (see constraints above). The IEA Wind Annex XXI, *Dynamic models of wind farms for power system studies,* is accelerating the learning process.

The dispersed island geography of Greece has stimulated much research on micro-grids and their management and control with increased wind power penetration. In 2003, the Electric Power Division of the National Technical University of Athens (NTUA) worked on an advanced control system called MORE CARE. It comprises modules on load and wind power forecasting, unit commitment and economic dispatch, and on-line dynamic security assessment. Installed on Crete, it is currently under evaluation with promising preliminary results.

The Dutch agency Novem carried out a *Survey of the integration of 6,000 MW of offshore wind power into the Netherlands electricity grid in 2020.* The study showed that the extra investment costs for grid reinforcements were between 275 and 570 million euro. This constitutes 3% to 5% of the estimated wind capacity investment.

Portugal is focusing efforts on combined wind and hydro regulation, because of its substantial and sometimes excessive hydro capacity and the high correlation between its availability and wind during the winter months.

Resource Assessment and Forecasting

Resource studies continue to be an important activity for many countries and regions. This year, Portugal completed a wind atlas together with a national database of wind characteristics drawn from around 50 anemometric stations. Italy concluded a comprehensive resource assessment aimed at assisting regional energy planning. The work was conducted in co-operation with the University of Genoa and used flow modelling, geostrophic wind data, and measurements from over 240 wind monitoring masts.

Japan started a monitoring program to improve the characterization of its wind regime, which is special because of the complexity of the terrain. The results will be used to generate models used to define design standards appropriate to Japan.

Government Programs

New test stations are underway in the Netherlands and Norway. ECN and Delft Technical University have built a new blade test facility close to the ECN test site in the Netherlands. The facility is located at a small harbour, which enables water transport of large blades of up to 70 m to be brought in for extreme load and fatigue testing. Construction has now started on a Norwegian test site, the product of a joint venture between the Institute for Energy Technology (IFE) and the Trondheim University. The coastal wind turbine test site is in Mid-Norway and will be in operation in 2004 or 2005.

The total R&D budget across the IEA R&D Wind member countries was about 70 million USD in 2003, though the Italian and Swiss budgets were reduced.

3.9 OPERATIONAL EXPERIENCE

Performance

Cost of energy is the correct economic performance measure (see below). In general, the installed turbines have performed well with few operational difficulties. On average, commercial plants operate with availabilities of over 98%. Finland reports lower availabilities, resulting from the turbines operating in extremely cold climates. Capacity factors are typically between 0.20 and 0.35, depending on the wind speed and the turbine used. Spain reported an average capacity factor of 0.21 for 2003, and the United States estimates an average capacity factor of 0.29. Capacity factors for wind turbines installed in Ireland to date generally exceed 0.35, and capacity factors exceeding 0.40 are not uncommon.

Turbine Life

Wind turbines are designed with a life of 20 years or more. Consumables such as gearbox oil and brake pads are often replaced at intervals of one to three years. Parts of the yaw system might be replaced every five years and vital components exposed to fatigue loading, such as main bearings and gearbox bearings, might be replaced once in the design life. A cost model developed in Denmark and based on statistics from 1991, 1994, and 1997, includes a re-investment of 20% of the turbine cost in the 10th year, financed over the following 10 years. The average age of machines on the German Scientific Measurement and Evaluation Program is 10 years, and no significant increase in failures with operational time has yet been found.

Reliability

Overall reliability can be considered high, reflected in the availabilities achieved. There are occasional component faults that affect a large number of operating machines. There have been several such cases involving gearboxes and blades over the years. These require large retrofit programs conducted at the expense of the component or turbine manufacturer.

There were turbine failures caused by rare events in Japan and Portugal this year. An exceptionally powerful typhoon struck Miyako Island in Japan, causing severe damage to a wind farm of seven turbines. Three had tower failures, three lost their blades, and one lost its nacelle cover.

In Portugal a succession of unlikely problems contrived to cause the over-speed and collapse of a single Mitsubishi 500-kW wind turbine. Problems arose with a grid loss, followed by the failure of two rotor over-speed protection systems. The main reason for the failure was attributed to a poorly installed blade, set to the wrong pitch angle during routine maintenance.

Clearly the level of maintenance affects turbine life and in Germany it is estimated that one permanent service person is required for every 20 MW installed.

3.10 COSTS

Cost of Energy

The cost of wind-generated electricity continues to fall steadily. This is driven by technological development and increased production levels, together with the use of larger machines. In many areas of the United States, the projected cost of energy for utility-scale production can be as low as 0.04 to 0.06 USD/kWh, given an excellent resource and MW-plus scale turbines. In the United Kingdom, projects have been developed for under 0.03 UK pound/kWh (0.05 USD) under long-term fixed price power purchase contracts, where wind speeds are high (over 9.0 m/s at hub height).

The costs are a little higher in Japan because of the additional cost of transporting imported turbines from Europe and the United States, and higher than average installation and gird connection costs. In Japan, the costs are 7 to 9 Yen/kWh (0.065 to 0.084 USD) for large wind farms using MW-plus-sized turbines.

Capital Costs

Because of the commercial nature of wind farms, there is very little firm cost data available, though most countries provide estimates. Note that the costs appear to be higher in 2003 than in 2002, but this is due to the falling value of the U.S. dollar. The real costs have not changed. For complete wind farms, the estimates of average cost vary according to country, between about 1,000 to 1,400 USD (800 to 1,100 euro) per kilowatt of installed capacity, with 1,250 USD (1,000 euro) as the round average. In reality, system costs have a range that depends on location, project size and other factors. The cost of the turbine and tower alone varies between about 800 to 1,150 USD (630 to 900 euro), with 950 USD (750 euro) typical. These costs show a split of roughly 75% for the turbine (including tower) and 25% for the balance of plant (foundations, electrical infrastructure, and roads).

For the recent MW-plus machines, the installed costs per unit capacity might not be lower, but the overall economics continue to improve. This is because the turbines are on taller towers, which give rise to higher wind speeds and improved energy yields.

Operating Costs

Operating costs include servicing, repairs, site rental, insurance, and administration. A thorough study was conducted in Denmark, tracking operating costs for turbines in the size range 150 kW through to 600 kW. Tables are presented in the Danish chapter of this report. The work shows near contemporary turbines (500 to 600 kW) having annual operating costs steadily increasing from 1% of the investment cost in the first year, to 4.5% after 15 years. These figures are consistent with Portuguese estimates of 2% to 4% and Dutch estimates of 3.4% for smaller projects. The maintenance and repair costs account for roughly one-third of the total operating costs.

3.11 DEVELOPMENTS IN INDUSTRY

Globalization of Wind Turbine Supply

The trend towards wind turbine manufacturers operating as large multinational companies continues. Manufactures are merging and established multinationals are buying into this high-growth and increasingly high-turnover sector. Manufacturers, and to a lesser extent component suppliers, are also establishing factories across the world.

At the end of this year, the two largest turbine manufacturers in terms of installed machines, Vestas and NEG Micon, announced merger plans. The leading Spanish manufacturer Gamesa Eólica acquired MADE, one of the pioneering turbine companies in Spain. Another Spanish company, ECOTECNIA, was incorporated into the MCC group, which is one of the world's biggest co-operatives with activities in the industrial, distribution, and financial sectors.

The independent Dutch manufacturer Lagerwey went bankrupt at the end of September. Assets of its 750-kW technology are being sold. Earlier in the year, the technology rights for their 2-MW turbine were sold to Zephyros, a new company run by former employees and management from Lagerwey and owned by the Triodos bank and BVT, a German developer.

New factories were opened in Australia and Norway. Vestas Australia opened its first wind turbine assembly plant in the state of Tasmania, costing 11 million USD and capable of supplying 75 to 100 nacelles per year. UMOE Ryving, a Norwegian-based investment company, is now in series production of 1,500-kW wind turbine blades. The company delivered its first blade set in February 2004, and initial operating results are good.

Also this year, Portugal announced its intention to install two turbine assembly plants in the north and center interior and a new production factory in the northern littoral.

Finance

In 2003, a new wind investment trend surfaced in the United States. Traditional strategic investors are being partially displaced by institutional investors. Strategic investors are companies like Florida Power and Light and American Electric Power. Institutional investors are mainly passive and motivated by tax benefits and overall returns, perhaps having previous experience with other tax-advantaged industries. If the production tax credit is extended beyond 2005, this largely untapped market will become critical for the future of the industry as it will unleash substantial new capital.

Turbine Size

The average new turbine size increased again this year, continuing a trend. In Germany, which typically deploys the largest onshore turbines, the average size in 2003 increased by 11% to 1,552 kW. In Japan, the increase was much more dramatic, rising from 700 kW last year to nearly 1,200 kW. Italy and Spain generally install smaller machines, because of the difficulties presented by the terrain. In those two countries, 800 kW was the average machine size.

The average new turbine deployed was approximately 1,217 kW (based on data from CN, DK, DE, IT, JP, NL, NO, PO, ES, SW), which is an increase of 4% from last year. In 1995, the average new turbine had a capacity of just 440 kW. The trend was affected by Denmark this year, which installed most of its new capacity offshore and, as a consequence, used much larger turbines. Increasing numbers of machines going offshore will continue to push up the average turbine size.

3.12 NATIONAL STATISTICS OF THE MEMBER COUNTRIES OF IEA R&D WIND

Table 3.3 includes statistics provided by the countries participating in the IEA Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems. Numbers presented in italic are estimated.

Author: Ian Fletcher, Wind Business Support, United Kingdom

Country	Total installed capacity	Offshore installed capacity	New installed capacity in 2003	Total No. of Turbines	Average new turbine size	Wind generated electricity	2003 National electricity demand	Typical wind system costs	Price paid to wind generators
	(MW)	(MW)	(MW)		kW	GWhrs/yr	TWhrs/yr	USD/kW	USD/kWh
Australia	198.0	-	93.0	-	-	-	192*	-	-
Canada	317.0	-	85.0	423.0	682.0	*724.0*	590	*1,161*	0.054
Denmark	3,114.0	406.0	225.0	5,389.0	2,045.0	5,542.0	35.2	*1,107*	0.061
Finland	*47.0*	-	*4.0*	-	-	-	81*	-	-
Germany	14,609.0	-	2,608.0	15,387.0	1,552.0	*26,000.0*	476*	-	-
Greece	424.4	-	69.0	772.0	793.0	850.0	50	*1,323*	0.101
Ireland	190.0	-	51.7	-	-	-	*24**	-	-
Italy	904.0	-	116.0	1,491.0	800	*1,450.0*	*319.7*	*1,134*	0.103
Japan	*506.0*	1.2	172.0	609.0	1,180.0	569.0	841.5	*1,167*	-
Mexico	2.2	-	-	8.0	-	5.0	179.4	-	-
Netherlands	905.0	-	227.0	1,612.0	1,621.0	*1,610.0*	110.0	*1,410*	-
New Zealand	36.9	-	0.5	57.0	-	-	*39**	-	-
Norway	100.0	-	3.0	65.0	1,540.0	-	115.0	*1,254*	0.031
Portugal	288.6	-	94.8	352.0	1,900.0	*720.0*	50.2	*1,260*	0.101
Spain	6,202.0	-	1,323.0	-	840.0	*11,370.0*	234.8	*1,179*	0.079
Sweden	404.0	22.5	59.0	675.0	980.0	690.0	145.6	*1,230*	0.046
Switzerland	5.4	-	-	21.0	-	5.0	55.0	-	0.085
United Kingdom	647.6	63.8	95.6	1,057.0	1,648.0	-	397.0	-	0.120
United States	6,374.0	-	1,689.0	n/a	1,400.0	*19,500.0*	3,602*	*1,000*	0.045

*** 2002 national electricity demand**
- no data available

Table 3.3 National statistics of the IEA R&D Wind member countries

Chapter 4 Australia

4.1 INTRODUCTION

The past two years have witnessed both exceptional growth and great uncertainty for the Australian wind industry. Since 2001, the industry has demonstrated rapid expansion by more than doubling the nation's installed wind capacity, bringing the cumulative total to 198 MW at the end of 2003.

The industry has also consolidated and developed in other important ways. During 2003, Vestas Australia opened its first wind turbine assembly plant in the state of Tasmania. And at the end of 2003, the first Australian wind-tower component export contract was signed by the engineering firm, Keppel Prince.

However, the industry was also greatly affected by uncertainty created by the federal government's drive for a new approach to a national energy strategy. The year 2003 began in the wake of a federal government report, the *Parer Report*, which recommended abolition of the most significant policy driver behind renewable energy sector growth, the Mandatory Renewable Energy Target (MRET).

Many in the industry expressed concern when the Review Committee's report, released in January 2004, recommended that the current target for 2010 remain unchanged. Although it has fostered considerable renewable investment thus far, the 9,500 GWh fixed target is an insufficient stimulus to establish a robust wind-manufacturing base in Australia.

The Australian industry is now focused on the outcome of a legislated review of the MRET measure. The review has been completed, but the government's response is still awaited, expected some time in early 2004. The government's final decision on the future of MRET will undoubtedly have a significant impact on the wind industry in Australia.

4.2 NATIONAL POLICY

Strategy

The development and growth of the renewable energy industry in Australia is primarily supported by the strategic initiatives from the federal government's 1998 National Greenhouse Strategy (NGS). The Australian government has invested nearly 1 billion Australian Dollars (AUD) to fund a wide range of greenhouse abatement measures across the economy, especially within the energy, transport, and agricultural sectors. Renewable energy industry development is supported through a range of NGS measures.

Mandatory Renewable Energy Target (MRET)

A cornerstone of federal government support for the Australian renewable energy industry is the MRET initiative. This initiative proceeded from the Prime Minister's 1997 *Safeguarding the Future* package of measures, which is a core component of the NGS. Current MRET legislation mandates the sourcing of 9,500 GWh of extra renewable electricity per year by 2010, through 2020.

The program requires electricity wholesalers and retailers to source an annually increasing percentage of their supply from registered renewable generators or pay a shortfall pen-

Figure 4.1 Tower construction at Challicum Hills wind farm
Image courtesy Keppel Prince

alty of 40.00 AUD/MWh. The MRET was a "world first" in creating a national renewable energy market that is backed by legislation, using an innovative market-based system of tradable certificates.

In 2002, the *Parer Report* to the Council of Australian Governments (COAG) on national energy reform recommended the abolition of the target, a suggestion that caused great uncertainty in the industry. Subsequently, the legislation underpinning the MRET underwent a scheduled review process, beginning in March 2003.

There have been widespread calls for significant changes to the legislation, such as an increased target and an extension to the time period over which the target is mandated. After consulting with stakeholders, the MRET review panel tabled their report in the Australian Parliament during January 2004. The government's response to the report is also expected early in 2004 either before, or as part of, a national energy policy statement.

Renewable Energy Action Agenda (REAA)

The REAA is another NGS initiative. It was developed in 2000 and established a partnership between government and industry to support and advance the domestic renewable energy industry. The agenda reflects a multi-pronged approach that includes an analysis of current industry performance, identification of impediments to growth, and development of priorities for action. It strives to foster a competitive energy market with clear signals to investors, and it aims to achieve annual renewable energy industry sales of 4 billion AUD by 2010. The agenda is on track – 2002 to 2003 sales were estimated at 1.8 billion AUD.

A Renewable Energy Technology Roadmap followed the REAA. The roadmap provides analyses of strategic technology development crucial to establishing and maintaining a long-term competitive advantage. It outlines a long-term R&D plan that defines the industry's collective future and establishes clear pathways forward.

Other Programs

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

1. The 264 million AUD Renewable Remote Power Generation Program
2. The Renewable Energy Equity Fund, which provides venture capital to high-growth and emerging companies commercializing directly to or enabling renewable energy technology services
3. The Renewable Energy Commercialisation Program (RECP)
4. The Renewable Energy Showcase, which provides seed funding and/or promotion of leading edge technologies that are approaching commercialization.

In addition to the above, the National Green Power Accreditation Program (Green Power), which was initiated by the Victoria state government, encourages expansion of green power electricity generation by allowing customers to request, for a small premium on their electricity bill, that participating power retailers provide them with electricity from renewable resources.

State-Based Greenhouse Gas Abatement Schemes

In addition to Australian federal government strategies, some Australian states have also established their own greenhouse gas abate-

Figure 4.2 Mist below Challicum Hills wind farm during construction
Image courtesy Keppel Prince

ment programs. For example, New South Wales (NSW) established the Renewables Investment Program, which provides grants, loans, and equity for companies demonstrating new renewable energy technologies or new applications on existing technologies.

The NSW Greenhouse Benchmarks Scheme provides retail electricity suppliers with a compulsory greenhouse gas reduction target proportional to their market share of emissions, as well as support for low-emission power-generation projects. This program's impact on the renewable energy industry is unknown, but is unlikely to be high.

Queensland established the Queensland Sustainable Energy Innovation Fund, which provides matching funds for the demonstration of renewable energy technologies. The Queensland 13 Percent Gas Scheme requires electricity retailers and other liable parties to source at least 13% of their electricity sold in Queensland from gas-fired generation, beginning 1 January 2005.

Victoria has a variety of programs that support the renewable energy industry, including a 22.95-million-AUD fund for the development of new technology and the introduction of small-scale renewable energy projects.

Progress Towards National Targets

The MRET measure has performed strongly since coming into force in April 2001. It has generated a high level of renewable energy project planning and development activity, especially in the wind sector. Compliance with the scheme rose from just more than 92% in 2001 to more than 99% in 2002. These compliance results indicate the MRET is working, that electricity retailers are buying renewable energy, and that there are ample renewable energy supplies available for purchase.

According to the Australian Bureau of Agriculture and Resource Economics (ABARE), the average annual growth in wind-generated electricity is expected to exceed 25% until 2020. This was certainly the case in 2003, during which time it grew by 88%. Specifically, total installed capacity grew from 105 MW at the end of 2002 to 198 MW at the end of 2003. Victoria is home to almost half this total, with 91.65 MW of wind now installed in the state.

By the end of 2003, proposed Australian wind farms – with a capacity of 1,629 MW – had received planning approval. The 2003 industry goal of the Australian Wind Energy Association (AusWEA) is for 5,000 MW of installed wind capacity in Australia by 2010.

Figure 4.3 and Figure 4.4 indicate the percentage of Renewable Energy Certificates registered against the different sources of renewable energy as of December 2002. Although the percentage increase for wind from 2001 to 2002 appears as only 2%, this actually represents a significant increase from 100,191 MWh to 207,145 MWh.

4.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The total installed capacity of commercial wind turbines (10 kW or greater) reached more than 198 MW at the end of 2003, an increase of 88% over the 2002 value (Figure 4.5). More than 164 MW of this total is grid-connected, while the remainder is located in remote wind-diesel power systems (Figure 4.6).

New installed capacity for 2002 was 31.56 MW, with 31.50 MW of that total grid-connected and the remaining 60 kW in remote wind-diesel power systems. The projects were Toora (21 MW), Woolnorth Stage 1 (10.5 MW), and Exmouth Advanced (0.06 MW).

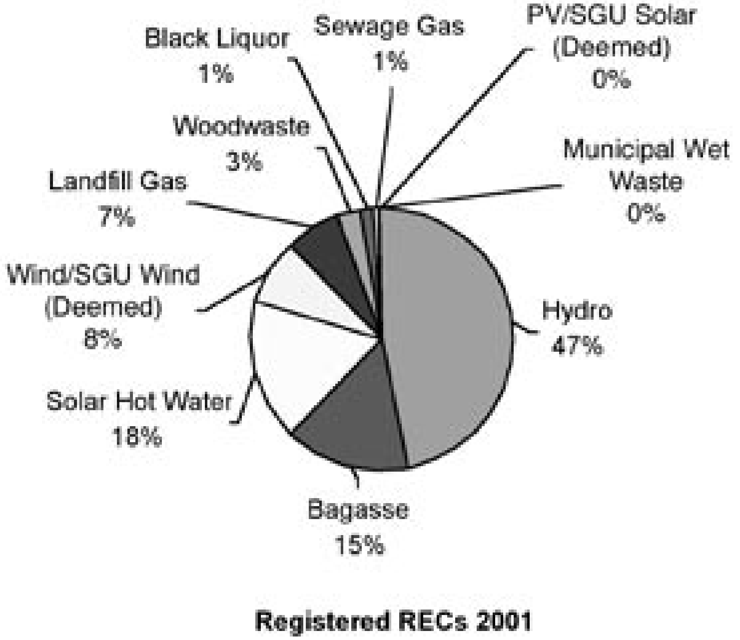

Figure 4.3 Renewable Energy Certificates registered against specific generation modes in 2001

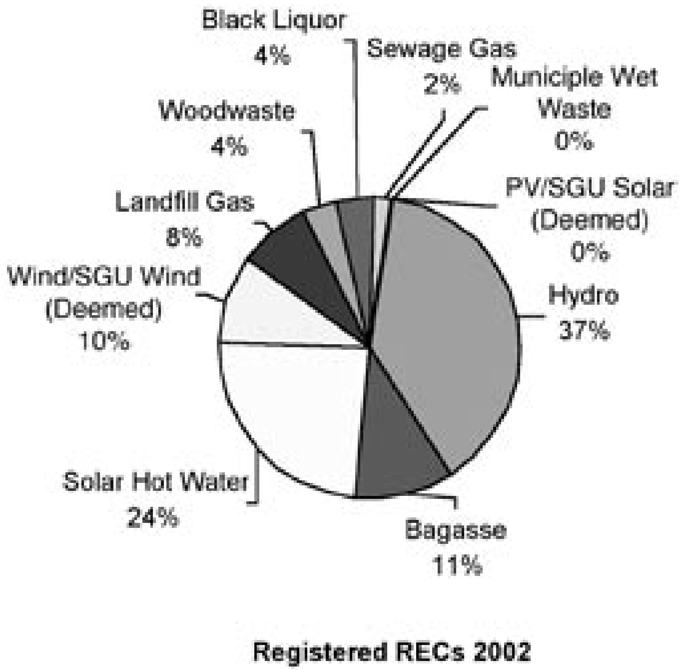

Figure 4.4 Renewable Energy Certificates registered against specific generation modes in 2002

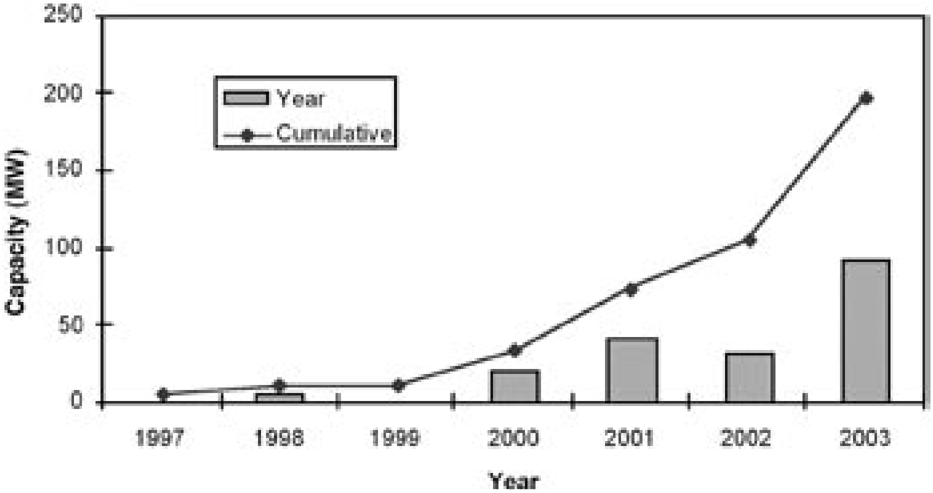

Figure 4.5 Total installed wind capacity in Australia at the end of 2003 (MW)

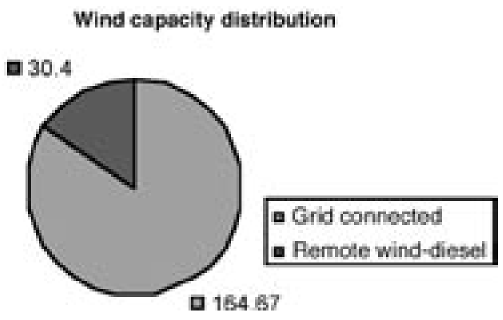

Figure 4.6 Grid versus remote supply of wind capacity

New wind installations soared in 2003 to 92.90 MW across five wind farm sites. These are the Mawson Base in Antarctica (0.6 MW), Starfish Hill (34.5 MW), Challicum Hills (52.5 MW), Huxley Hill Extension (1.7 MW), and Nine Mile Beach (3.6 MW). Of this new 2003 capacity, 87 MW is grid-connected, and 5.9 MW is located in remote wind-diesel power systems.

Three of the earliest Australian wind installations, totaling 430 kW, have been decommissioned. These are: Breamlea wind turbine located near Queenscliff, Victoria (a single, 60-kW Westwind turbine installed in 1987); Coconut Island, Queensland (a single, 10-kW Bergey-Westwind turbine installed in 1992); and Salmon Beach wind farm near Esperance, West Australia (six, 60-kW Westwind turbines installed in 1988). Six larger turbines at Nine Mile Beach near Esperance have replaced the Salmon Beach wind farm, and the Breamlea wind turbine is undergoing an upgrade.

The outlook for further installations of large, grid-connected wind is positive. At the end of 2003, more than 1,629 MW worth of projects had received planning approval, and more than 555 MW of capacity were already under tender or construction. The projects are spread over the four states of South Australia, Tasmania, Victoria, and West Australia, which all have large tracts of cleared farmland in coastal areas. In addition, four remote wind-diesel projects, totaling 3.28 MW have received planning approval and will be built in 2004.

An additional 3,180 MW of public domain projects have been identified, but have not yet gained planning approval. Some of these projects may not proceed once they have been tested against local planning approval criteria, availability of grid transmission infrastructure, and financing. There are, in addition, a large number of identified potential projects not yet in the public domain. AusWEA is aware of approximately 2,000 MW within this category.

Rates and Trends in Deployment

Over the past four years, Australia's wind capacity has undergone an average growth rate of 120%. This rapid growth rate is expected to continue until about 2007, as requirements for electricity retailers to source more renewable energy ramp up towards the current legislated MRET of 9,500 GWh of renewable energy by 2010. In the absence of a higher MRET, it is highly likely that the rate of investment in wind energy projects will quickly drop off after 2007.

The timeframe and incremental increase required under the MRET has caused the amount of electricity produced per annum from wind energy to grow rapidly since the target commenced in 2001 (Figure 4.7).

A green power program, mentioned earlier, also encourages renewable energy development. Increasingly popular, this program now has 75,000 customers and more than 3,000 businesses enrolled. During 2001 to 2002, green power programs purchased more than 405 GWh of renewable energy, of which 18% came from wind energy.

Wind energy projects in Australia so far have all been land-based. Australia is sparsely populated, and several states have extensive private coastal farmlands that possess good wind regimes. Over the past three years, the trend has been toward larger wind projects. With 32 turbines and a total capacity of 52.5 MW, the Challicum Hills wind farm near Ararat in the state of Victoria is the largest in Australia to date, and it is also the largest wind farm in the southern hemisphere. Several projects of more than 100 MW have already received planning approval and will be built in stages.

Additional projects are still being identified, particularly in inland regions of Victoria, NSW, and the Australian Capital Territory (ACT). In January 2004, the Victoria state government released a detailed state wind map that indicated viable inland areas. Following widespread bushfires in NSW and ACT, which destroyed large tracts of plantation forests, the state forests of NSW called for "expressions of interest" for wind developments in those regions.

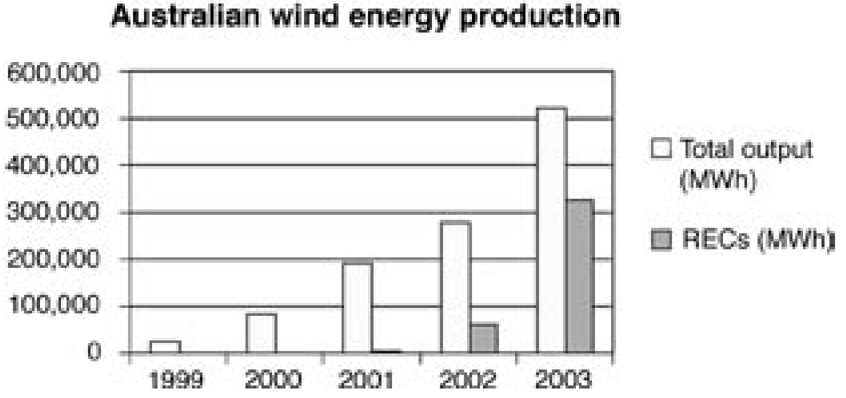

Figure 4.7 Estimated cumulative wind energy output and number of registered renewable energy certificates.
(Note: one REC = one MW; from www.orer.gov.au)

In addition, there is a trend towards installing larger turbines for grid-connected projects. The largest turbines installed in 2003 used 1.75-MW Vestas equipment. Some upcoming wind developments are expected to use 2-MW turbines. Smaller wind turbines, including Westwind and Enercon machines, are being utilized for small remote wind-diesel projects.

A focus of the wind industry has been to encourage local manufacture of wind turbines and towers, with a trend toward construction contracts based on commitments to local industry development. Grid-connected projects have so far been able to award approximately 50% of construction contracts to local Australian companies. The industry goal is to increase this to 90% local content in projects by 2010.

Contribution to National Energy Demand

The most recent statistics for electricity generation in Australia are from 2001 to 2002. As of June 2002, total Australian generation capacity of 42,942 MW produced 205,407 GWh of electricity (excluding independent power producers).

Corresponding to this period, the installed capacity of wind for 2002 was 105 MW, or 0.24% of national electricity capacity (Figure 4.8). In 2002, Australian wind generators produced approximately 277 GWh of electricity, of which 207 GWh was provided to various state transmission systems and 63 GWh to remote power systems.

In 2003, the installed capacity of 198 MW was estimated to have produced more than 520 GWh of electricity with more than 442 GWh provided to state transmission systems and 78 GWh to remote power systems. Caution should be applied in the use of these estimates because actual production figures are not reported in Australia.

4.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The most influential market stimulant in Australia for wind power continues to be the MRET, which requires an additional 9,500 GWh of new electricity to be generated per year from renewable and specified waste sources by 2010. Though the MRET was

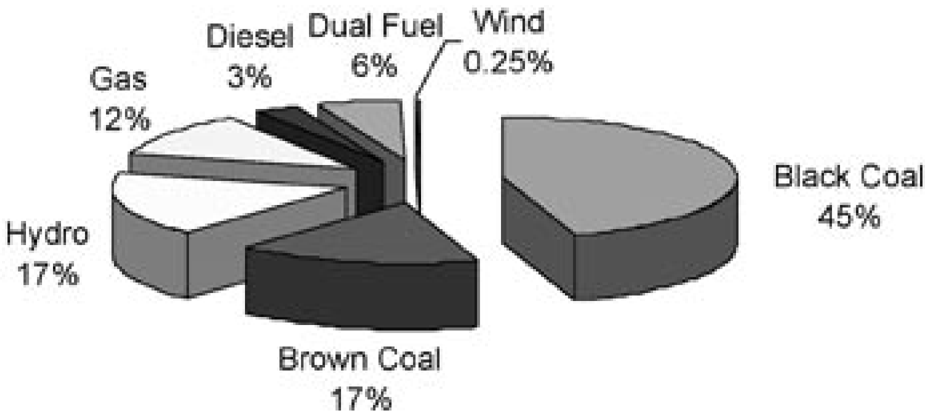

Figure 4.8 Contribution of wind to national electricity capacity in 2002

originally set at 2% new renewable energy by 2010, the target was subsequently converted to the stated fixed quantity. Due to rising total energy demand, this fixed target will amount to less than a 1% increase by 2010. As stated earlier, the MRET legislation is currently under review; the results of this review will undoubtedly be significant for the future growth of the Australian wind power industry.

Another federal government strategy is the REAA, described previously. This government/industry partnership is on-track toward achieving annual renewable sales of 4 billion AUD by 2010, with 2002 to 2003 sales estimated at 1.8 billion AUD. The Renewable Energy Technology Roadmap, which followed the REAA, provides strategic long-term direction to the industry.

Other federal government support for renewable energy includes the following:

1. The Renewable Remote Power Generation Program (RRPGP), which is funded to 264 million AUD, available over four years commencing in 2000
2. The 54-million-AUD RECP, launched in 1999 and continuing for five years
3. The 26.5-million-AUD Renewable Energy Equity Fund
4. An R&D Tax Concession administered by the federal Department of Industry, Science, and Resources and the Australian Taxation Office, which fosters renewable energy innovation with a 1.25-AUD deduction for every dollar spent on eligible R&D activities

In addition, the Australian Greenhouse Office is providing up to 6 million AUD over four years to foster the industry and guide standards development. It granted an 88,000.00 AUD award to AusWEA to develop *Best Practice Guidelines for the Implementation of Wind Energy Projects* in Australia in 2001. These guidelines are intended to be a live document to ensure that they represent the best in development practice in the light of ongoing knowledge and experience. An additional grant to AusWEA, of 170,000.00 AUD, followed in 2003 for the Wind Industry Development Project. This project aims to develop bird protocols and dataset standards, and develop and disseminate fact sheets on key wind farm issues as an adjunct to the *Best Practice Guidelines*.

The Australian Greenhouse Office, established in 1998, remains the principle federal government agency on greenhouse matters. A separate entity, AusIndustry, is the main federal government agency for delivering information, programs, and services that support industry research and innovation.

A notable 2003 development was the termination of federal government funding for the Australian Cooperative Research Centre for Renewable Energy (ACRE).

In some cases, wind energy projects are also supported at a state level. In Western Australia, the Sustainable Energy Development Office, created in 2001, continues to deliver state-sustainable energy policy in that region. In 2003, the Sustainable Energy Development Agency (SEDA) of NSW was moved to the state's Department of Energy. And the Sustainable Energy Authority of Victoria (SEAV) works to accelerate progress toward a sustainable energy future for the state, by facilitating investment in demonstration of innovative renewable energy technologies.

The NSW and Victorian agencies have each produced a state-based wind atlas, SEDA in 2002 and SEAV in 2004. During 2002 and 2003, SEDA's WindBusiness unit produced data to assist the NSW industry to choose favorable sites and harness the maximum available energy at any site. In Victoria, the

Figure 4.9 Turbines at the Woolnorth wind farm in Tasmania
Photo courtesy Hydro Tasmania

8.45-million-AUD Renewable Energy Support Fund, administered by SEAV, aims to support new and innovative applications of medium-scale, renewable energy technologies and can provide up to 20% of the capital cost of eligible projects.

4.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Although new Australian wind capacity deployment dropped off slightly during 2002 from 2001 levels, installation redoubled in 2003, during which time the highest-ever quantity of new capacity was connected to the grid.

In 2002, Tasmania was home to the largest share of new installed capacity (10.5 MW). During 2003, Victoria (52.5 MW) and South Australia (34.5 MW) underwent a surge in new capacity as some large wind farms were completed (Figure 4.10). South Australia, Western Australia, Victoria, and Tasmania all show great promise for future development, with major wind farm projects already approved by planning agencies in these states.

The majority of turbines deployed in 2002 and 2003 had a capacity greater than 1 MW. However, they ranged in size from 20 kW to 1.75 MW. In 2002, eighteen 1.75-MW turbines were installed, and six 20-kW turbines. In 2003, fifty-eight turbines with a capacity great than 1.5 MW were installed, along with two 850-kW machines, six 600-kW machines, and two 300-kW turbines.

Operational Experience

Australian wind farm contribution to electricity supply continues to rise. In 2002, wind farms produced approximately 277 GWh of electricity; in 2003, they produced 520 GWh.

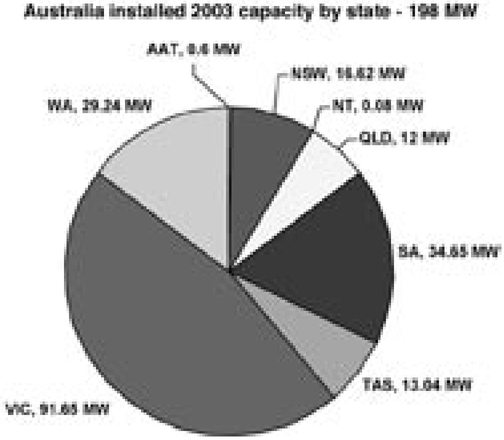

Figure 4.10 Australian installed capacity to the end of 2003

Main Constraints on Market Development

The market development constraints are mainly: (1) the market price for electricity from renewable sources, (2) access to the grid for export of power, and (3) planning approval.

Renewable energy development in Australia faces a serious competitive challenge in the form of some of the lowest electricity prices in the world, largely due to the generation sector's reliance on cheap, abundant coal for approximately 84% of electricity. The market price for electricity from wind farms is set by a number of sources, including market spot price, value of renewable energy certificates, green power component, and emission reduction rights.

Issues associated with the connection of wind farms to Australia's transmission and distribution grids, now and in the future, are of high importance to the wind energy industry. These issues have the potential to make or break the development of new wind farms, depending on the location of the project within the transmission and distribution systems.

To address these issues, AusWEA has established a Wind Grid Working Group. Consultation with stakeholders will be followed by the development of potential solutions, actions, and strategies, scheduled for completion by mid-2004. Recommendations based on these analyses will then be made available to the regulatory bodies capable of approving and implementing them.

In 2003, high-growth plans proposed by developers continued to face rising community concerns over the deployment of wind farms, particularly in coastal areas of the state of Victoria.

In response to calls from community leaders, SEAV has released wind farm planning guidelines. And in early 2004, AusWEA and the country's foremost landscape conservation body, the Australian Council of National Trusts, launched a joint project to address landscape concerns. The project aims to develop mutually agreed methodologies for assessing landscape values to assist siting wind farms. Stage 1 of the project is being funded by the federal government through the Department of Environment and Heritage, and the Australian Greenhouse Office.

Weighing the perceived loss of visual amenity against considerable economic and environmental benefits, both to local communities and the whole nation, is crucial. Other issues include the potential impact of wind farms on rare and endangered species such as migratory, orange-bellied parrots (protected by federal legislation); neighbors potentially affected by noise; changes in land values; and interference with television reception. The lack of a national, coordinated approach to planning the location of future wind farms is also of concern.

AusWEA's comprehensive *Best Practice Guidelines for the Implementation of Wind Energy Projects in Australia* aids in appropriate installation of wind farms. The guidelines were prepared by consulting with diverse stakeholder groups including developers, local councils, consultants, environmental groups, state agencies, network operators, and retailers. Although not mandatory, AusWEA is encouraging all of its members to follow these guidelines.

Standards Australia has also established a Wind Turbine Noise Committee to address the lack of an Australian standard in this area. Their Australian Standard for the Prediction, Measurement and Assessment of Noise from Wind Turbines will provide a detailed methodology and examples (but no recommendations) for criteria or limits because these are the responsibility of the relevant regulatory authorities. The Draft Standard is scheduled for public release and comment in early 2004.

4.6 ECONOMICS

Trends in Investment

Growth of capital expenditure on wind farms has been rapid over the last two years and is forecast to continue at an extraordinary rate in the short-to-medium term. Current growth rate predictions estimate a total expenditure of 5 billion AUD by 2007 forward. However, the accuracy of this forecast depends heavily on the outcome of the MRET review currently being undertaken by the federal government.

Trends in Unit Costs of Generation and Buy-Back Prices

The potential for ongoing improvements in technology is highlighted by major wind turbine manufacturer NEG Micon's commitment to achieving 5% to 10% cost reductions (on a Australian dollar per megawatt-hour basis) between successive generations of machines, typically released every two years. With Australia's world-class wind sites, the industry should be able to track the lower of published price curves. However, wind energy price will depend not only on sites and technology, but also on the commercial environment and economies of scale.

4.7 INDUSTRY

Manufacturing

Australia has a small but viable manufacturing industry for wind turbines in the battery charger sizes, and the manufacture of 5-kW to 20-kW turbines for export is another growing Australian industry. Demand for large wind-turbine generator components has also spawned a vibrant domestic industry for steel tower manufacturing. In 2003, a further milestone was achieved when a Vestas nacelle assembly plant opened in Tasmania, signifying continued industry diversification. In Queensland, Notus Energy – in partnership with German turbine manufacturer, RePower – is also hopeful of developing an Australian turbine manufacturing facility in the near future.

Current Australian content of new wind farms is estimated at about 50% of total capital cost, with the balance largely coming from

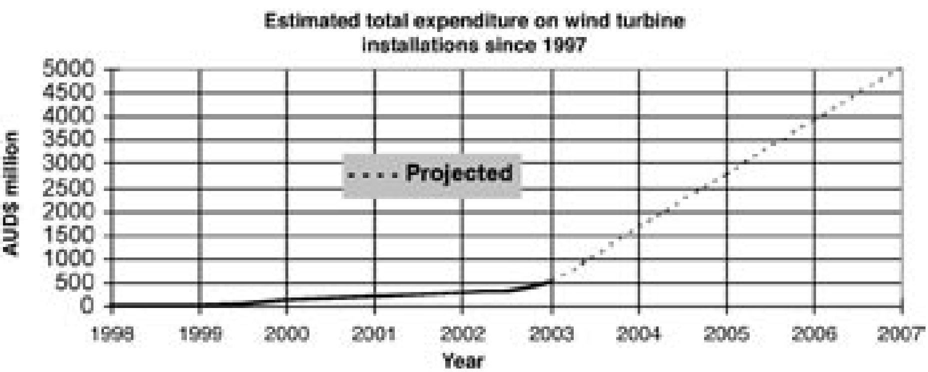

Figure 4.11 Estimated total expenditure on wind turbine installations since 1997

Danish and German manufacturers. With increased scale, it may be possible in the near future to source up to 90% of turbine manufacturing within Australia. This would comprise blade, nacelle, and tower manufacturing.

Industry Development and Structure

A range of different types of companies is active in the Australian wind industry. Wind farm developers and owners include private equity investors, public companies, and government-owned generators and utilities both from within Australia and offshore. In addition, a wide range of companies (both public and private) provides the industry with materials, specialist expertise, labor, and ancillary services including finance.

Domestic manufacturing has progressed in a number of important ways in recent years. Manufacture of steel towers continues to grow as an industry, with excellent capability at many centers around Australia. Tower manufacturing generally proceeds on a project-by-project basis, with suppliers usually located in the same region as the developing wind farm in order to maximize regional and local economic benefits. This manufacturing industry took an important step forward at the end of 2003, with Australia's first wind turbine tower component export contract. It will see the Portland, Victoria-based engineering firm, Keppel Prince, supply embeds to Meridian Energy's Te Apiti wind farm in New Zealand.

In 2003, another industry breakthrough was the opening of the first Vestas nacelle assembly plant, in Wynyard, Tasmania. The 15-million-AUD plant is expected to supply nacelles for 75 to 100 wind turbines per year. It brings 73 new jobs at the factory, plus an additional eight support jobs in Wynyard, a considerable economic stimulus for this regional center of 4,900 inhabitants.

Manufacturing in Australia of turbine blades has been the subject of feasibility studies by some of the world's largest manufacturers since the MRET was announced. The key impediment has been guaranteeing demand for sufficient numbers of machines in order to justify the start-up costs for such facilities. The states of Victoria and Tasmania are the most likely locations for proposed blade plants.

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

The manufacture and installation of small wind generators (up to 200 kW) is a growing market in Australia. Responding to this opportunity, in 2003, AusWEA established a Small Wind Working Group to focus on developing standards for small wind generators and promoting Australian manufactured equipment.

4.8 GOVERNMENT-SPONSORED R,D&D

New R,D&D Developments

New government R&D sponsorship came through the funding programs of the Australian Greenhouse Office, state government sustainable energy organizations, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and universities.

Australian Greenhouse Office (AGO) Initiatives

The key AGO programs of benefit to wind energy projects are the RECP, the Renewable Energy Industry Development Program (REID), and the RRPGP.

There have been six rounds of the RECP to date. Two types of wind energy projects were funded under the last round of the commercialization component and the industry development component of RECP: (1) the Commercialisation Project and (2) Industry Development Projects.

For the Commercialisation Project, Powercorp Pty Ltd. received a 1-million-AUD grant for the commercialization of its Intelligent Power Systems (IPS) Wind/Diesel/Energy Storage technology to enable successful marketing and installation of this innovation in Australia and overseas.

There were three Industry Development Projects, which were awarded financing as follows:

1. An award in the amount of 238,400.00 AUD was made to Wind Corporation Australia Ltd. to produce Comprehensive Guidelines for the Development of Embedded Wind Farms Connected in Rural Australia.
2. An award in the amount of 38,600.00 AUD was awarded to the Wind Energy Research Institute of CSIRO Land and Water to produce a *Planners Guide for Wind Resource Assessment in Australia*.
3. AusWEA was provided with 88,000.00 AUD to develop *Best Practice Guidelines for Grid Connected Wind Projects*.

REID supports the growth of the Australian renewable energy industry, mainly through grants to Australian companies that demonstrate that their projects would assist the wider development of the Australian renewable energy industry.

The single wind project funded under the most recent REID round in March 2003 provided AusWEA with 170,000.00 AUD. The funding was given in order to develop assessment protocols and dataset standards with regard to wind turbine impacts on birds, and to develop and disseminate a range of educational material on Australian wind farms.

RRPGP provides financial support to increase the use of renewable energy generation in remote parts of Australia that presently rely on diesel for electricity generation. The objective of the RRPGP is to increase the uptake of renewable energy technologies in remote areas of Australia, which will assist in doing the following:

1. Providing an effective electricity supply to remote users
2. Developing the Australian renewable energy industry
3. Meeting the energy infrastructure needs of indigenous communities
4. Reaching long-term greenhouse gas reduction goals

More than 200 million AUD is expected to be available over the life of the RRPGP. The RRPGP provides support for up to 50% of the capital costs of renewable generation equipment.

Other Initiatives

In 2003, the government also funded five other initiatives, explained in more detail in the following paragraphs. They were: (1) the SEAV Wind Atlas, (2) CSIRO, (3) ACRE, (4) RESLab, and (5) the University of Newcastle Wind Energy Group.

In 2003, SEAV funded the development of a Victorian Wind Atlas and Map, which was released in January 2004. This product seeks to increase the quality of publicly available information about the state's wind resources. Average annual wind speeds were modeled using the WindScape wind resource mapping tool developed by the Wind Energy Research Unit of CSIRO Land and Water. WindScape uses atmospheric data and regional topography to model wind resource. The wind speeds have been

Figure 4.12 Woolnorth wind farm in Tasmania

modeled at 65 m above ground level to a resolution of three kilometers.

CSIRO is Australia's premier scientific organization and it makes its major contribution to wind energy research through its Wind Energy Research Unit (WERU). The WERU has primarily focused on developing capabilities for regional wind assessment tools and modeling wind flow over complex topography. A business unit resulting from this work, Windlab Systems Pty Ltd., was established and spun out from CSIRO during 2003.

ACRE was opened in 1996 under the Australian Government's Cooperative Research Centres Program. The various cooperative research centers facilitate technology development and commercialization through university, government, and industry collaboration. ACRE, based at Murdoch University in Western Australia, sought to facilitate creation of an internationally competitive renewable energy industry. However, the federal government terminated funding for ACRE, and the center closed its doors in December 2003. There is currently no similar research center in Australia.

RESLab is a testing laboratory for renewable energy components and systems. Formerly a project of ACRE, at which time it was known as ACRELab, the lab was shifted to a new center within Murdoch University, called the Australian Sustainable Energy Centre (ASEC) near the end of ACRE's term. Continuing under the name RESLab, the laboratory provides testing, design, certification, and training services for the renewable energy industry. It also conducts standards development, product development, research, and commercial consultancies.

The University of Newcastle Wind Energy Group's research focuses on small wind turbines. As a consequence of past research, three turbines have been designed for remote-area power systems: (1) a 600-W machine being marketed by Australian Wind Power, (2) a 5-kW turbine being manufactured in China, and (3) a 20-kW prototype. The current research program focuses on aerodynamics and structural dynamics.

Offshore Siting

Does not apply.

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Chapter 5
Canada

5.1 INTRODUCTION

Canada ratified the Kyoto Protocol in 2002 and is pursuing the implementation of wind energy as part of its response to the climate change challenge. In addition, the country supports the development of this renewable resource to achieve the goals of energy diversification, technology development, job creation, and increased trade. Canada has tremendous wind energy potential, and federal and provincial governments support its deployment through an increasing number of incentive programs. The main vehicle of technical support at the national level is the Wind Energy Research and Development (WERD) Program, at Natural Resources Canada, a department of the federal government of Canada. In 2002, Canada introduced the Wind Power Production Incentive, a 260 million Canadian dollars (CAD) program to accelerate the introduction of wind energy in Canada.

5.2 NATIONAL POLICY

Strategy

The main elements of the WERD program are technology development, resource assessment, test facilities, and information/technology transfer. Field trial projects are selected to evaluate the performance of the new technology under special environmental conditions or for specific applications.

Progress Towards National Targets

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. 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.

5.3 COMMERCIAL IMPLEMENTATION

Installed Wind Capacity

By December 2003, a total of 315 MW of wind power had been installed in Canada. Alberta is the province with the highest installed capacity, totaling 255 MW. While Quebec did not see a big increase of installation since the Le Nordais installation in 1999, it is poised for increased development in the near future, with two new 54-MW wind farms slated to be commissioned by the end of 2004, and installation of the 1,000-MW request for proposals (RFP) starting in 2006.

New installations in 2003 included the MacBride Wind Farm (75.9 MW) in Alberta, the North Cape Wind Farm Expansion (5.3 MW), and the Aeolous Wind Turbine (3 MW) in PEI, the Parc éolien du Renard (2.25 MW) in Quebec, the Cypress Hill Wind Farm Expansion (4.6 MW) in Saskatchewan, and the Ontario Place Wind turbine (0.75 MW) in Ontario.

Rates and Trends in Deployment

Installed wind power capacity in Canada has experienced an average annual growth rate of 60% over the past five years. Though average growth is high, it has varied widely from year to year. Large capacity additions occurred in 1999 (100 MW) and 2001 (77 MW). With an estimated 18 MW of capacity additions in 2002, the year-over-year growth was only 8%. In spite of this recent, subdued increase, it is expected that the commencement of new projects supported by WPPI will ensure rapid growth in 2003 and the following four years.

Contribution to National Energy Demand

The national electrical energy demand in Canada in 2003 was 590 TWh. Total installed generation capacity at the end of 2003, the most recent year for which statistics are available, was projected at 112 GW, which includes hydropower, coal, nuclear, natural gas, oil-fired, wood-fired, tidal, and wind plants. The installed wind capacity was 317 MW by the end of 2003, and an estimated 765 GWh of wind energy was produced that year.

5.4 MARKET DEVELOPMENT AND STIMULATION INSTRUMENTS

Main Support Initiatives and Market Stimulation Incentives

Currently, Class 43.1 of the federal Income Tax Act provides an accelerated rate of write-off (30% per year on a declining balance basis) for certain capital expenditures on equipment that is designed to produce energy in a more efficient way or to produce energy from alternative renewable sources.

In 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 newest, and likely the most influential market stimulation instrument so far, is the federal government's 260-million-CAD WPPI program for wind energy developers. This initiative is for projects commissioned after 31 March 2002 and before 1 April 2007. Qualifying wind energy facilities receive an initial incentive payment of 0.012 CAD/kWh of production, declining to 0.008 CAD/kWh of production by the fifth year of the program. The incentive is available for the first ten years of production and helps to provide a long-term, stable revenue source. The program is intended to help address climate change and improve air quality.

Interest in WPPI has been high – by December 2003, the program had registered Letters of Interest applications totaling 110 projects and 5,300 MW of capacity. (Funding, however, is limited to supporting about 1,000 MW of wind power.) On the basis of quantity and quality of applicants, it is expected that 2004 will be a watershed year for wind power development in Canada.

Provincial and territorial governments are being encouraged to provide additional support, and a number of provinces have begun to develop their own complementary programs. For example, Quebec has announced RFPs for 1,000 MW to be built between 2006 and 2012. Ontario has also recently announced support for renewables through a significant tax rebate program and RPS. So far, however, none of the provincial programs offers the same level of incentive as that provided by WPPI.

Unit Cost Reduction

Does not apply.

5.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Several wind turbines of 150-kW or less are deployed in Canada, in addition to the following higher-capacity wind turbines:

- 57 US Windpower (Keneteck) 360-kW and 375-kW wind turbines
- One NEG-Micon 900-kW and 136 NEG-Micon 750-kW wind turbines
- 20 Nordex 1.3-MW wind turbines
- Five Vestas V44-600-kW, 87 Vestas V47-660-kW, and seven Vestas V80-1.8-MW wind turbines
- One Enercon E 40-600-kW wind turbine
- One Turbowinds 600-kW wind turbine
- One Tacke 600-kW wind turbine

Operational Experience

Most of the wind turbines presently operating in Canada are privately owned, which makes it very difficult to obtain their operating performance data.

Main Constraints on Market Development

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 recently announced 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.

5.6 ECONOMICS

Trends in Investment

The budget for the WERD program of Natural Resources Canada is about 550,000.00 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. So far, about 2 million CAD has been accessed to leverage projects sponsored by WERD in the last three years.

The WPPI program is an incentive on production given directly to the developers of wind farms. It represents about 0.01 CAD/kWh for a ten-year period.

Trends in Unit Costs of Generation and Buy-Back Prices

Electricity deregulation in Alberta resulted in the restructuring of government-owned utilities into a free-market system. 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 set-back 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. On the other hand, the large Le Nordais project in Quebec pre-negotiated special buy-back rates from Hydro Quebec, which are believed to be above the utility's avoided costs.

5.7 INDUSTRY

Manufacturing

The following five companies manufacture wind energy components in Canada:

1. Dutch Industries produces water pumping units in Regina, Saskatchewan.
2. Wenvor-Vergnet of Guelph, Ontario, and Plastique Gagnon of Quebec develop small, 20-kW to 30-kW wind turbines.
3. Vergnet Canada of Montreal, Quebec, develops 10-kW to 275-kW wind turbines for grid-connected, remote communities and stand-alone applications.
4. Novelek Technology of New Brunswick has developed 10-kW and 25-kW inverters for the commercial wind turbine market.
5. Bolwell Corporation of Huron Park, Ontario, manufactures blades for 10-kW to 1.5-MW wind turbines. The company produces rotor blades on spec for wind turbine manufacturers and also has a generic blade design, suitable for turbines in the 750-kW to 900-kW range.

Industry Development and Structure

Industries that are related to wind energy include manufacturers of rotor blades, control systems, inverters, towers, and small wind turbines as well as wind resource assessment firms and wind farm developers.

5.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The focus of the Canadian national wind energy program continues to be on R&D to develop 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.

New R,D&D Developments

The program supports new technology development activities related to the following:

- Components for wind turbines in the range of 600-kW to 2-MW
- Small- to medium-sized 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

Offshore Siting

The government is studying the impacts and regulation of offshore wind farms in the context of large projects off the coast of British Columbia in the Pacific.

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Chapter 6
Denmark

6.1 INTRODUCTION

The total installed wind power capacity in Denmark by the end of 2003 was approximately 3,114 MW. Of this capacity, 2,708 MW is installed onshore and 420 MW offshore. In a year with normal wind conditions, the electricity produced from wind energy will cover almost 20% of the country's present electricity demand (35,200 GWh in 2003).

Danish offshore wind power plants presently constitute more than 80% of the total installed offshore capacity in the world. Information about the offshore installations and the preliminary experience are included in this report.

6.2 NATIONAL POLICY

Strategy

Development and implementation of wind energy has been included in all Danish energy strategies. Both demand-pull policy instruments (financial and other incentives) and technology-push policy instruments (certification schemes and R,D&D programs) have been used as tools in the strategies.

In the 1980s and the 1990s, Denmark implemented vigorous energy policies with broad political support involving a broad range of actors: energy companies, industry, municipalities, research institutions, nongovernmental organizations (NGOs), and consumers. The latest pull-policy instrument is a re-powering scheme motivating owners of old turbines (with capacities of less than 150 kW) to scrap those and invest in new, larger-capacity machines. The re-powering scheme has been a time-limited program running from the beginning of 2002 until the end of 2003. The support scheme has resulted in the replacement of 1,200 old, small turbines with 300 new, larger machines.

The technology-push instruments have been reduced in steps with the development of a liberalized market for electricity including wind energy. The government also changed its focus for support to R,D&D. Funds for the Energy Technology Programme were reduced, and the special Development Programme for Renewable Energy Sources was stopped in 2002.

In place of these programs, the government introduced a new overall strategy for renewable energy research, which will be implemented over the coming years. The Public Service Obligation funds within the electricity sector for supporting the development of clean energy technologies continues.

The area resources for wind turbines on land are limited in Denmark. Furthermore, wind conditions at sea are considerably better than those on land, and wind turbines erected offshore are expected to become competitive in step with the development of technology.

For this reason, the main part of new development in Denmark is expected to take place offshore. Renovation of wind turbine areas and removal or replacement of existing wind turbines in accordance with regional and municipal planning will affect wind turbine capacity on land, among other things, after 2005.

In spring 1999, an electricity reform was introduced that unbundled the electricity sector. The reform also contributes to ensuring the fulfilment of the long-term, international environmental commitments for 2008 to 2012. The agreement covers the years from 2000 to 2003 and is a framework for carbon dioxide emissions from the electricity sector and for the development of renewable energy.

The Danish government's policy is to strengthen the use of market-based instruments in the energy sector. In its 2002 strategy for liberalization of the energy markets, the government emphasized the need to increase competition in the energy sector and encourage cost efficiency in renewable energy plants.

In its 2003 climate strategy, the government again emphasized cost efficiency and prioritized the most cost-efficient instruments for carbon dioxide reduction.

The instruments planned to support wind energy are: (1) providing economic incentive to gradually change to market prices with the "electricity plus environmental bonus," (2) strengthening fundamental research, and (3) offering tenders for offshore wind.

Progress Towards National Targets

The electricity from wind energy alone has covered nearly 16% of the total electricity consumption in 2003, fulfilling a major part of the target of 20% total renewable energy production.

Denmark is a densely populated country, and the Danish onshore wind resource is limited by zoning restrictions and the balance between wind energy development and other claims or interests in the open land. For this reason, The Danish Energy Authority estimates little future capacity growth on land after 2003.

Several investigations of offshore wind resources have been prepared since 1977. In July 1997, a plan of action for offshore wind farms was submitted to the Minister of Environment and Energy. Two utility associations, Elkraft and Elsam, and the ministry's Energy Authority and Environmental Protection Agency, prepared the plan.

The plan shows how a total capacity of 4,000 MW offshore wind power in Denmark by 2030 could be established. The corresponding annual electricity production would be 12 TWh to 14 TWh, which is more than one-third of the present electricity demand of 35 TWh. Based on the plan, the first major 160-MW wind farm at Horns Rev in the North Sea was installed in 2002 and followed by a second, 160-MW wind farm in 2003 at Nysted in the Baltic sea south of the Island of Lolland.

Future offshore installation will be decided based on economical possibilities and needs specified by the government's future climate policy. The Danish Energy Authority is preparing tender documents for a third offshore wind farm to be announced early in 2004.

6.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The total capacity of wind power in Denmark increased to 3,114 MW by the end of 2003, distributed with 2,372 MW in western Denmark, and 742 MW in eastern Denmark. The total number of turbines was 5,389.

The development in accumulated wind turbine capacity and number of wind turbines is shown in Figure 6.1. In spite of the growing total capacity, the number of wind turbines decreased, illustrating the success of the re-powering scheme.

Rates and Trends in Deployment

The deployment rate in Denmark in numbers and accumulated capacity are shown in Figure 6.2. Deployment has been almost constant from 1996 to 1999, adding approximately 300 MW of wind power capacity onshore annually.

In 2000, an extraordinary high capacity of about 600 MW was installed. In 2001, that figure fell to 117 MW, whereas in 2002, about 490 MW of new capacity was installed, including 160 MW offshore. In 2002, about 1,230 old wind turbines – amounting to a capacity of 110 MW – were removed.

The average size of the new installed wind turbines has grown gradually, from 750 kW in 1999; 889 kW in 2000 and 2001; 1.36 MW in 2002; and 2 MW in 2003. The development in wind turbine size is illustrated in Figure 6.2.

In 2003, offshore installations accounted for 196 MW, whereas onshore capacity only increased by 29 MW. This also means that private investment in wind turbines – during which the whole history of deployment in Denmark has been the main driver – now has been taken over by professional investors and utilities. By the end of 2003, a little more than half of the capacity in eastern Denmark was owned by utilities, whereas more than 80% was privately owned in the whole country.

Contribution to National Energy Demand

The total electricity production from wind energy in 2003 was 5,542 GWh, corresponding to about 15.7% of the total electricity demand in Denmark. The wind

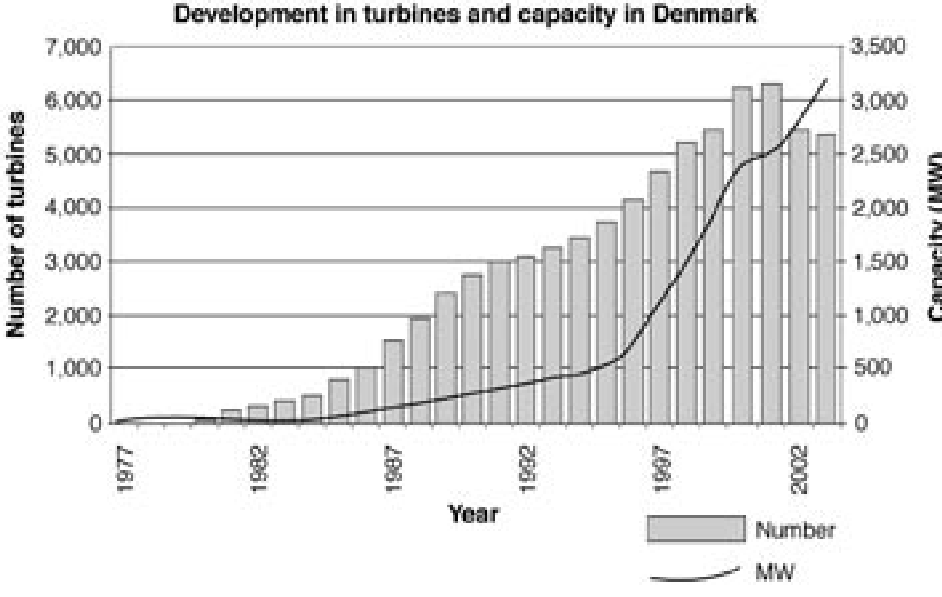

Figure 6.1 Development in number of wind turbines and accumulated electrical capacity in Denmark

energy index in 2003 (which describes the energy in the wind for a normal year) was similar to 2002: relatively low (approximately 84%).

For the western part of Denmark, Eltra reports that wind energy has covered 20.7% of the total electricity demand of 21 TWh in the Jutland-Fyn region. Development in the wind energy index is shown in Figure 6.3.

6.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

On 19 June 2002, the government entered into an agreement with the opposition about the future conditions for wind turbines. Consumers' obligations to purchase electricity from wind turbines are to be phased out. The support will be remodelled as financial support of 0.10 DKK/kWh, corresponding to the carbon dioxide tax on electricity. Total support-plus-market price will be capped. New turbines must be encompassed by the new system of environmental bonuses with an aggregate cap for support-plus-market price of electricity of 0.36 DKK/kWh.

An overview of the selling prices for electricity produced by wind turbines in 2003 is shown in Table 6.1. On average wind turbines were paid approximately 0.5 DKK/kWh.

Present deployment activities are mainly due to the scheme for replacement of old wind turbines, which is valid until the end of 2003. New wind turbines installed according to this scheme receive an additional support of 0.17 DKK/kWh for the first 12,000 full-load hours. The replacement scheme is limited to wind turbines up to 150 kW.

For scrapped turbines of less than 100 kW, the additional support can be had for three

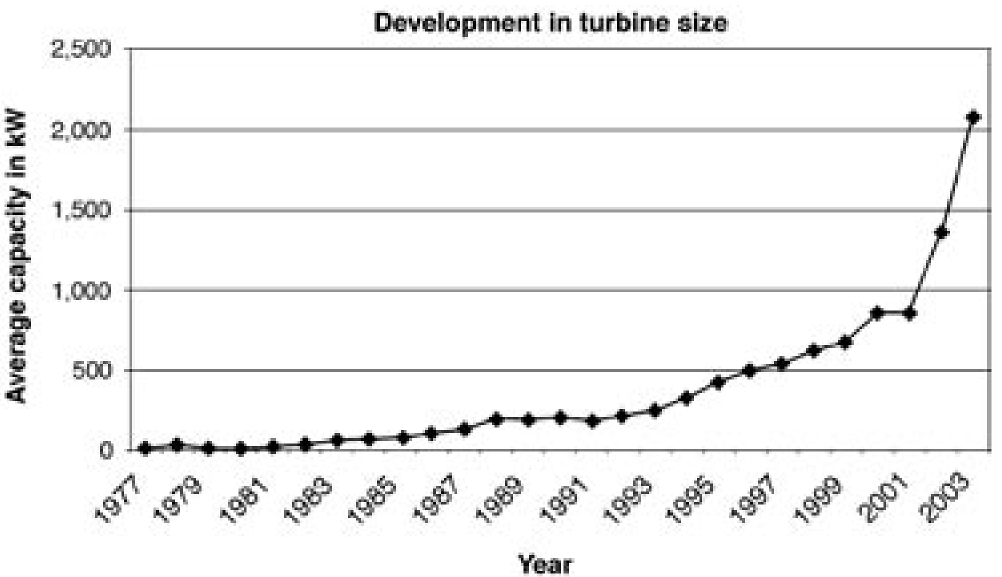

Figure 6.2 Development of average capacity of wind turbines installed in Denmark

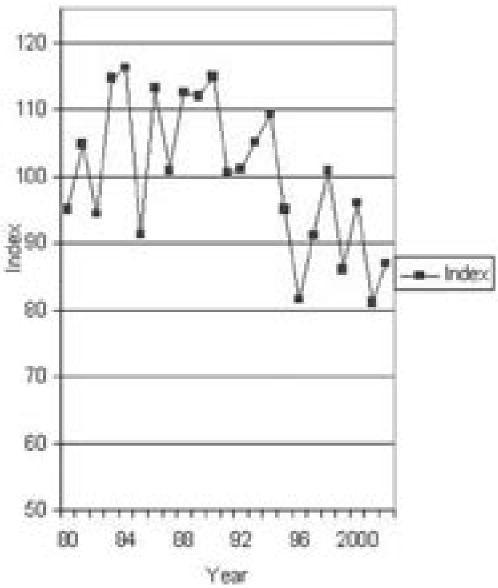

Figure 6.3 Annual wind energy in Denmark, illustrated by the wind energy index

times the scrapped capacity. For scrapped wind turbines in the range of 100 kW to 150 kW, support for twice the scrapped capacity can be had, provided that the scrapped wind turbines are situated less than 2.5 km from a wind turbine less than 100 kW, which will also be scrapped.

Favorable taxation schemes have earlier been used to stimulate private wind turbine installations. Today, income from wind turbines, by and large, is taxed depending on ownership as any other income.

Wind turbines erected in Denmark still have to fulfill the Danish approval scheme for wind turbines. The approval is partly based on a type-approval of the turbine and partly on a certified quality assurance system for the production and installation of the turbine. Today, all manufacturers have an ISO 9000 quality assurance system.

The Danish Energy Authority is responsible for administration of the scheme. Risø National Laboratory acts as secretariat and information center for the approval scheme. All documents related to the approval scheme can be found on the Internet at http://www.dawt.dk.

The approval scheme is undergoing a transition into an international scheme, in step with development and recognition of international standards for wind turbines by IEC and CENELEC. Since 1979, Risø has been authorized by the Danish Energy Agency to issue licenses or type-approvals for wind turbines, as well as to perform the tests and measurements required for the approvals. Today the market for these services is liberalized, and private enterprises can be authorized to perform type approvals, certifications, tests, and measurements. This market is open for international competition, and several foreign enterprises are active (Table 6.2).

6.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Wind turbines are typically installed in clusters of three to seven machines. Local and regional planning authorities prefer clusters of wind turbines in spatial planning. Larger wind farms are allowed in some places.

Denmark's largest wind farm on land (in capacity) is still Rejsby Hede from 1995, with 39 machines of 600 kW each. The largest offshore wind farms are: (1) the 160-MW Horns Rev wind farm, consisting of 80 wind turbines of 2 MW each, placed in the North Sea, 14 km to 20 km offshore Blaavands Huk; and (2) the 165-MW Nysted wind farm south of Lolland in inland waters consisting of 72 wind turbines of 2.3 MW each.

Different groups own wind turbines: private individuals, private co-operatives, private industrial enterprises, municipalities, and

Wind turbines bought until 31 Dec 1999	Wind turbines bought after 1 Jan 2000.	New turbines from 2003
0.60 DKK/kWh until end of assigned full load hours, then 0.43 DKK/kWh until age 10 years with purchase obligation. From age 10 to 20 years market price plus financial support of 0.10 DKK/kWh. Cap of total support plus market price will be 0.36 DKK/kWh. No purchase obligation.	**0.43 DKK/kWh for 22,000 full load hours with purchase obligation. From then on market price plus financial support of 0.10 DKK/kWh. Cap of total support plus market price will be 0.36 DKK/kWh. No purchase obligation.**	**Market price plus financial support of 0.10 DKK /kWh. Cap of total support plus market price will be 0.36 DKK/kWh. No purchase obligation.**

Table 6.1 Prices and subsidies for 2003

power utilities. During the 1980s and early 1990s, most new turbines were installed by cooperatives. Since the mid-1990s, primarily farmers have installed wind turbines. This development is due to several factors: general interest rates have decreased; prices for wind power electricity have slightly increased; and laws for facilitating structural changes in the farming sector have, as a side effect, opened up new possibilities for farmers. Since the withdrawal of regulation, ownership has become more mixed. From the beginning of 2003 – when the new, liberal, market-based price system with a cap of 0.36 DKK/kWh including carbon dioxide compensation went into effect – the private investment in wind turbines has come to a complete stop.

The two 160-MW offshore wind farms at Horns Rev (Figure 6.4) and Nysted (Figure 6.5) are owned by utilities alone, whereas the 40-MW Middelgrunden offshore wind farm is a 50-50 shared ownership between a private co-operation and a utility. The smaller offshore wind farm of 23 MW south of Samsoe, which was completed in 2003, is owned partly by municipality and private investors.

Operational Experience

Technical availability of new wind turbines in Denmark is usually in the range of 98% to 100%. The Danish Wind Turbine Owners' Association is recording operational experiences.

Technical lifetime or design lifetime for modern Danish machines is typically 20 years. The maintenance scheme may require that individual components are replaced or renewed with shorter intervals. Consumables, such as gearbox oil and braking clutches, are often replaced with intervals of one to three years. Parts of the yaw system might be replaced with intervals of five years. Vital components exposed to fatigue loads, such as main bearings and gearbox bearings, might be replaced halfway through the total design lifetime. This is dealt with as a re-investment.

Operation and maintenance (O&M) costs include service, consumables, repair, insurance, administration, lease of site, etc. The Danish Energy Agency, E&M-Data, and Risø National Laboratory have developed a model for annual O&M costs. The model is based on statistical surveys and analyses in

Service	Authorised body
Type approvals of wind turbines	Det Norske Veritas Germanischer Lloyds
Production and installation certification	Germanischer Lloyds Certification GmbH Det Norske Veritas Certification of Mgt. Systems Bureau Veritas Quality Assurance
Basic tests	Risø, Test & Measurements Tripod Consult Aps Wind Test GmbH Ingenieurbüro für Windenergie
Power curve measurement	Risø, Test & Measurements DEWI, Wilhemshafen Tripod Consult Aps Wind Test GmbH Windconsult GmbH Ingenieurbüro für Windenergie
Testing of systems and concepts	Risø, Test & Measurements
Blade testing	Risø, Sparkær blade test centre
Noise measurement	DEWI, Wilhemshafen Wind Consult GmbH Wind Test GmbH DELTA Akustik & Vibration + bodies approved by DELTA

Table 6.2 Bodies authorized by the Danish Energy Authority to provide services under the Danish scheme for certification and type-approval for wind turbines

1991, 1994, and 1997. The model includes a large re-investment, after the tenth operational year, on 20% of the cost of the wind turbine. This re-investment is distributed over the operational years 10 to 20 (Table 6.3).

Based on a previous study, results on operational experience are gathered in Table 6.4. The first part of this table shows the costs of repair and maintenance, while the second part presents the total O&M costs (i.e., including costs from items such as insurance, service, administration, and site rental).

Main Constraints on Market Development

Since the mid-1990s, the Danish market has been of a significant size and has remained remarkably constant. It was expected that the market would slow down due to uncertainty on future purchasing prices and constraints due to spatial planning. But for 2002, the replacement program and offshore development have kept the market up. However, from the beginning of 2003, the market has vanished due to the low and unpredictable purchasing prices of wind electricity on the liberalized market. In certain regions of Denmark the deployment of wind energy has now reached a point of saturation with respect to spatial planning. Therefore, future inland market development will mainly be tied to replacement of smaller wind turbines with new, megawatt machines.

The conditions for connecting wind turbines to the grid and the establishment of future offshore farms have now been laid down in the electricity law as a result of the reformation of the Danish electricity sector. According to that law, the right to

Figure 6.4 Offshore wind farm at Horns Rev, 160 MW
Published with the permission from Elsam

exploit energy from water and wind within territorial waters and the economical zone (up to 200 nautical miles) around Denmark belongs to the Danish Government.

Approval of electricity production from water and wind and pre-investigation of such within the national territorial waters and within the economic zone belonging to Denmark are given by the Danish Energy Authority. Permission will only be given for specific areas, and the impact on the environment must be documented by an environmental impact assessment for each project.

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 (approximately 50%) of electricity from combined heat and power (CHP) and the high share (approximately 20%) from renewable electricity (mainly wind power), a substantial part of the Danish electricity production is derived mainly from weather conditions (outdoor temperature and wind speed). This limits the system's ability to adapt to quickly changing electricity prices on the market.

On cold, windy nights, an electricity surplus may arise. On one hand, this is a successful demonstration of how far CHP

Figure 6.5 Offshore wind farm at Nysted, 158 MW
Published with the permission of Energi E2

Machine size	year 1 - 2	year 3 - 5	year 6 - 10	year 11 - 15	year 16 - 20
150 kW	1.2	2.8	3.3	6.1	7.0
300 kW	1.0	2.2	2.6	4.0	5.0
5 – 600 kW	1.0	1.9	2.2	3.5	4.5

Table 6.3 Annual O&M costs by percent of wind turbine investment
Source: Danish Energy Authority, E&M-Data, and Risø National Laboratory

and electricity from renewable energy can be developed. On the other hand, it poses a new challenge to the electricity system and system operators 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. This happens already today in the western part of Denmark with increasing frequency – in the eastern part, it may be seen in the future. The economic benefit of reducing the surplus in general (rather than exporting it) depends on the price on the power market and on the environmental value of electricity export from Denmark. In general, more flexibility in power production and demand will be appropriate to be able to respond to market conditions. The best economic means are to: move the power demand, move production with heat storage, replace CHP with heat pumps, and replace CHP with heat boilers fired with natural gas or biomass. Stopping the wind turbines for a few hours can also be a solution.

Offshore Wind Energy Development

With a couple of pilot projects in the 1990s and a number of large demonstration projects in recent years, Denmark has taken the lead in exploiting the specially favorable wind conditions at sea for carbon-dioxide-free electricity production from large, megawatt wind turbines. Danish experience encompasses the special production

Reparation and maintenance costs (DKK/kW) after age				
Machine size	Year 0-4	Year 5-9	Year 10-14	From year 15
55-65 kW	100	300	300	250
75-200 kW	80	120	150	200
210-599 kW	60	100	120	-
600-750 kW	30	40	-	-
Summarized O&M-costs (DKK/kW) after age				
Machine size	Year 0-4	Year 5-9	Year 10-14	From year 15
55-65 kW	330	530	530	480
75-200 kW	290	330	360	410
210-599 kW	225	265	285	-
600-750 kW	155	165	-	-

Table 6.4 O&M costs in DKK/kWh after machine size and year
Source: Danish Energy Authority, E&M-Data, and Risø National Laboratory

conditions with stronger wind and less turbulence at sea, the technical conditions for grid connection, and the environmental impacts. There is great interest in the Danish experience at the international level, and several other European countries are now running offshore wind turbine projects.

Interest in the potential development of offshore wind energy has generally grown in step with the up-scaling of wind turbines. The overall maximum height of the tower and rotor of the wind turbine of about 150 m means that megawatt-scale wind turbines will dominate the landscape and that the precondition for continued large-scale development of wind energy in Denmark will be the exploitation of offshore potential.

The mapping of potential major sites for offshore wind farms in 1997 identified an immediate potential of approximately 4,000 MW in Danish waters. However, there are many indications that along with the development of more cost-efficient foundations, more sites can be found because wind turbines can be located at greater depths than foreseen in 1997.

The increased costs of foundations, grid connection, and service inspections for offshore wind farms will, to a steadily increasing extent, be balanced by higher energy production and longer lifetimes. The additional costs of electricity production from offshore wind farms for the largescale demonstration projects in Horns Rev and Nysted have been estimated as 20% in relation to good locations onshore. But when experience from these projects can be incorporated into incoming projects, additional costs are expected to be significantly reduced.

During the 1990s, Denmark implemented two pilot projects that provided crucial new knowledge about the economic and environmental conditions for developing offshore wind farms. These two small demonstration farms are owned by utilities and are located at Vindeby (4.95 MW) and Tunø Knob (5 MW), respectively. They have remained in operation since the 1990s.

Since 2001, these projects have been followed up by a pilot project at Copenhagen (Middelgrunden), and three large-sale demonstration projects at Horns Rev at Esbjerg, and Nysted at Rødsand, respectively, with a total installed output of approximately 360 MW and wind turbines of 2 MW to 2.3 MW. The two large demonstration projects at Horns Rev and Nysted were constructed following orders from the government to the power sector.

The main data of the two Danish large wind farms at Horns Rev and Nysted are given in Table 6.5.

The 40-MW project at Middelgrunden, 2 km outside the Copenhagen harbor in shallow water (3 m to 5 m) was put into operation at the beginning of 2001. The farm comprises 20 Bonus wind turbines, each of 2 MW.

In December 2002, the last wind turbine in the 160-MW Horns Rev farm became operational. The farm is located 14 km from the coast at Blåvandshuk. The turbines are 2-MW Vestas with a total height of 100 m to 110 m, and the farm occupies an area of 20 km^2. (Figure 6.4)

The Nysted 72-turbine wind farm project, comprised of 2.3-MW Bonus wind turbines, has also been completed. For this wind farm, grid-connection work began in April 2002, installation of cables and turbines started in May 2003, and the last turbine was put into operation in September 2003. The total approved and installed wind farm capacity offshore is currently 406 MW. (Figure 6.5).

On 28 February 2003, the Samsø offshore wind farm, consisting of ten Bonus wind turbines, was inaugurated. The farm has an installed capacity of 23 MW and is located approximately 4 km south of Samsø. The turbines have a height of 100 m and are erected on monopiles.

In 2003, Elsam established an experimental offshore wind cluster of four wind turbines on a harbor site in Frederikshavn. It consists of two 3-MW Vestas turbines, one 2.3-MW Bonus turbine, and one 2.3-MW Nordex turbine.

Due to the special status of the demonstration program, an environmental measurement and monitoring program more comprehensive than the EIA's, has been initiated to investigate the effects on the marine environment before, during and after the completion of the wind-farms. The point is to provide a solid basis for decisions for the further development of offshore wind power. An environmental committee involving authorities and project-responsible personnel to conduct the demonstration program has been established. Further, the appointment of an international panel of experts with the objective to evaluate the demonstration program mirror the importance of gaining solid experience for large-scale wind-farms in our endeavor to increase the share of renewable energy and reduce the negative impact on the environment.

Also the economic and technical aspects are to be evaluated as part of the demonstration program. The objective is to ensure that the future offshore development is based on market conditions in an economically efficient way.

6.6 ECONOMICS

Trends in Investment

New information on investment costs is not available due to the new installed capacity being large, offshore projects.

Wind farm characteristics	Horns Rev Wind Farm	Nysted wind farm
Installed capacity	160 MW	158.4 MW
Number of turbines	80	72
Wind turbine type	Vestas 2 MW	Bonus 2.2 MW
Expected annual production	600 GWh	595 GWh
Hub height	70	70 m
Wind farm area	20 km^2	24 km^2
Water depth	6.5-13.5 m	6-9.5 m
Distance to shore	14-20 km	10 km
Distance between rows	560 m	850 m
Distance between turbines in rows	560 m	480 m
System solution type	B	A
Internal grid voltage	34 kV	33 kV
Transmission to shore voltage	150 kV	132 kV

Table 6.5 Main data of the two large Danish wind farms at Horns Rev and Nysted

The ex-works cost of wind turbines decreased significantly with the introduction of the 600-kW and 750-kW generation (44-m to 48-m rotor diameter). For 600-kW machines installed in 1997 and 1998, the ex-works cost was typically 3.1 million DKK to 3.5 million DKK. For 750-kW in 1998, the ex-works cost was 3.4 million DKK to 4.1 million DKK, depending on rotor diameter and tower height.

For the recent megawatt machines, the ex-works cost might be slightly higher per kilowatt capacity. But because the wind resource at rotor height is larger and the harvest of wind energy therefore improved, the total economy of the megawatt projects is improved.

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 ten years.

Additional costs depend on local circumstances, such as the condition of the soil, road conditions, and proximity to electrical grid sub-stations. Additional costs on typical sites can be estimated to approximately 20% of total project costs. Only the cost of land has increased during recent years.

Component	kDKK
Turbine ex works	5,364
Foundation	321
Grid connection	464
Electrical installations	79
Communication	12
Land	114
Roads	64
Consulting	38
Finance	27
Other	16
Total	6,500

Table 6.6 Cost of a 1,000-kW wind turbine project
Source: E&M-Data, November 2001

Based on information from 65 new 660-kW to 1,000-kW wind turbine projects, the average cost of a 1,000-kW wind turbine project is estimated in Table 6.6.

Trends in Unit Costs of Generation and Buy-Back Prices

The production cost for wind-generated electricity per kilowatt-hour has decreased rapidly over the last 18 years, and today the costs are getting close to the cost of electricity production from a new, coal-fired power station based on condensation.

The average consumer (4,000 kWh/yr) net electricity price from power distribution utilities is approximately 0.56 DKK/kWh. This figure comprises subscription, grid, PSO tariff, and commercial and prioritized power costs. For private consumers (connected to the 400/230-V distribution grid), a number of taxes are added to this price. On the top, is a 25% value-added tax (VAT). In 2002, the total consumer price for Danish low-voltage customers was about 1.59 DKK/kWh in the eastern part and 1.67 DKK/kWh in the western part of Denmark.

With the 2000 regulation, the whole payment for wind-generated power comes from electricity consumers. The price that the distribution companies pay after a transition period will be the actual market prices for electricity. On top of that, it was proposed that the producers of electricity from wind should receive green certificates. The implementation of a market for these certificates is awaiting an international agreement between several European countries on the practical arrangement.

Table 6.1 gives an overview of the price subsidies.

6.7 INDUSTRY

Manufacturing

The major Danish-based manufacturers of large commercial wind turbines up to 3-MW size are: Bonus Energy A/S, NEG Micon A/S, and Vestas Wind Systems A/S. Late in 2003, Vestas and NEG Micon announced their merger. Gaia Wind Energy A/S makes 11-kW machines for electricity to households. Calorius-Westrup A/S makes a 5-kW, heatproducing turbine.

A number of industrial enterprises have developed important businesses as suppliers of major components for wind turbines. LM Glasfiber A/S is a world-leading producer of fiberglass blades for wind turbines. Mita Teknik A/S produces controller and communication systems. Svendborg Brakes A/S is a leading vendor of mechanical braking systems. Danish subsidiaries of large international industries – such as Siemens, ABB, SKF, and FAG – have developed businesses in the wind power industry.

Industry Development and Structure

Industrial development in 2003 focused on refining the megawatt generation of turbines and adapting to the emerging offshore wind farms. This includes, among other things, upgrading the turbines with larger generators and larger rotor diameters. The largest prototype is the 4.2-MW wind turbine from NEG Micon, which was erected in late 2003 at the Høvsøre test site.

The estimated sales by the Danish wind turbine manufacturers (Vestas, NEG Micon, and Bonus) were 3,219 MW in 2003, which is only slightly higher than the figure for 2002 (3,147 MW). The global increase of wind power capacity in 2003 is estimated by BTM-Consult as 8,344 MW, bringing the world's total up to about 40,300 MW by the end of 2003. The rate of growth was 15% over 2002, giving an average growth rate during the last five years of 26.3%.

The Danish home market only amounted to 218 MW in 2003, considerably less than in 2002.

Manufacturers' internal service departments carry out service and maintenance of wind turbines in Denmark, but a handful of independent service companies have also been established. These are companies such as DWP Mølleservice A/S and DanService A/S. Some of the electricity companies service their own turbines.

Other industrial service enterprises have created important businesses in servicing the wind power industry. For example, various companies specialize in providing such products and services as cranes for installations of wind turbines; transport of turbines, towers, and blades domestically and for export; and insurance.

Companies with expertise in offshore construction and operation in the field of oil and gas activities are now offering their assistance to the wind energy business in connection with offshore wind farms. The major Danish consultancies in wind energy utilization are BTM Consult Aps, E&M Data, Elsam Engineering, WEA ApS, and Tripod ApS. Several experienced engineering consulting companies – such as Carl Bro, Rambøll, and Cowi – have shown increasing interest and are taking an active part in wind energy development.

The power production companies, Elsam and Energi E2, as well as DONG, have entered the wind energy business as developers, owners, and operators of wind farms in Denmark and internationally.

The two major organizations that represent the owners and the manufacturers are: (1) the Danish Wind Turbine Owners' Association (http://www.dkvind.dk) and (2) the Danish Wind Industry Association (http://www.windpower.org).

6.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The Danish Energy Authority, under the Ministry of Economic and Business Affairs, is responsible for the administration of the Energy Research Programme (EFP), which covers both conventional energy and renewable energy. The EFP is intended to contribute to establishing the technological possibilities required for the practical implementation of Danish energy policy. Therefore, using the results of the energy research projects creates part of the basis for Danish energy policy. The EFP is also intended to contribute to reinforcing exports of Danish energy technology and expertise. Active Danish participation in international standardization in IEC and CEN/CENELEC has a high priority, and R&D efforts supporting international standardization are encouraged.

Descriptions (in Danish) of the projects are available on the Danish Energy Authority's website, located at http://www.ens.dk. The budget for the EFP in 2002 and 2003 has been 40 million DKK, which is almost one-third that of previous years. Out of the budgets for 2002 and 2003, the following wind energy projects were supported. (In addition, EFP supports international R&D cooperation through IEA, with a total of approximately 1.4 million DKK from EFP 2002 and 2003). Wind energy projects funded by EFP in 2002 and 2003 are shown in Table 6.7.

Until 2002, the Danish Energy Authority also managed a program for development, demonstration, and information of renewable energy (UVE). The Test Station for Wind Turbines at Risø National Laboratory has been supported under that program. The budget for the test station task at Risø, including administration of the Danish Approval Scheme, was close to 7 million DKK for 2001. For 2002, the budget for related activities was reduced to 3.7 million DKK.

The Test Station for Wind Turbines conducted the following activities in 2002:

1. General support to the Danish Energy Agency
2. Secretariat for the Danish certification and type-approval scheme
3. Spot-check of type-approved turbines
4. Inspections of major break-down of turbines
5. Danish and international standardization
6. Development of framework for a new approval scheme
7. Preparatory tests for a new test station at Høvsøre

In 2003, a contract with a budget of 900,000 DKK between the Danish Energy Authority and Risø was signed, whereby Risø operates an administrative secretariat for the type-approval. The type-approval system will be further internationalized, basing it on IEC standards. The wind turbine manufacturers have agreed to support international standardization through IEC and CENELEC.

The PSO-Program of the Transmission System Operators

In addition to government R&D programs, the transmission system operators (ELTRA and Elkraft System) have PSO-subsidized R&D programs for non-commercial projects concerning new and environmentally friendly energy technologies.The programs include development of renewable energy

Title	Applic.	Total budget in 1,000 DKK	EFP support in 1,000 DKK
Application, demonstration and development of advanced aerodynamic models – EFP 2002	Risø	6,055	3,445
Aero-elastic integrated wind turbine control – EFP 2002	Risø	3,120	2,010
Material technology for surface coating of wind turbine blades and development of test methods for life time – EFP 2003	Force	4,670	2,355
Wind measurements, development and demonstration of new and existing methods for remote and in-situ measurements – EFP 2003	Risø	3,945	2,499

Table 6.7 Wind energy projects funded by EFP in 2002 and 2003

technologies including wind power. The final approval rests with the Danish Energy Agency.

Since 1998, 25 wind projects have started under Elkraft and 23 under ELTRA, with a total PSO-support of 72 million DKK. The project topics and the funding are shown in Table 6.8. Of the total annual budget of 100 million DKK, approximately 10% has been used on wind energy. Efficiency, costs, reliability of wind turbines, regulation, production forecasting, environmental impact, and maintenance are the items that take priority.

For the 2003 PSO-Program, 3 million DKK has been allocated for a project on remote condition monitoring of wind turbine blades. Because especially large offshore turbines are inaccessible, the perspective is to equip blades with sensors to create a continuous-as-possible condition monitoring from ashore. Risø is the main contractor together with Force, InnospeXion Aps, and STC and Demex.

For the environmental offshore demonstration program, a total of 84 million DKK has been allocated as a PSO in the period 2001 - 2006. Baseline studies have to be undertaken in the projected areas to be able to compare the existing environmental conditions to the introduction of a wind-farm in relation to topics such as birds, mammals, fish, benthic invertebrates and plants, hydrology and geomorphology as well as noise. In order to concentrate the investigations, it has been decided to conduct a monitoring program for prioritized subjects and to make effect-studies in areas where the presence of species to investigate can be expected to be high.

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 2003 and 45 million DKK in 2004 and 2005) will be devoted to strategic renewable energy research projects. An additional 15 million DKK were allocated for the 2003 call-for-proposals with a deadline of 1 October 2003. The funds will be administered by the Danish Research Agency – The Danish Technical Research Council.

The programs and the available funds, which may fund renewable energy R&D projects including wind energy, are summarized in Table 6.9.

Topic	Number of projects	Funding support in 1,000 DKK	Percentage
Wind resources	**13**	**17,891**	**24.8 %**
Loads and safety	**5**	**10,555**	**14.7 %**
Control and regulation	**3**	**5,000**	**6.9 %**
Power transmission and integration	**4**	**5,286**	**7.3 %**
Monitoring	**4**	**2,066**	**2.9 %**
Technology projects	**9**	**6,261**	**8.7 %**
Measurement programmes	**3**	**9,035**	**12.5 %**
Other	**7**	**15,915**	**22.1 %**
	48	**72,009**	**100 %**

Table 6.8 Topics and funding statistics for wind energy projects supported by the PSO-Program

Risø National Laboratory

In May 2002, in order to strengthen its competence to cover all sides of offshore development, and in order to strengthen the education of doctorate and engineering candidates, Risø formed a consortium with the Technical University of Denmark (TUD) in Lyngby, Aalborg University (AaU), and Danish Hydraulic Institute (DHI). This relationship builds on the existing close co-operation 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:
(1) climatic conditions; (2) wind turbine design; (3) electrical systems; (4) control and integration; and (5) society, market, and energy systems.

In addition to project co-operation between the consortium partners, the Council of Researchers Education recently gave a grant to a national research school, the Danish Academy in Wind Energy, with the purpose of strengthening the education of doctoral candidates and attracting visiting students, researchers, and professors.

During recent years, large efforts have been spent on establishing a new test site for multi-megawatt wind turbines. The test site has been selected at Høvsøre, 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 m high is 9.1 m/s. The test site consists of five test stands that allow turbines with heights up to 165 m and capacities of 5 MW each. West of each test stand, a met-mast has been erected, and two 165-m masts with light markings have been installed. Four manufacturers have leased test stands: Vestas, NEG Micon, Bonus, and Nordex. The first wind turbine at the test site, a 3-MW turbine with a 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 6.6.

	Consumption	Transmission/ distribution	Production
Objective	**Savings**	**System integration**	**Environment-friendly technologies**
Eltra/Elkraft general PSO		**(10 mio. DKK estimated)**	
Non-commercial (R&D) PSO	**10-25 mio. DKK?**		**100 mio. DKK**
EFP	**40 mio. DKK**		
Renewable energy R&D – Danish Research Agency	**35 mio DKK in 2003** **45 mio. DKK in 2004 and 2005**		

Table 6.9 Programs and available funds for renewable energy R&D projects including wind energy

Authors: Peter Hauge Madsen and Egon T.D. Bjerregaard, Wind Energy Department, Risø National Laboratory, Denmark; and Jørgen Lemming, Danish Energy Authority, Danish Ministry of Economic and Business Affairs, Denmark.

Figure 6.6 Høvsøre test site for megawatt-sized wind turbines

Chapter 7
Finland

7.1 INTRODUCTION

Commissioning of new wind energy capacity showed growth in Finland in 2003. Installed capacity was 9.2 MW in 2003, totaling 52 MW at the end of the year. The total wind energy production was 92.6 GWh, which corresponded to 0.1% of the annual gross electricity consumption of Finland.

7.2 NATIONAL POLICY

Strategy

The Action Plan for Renewable Energy Sources was updated. The Action Plan recognizes the 1997 Kyoto protocol on the reduction of greenhouse gas emissions and the EU white paper endorsed by the Commission in 1997 and the Council in 1998 as targets for renewable energy deployment.

The target is to increase the use of renewable energy sources by at least 50% (3 Mtoe/year) by the year 2010 from the 1995 level. Of this increase, 90% is expected to originate from bioenergy, 3% from wind power, 3% from hydropower, 4% from heat pumps, and less than 0.5% from solar power.

The share of renewable energy sources in power production would increase by 8.3 TWh (2010 MW) from the 1995 level. The major part, 75 %, would be generated from biofuels. Achieving the targets would reduce greenhouse gas emissions by about 7.7 million tonnes of carbon dioxide equivalent.

The vision for 2025 is an addition of 100% (6 Mtoe) of renewable energy from the 1995 level, with biomass still dominating but already several percents of the total electricity generated by wind.

The target for wind energy deployment is set to 500 MW in 2010 and is envisioned to be 2,000 MW in 2025. Thus wind energy production would reach 5 TWh/a in 2025, which is about 5% of the projected gross power consumption.

Progress Towards National Targets

During the review of the Action Plan for Renewable Energy, the progress towards the goals was assessed. It was recognized that the progress has been slow compared to the goals, especially for wind and solar energy. Also, the funds available for investment subsidy funding are not adequate to achieve the goals set by 2010.

The factors behind the slow progress in wind energy have been the low cost of electric energy in the market, together with the an average lower-than-earlier investment subsidy, the long lead time for planning of wind projects, and differing practices in grid-connection policies for distributed generation.

In the updated Action Plan for Renewable Energy, it is proposed that alternative subsidy systems for wind energy will be looked for. A working group set by the Ministry of Environment has set up a framework for planning and building permission procedures.

The Åland islands (between Finland and Sweden) constitute an autonomous region with their own legislation, budget, and energy policy. Wind energy deployment is steady, and in relation to the population, the targets are ambitious. Wind energy is expected to cover 10% of energy consumption in the region by 2006.

7.3 COMMERCIAL IMPLEMENTATION

Ten wind turbines were commissioned in 2003, bringing the total wind energy capacity to 52 MW by the end of the year. The total wind energy production was 92.6 GWh in 2003. The development in capacity and gross production are presented in Figure 7.1.

There is a drive towards offshore siting. Some semi-offshore installations at "artificial" islands – made out of gravel in shallow water – are already built. The new projects planned will be located either just on the shoreline or on small rock cliffs and islands, which are barely above sea level. There are no plans on new investments on *fjell* areas at the moment.

The gross electricity consumption in 2003 was 84.7 TWh. Wind energy constitutes about 0.1% of the national consumption.

7.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The Action Plan for Renewable Energy Sources states that the investment subsidy will remain the primary support mechanism, although new support mechanisms are to be investigated. For wind energy installation, an investment subsidy of up to 40% can be awarded, depending on the novelty in the project. Projects that have applied for subsidy in 2002, and are to be realized in 2002, have received an investment subsidy of about 30%.

In addition to the investment subsidy, a price premium of 7.00 euro/MWh is awarded. This corresponds to the tax on electricity that is paid by household consumers.

The Information Centre for Energy Efficiency (Motiva) is also promoting wind energy by publishing best practice guides and handbooks. The Finnish Wind Energy

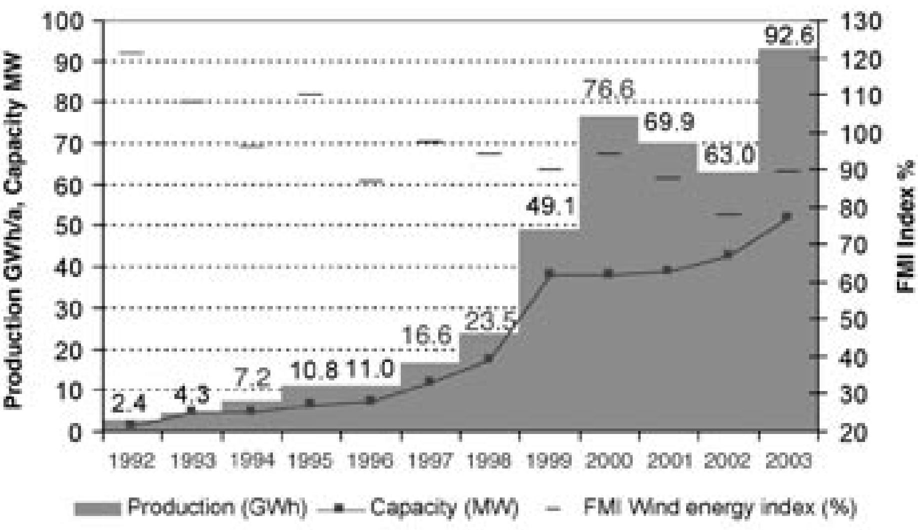

Figure 7.1 Development of wind energy production, installed capacity and FMI Wind energy index in Finland 1992 to 2003

Association is also actively promoting wind energy through seminars and political lobbying.

In the CLIMTECH-programme, financed by the National Technology Agency (TEKES), the possibilities of various technologies in the green house gas emission reduction, are being investigated, as well as new business opportunities. The investigation aims to provide guidelines for further support of the different technologies.

Export prospects for the Finnish wind industry seem to be promising and can be supported by active support on both R&D and the domestic market. The contribution of wind energy to the reduction of greenhouse gas emissions depends on the deployment rate of wind energy, which is expected to take off in the latter part of this decade.

Unit Cost Reduction

The cost development trends in wind investments were analyzed as part of the production and failure statistics in 2002. From 1991 to 2001, the average investment costs have been reduced from about 1.2 million euro/MW to 0.9 million euro/MW (in 2001 euro). There is, however, a wide spread in the costs of individual projects.

An attempt was also made to analyze the development of operation and maintenance (O&M) costs over the years. However, trend lines could not be drawn because of the scarcity and large spread of available data.

7.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

There were 74 wind turbines in operation in Finland at the end of 2003. Of this capacity, 75% originate from Denmark, 8% from Germany, and 17% from Finland. The size of the installed capacity ranged from 600 kW to 1,000 kW. Average wind turbine size was 700 kW at the end of 2003.

The turbines installed in the harsh climate at elevated sites of northern Finland are protected with ice-preventive equipment. Proximity of large, open waters is found to increase the possibility of wind turbine icing at lower latitudes and coastal areas in Finland as well. The same solution that has been tested in northern Finland has also been tested at sites in southern Finland where public safety is a concern due to occasional icing.

Operational Experience

Yaw system and brake system failures caused a major share of the down-time hours in 2003. Overall availability of the wind turbines was 95%. Compared to the average, the turbines that operate at more severe sites in northern Finland have lower availability.

Main Constraints on Market Development

The Finnish electricity market has been fully liberalized, down to the household consumers, since 1997. Thus all wind energy installations are operated by merchant producers that have to find their customers on a competitive market. Current market prices are low, and despite quite substantial support, wind energy cannot yet compete with spot prices for electricity. Most turbines are owned by or operated in co-operation with a local utility to facilitate energy market access.

The transmission and distribution charges for distributed generation vary very much across the country and are so high in some areas that they totally prevent local generation.

Wind energy deployment is slow, but there is still a continuous discussion on the environmental impact of wind turbines. Land-use restrictions and visible pollution,

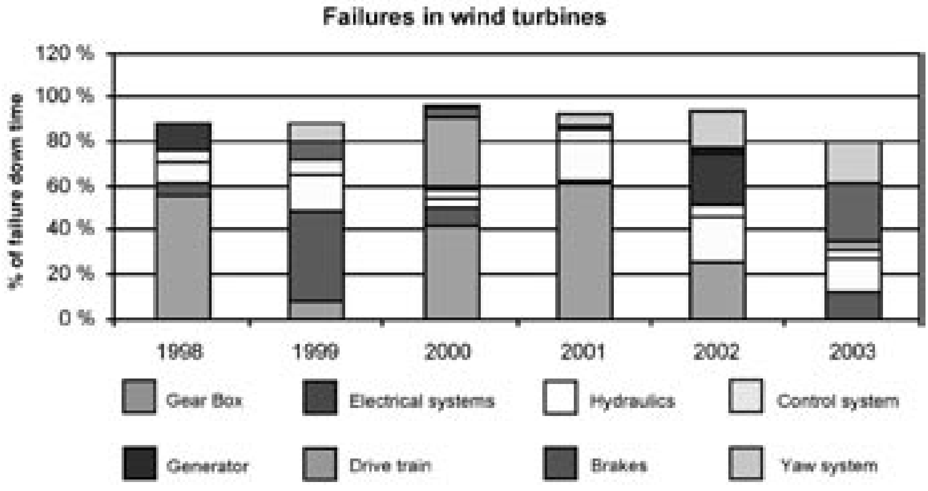

Figure 7.2 Development of down-time due to failures in Finland 1998 through 2003

especially in relation to summer residents and vacation activities, might yet prove to be a significant obstacle to development. In order to overcome these problems, the Ministry of Environment published guidelines for planning and building permission procedures for wind power plants.

7.6 ECONOMICS

At a good site on coastal Finland, the cost of wind energy production could be about 40.00 euro/MWh, or 240.00 Finland Markka (FIM)/MWh to 250.00 FIM/MWh, including an investment subsidy.

As previously stated, all wind energy installations are commercial power plants and have to find their customers in a free power market. In most cases, an agreement with a local utility is made, giving market access and financial stability. Some utilities have offered to buy wind energy production at a price higher than avoided costs in general.

There are several companies offering "green"or specifically "wind" electricity, certified by the association for nature conservation, at a price higher than the average for households. However, the market success for these initiatives has been modest. Only a few percent of household consumers have changed electricity suppliers at all since the liberalization.

7.7 INDUSTRY

A new Finnish manufacturer, WinWinD, presented its first prototype in spring 2001, which is now in operation in Oulu. The turbine has a rated power of 1 MW and will operate at variable speed. It has a one-stage planetary gearbox and a permanent magnet generator.

WinWinD manufactured eight of the ten new wind turbines installed in 2003. The aim of the company is to develop the concept further into a 3.0-MW to 3.5-MW turbine for offshore applications. The planning is well under way, and the first pilot is to be built in autumn 2004. WinWind also started its export marketing activities in 2004.

For some time, the Finnish industry has been able to produce main components, such as gearboxes and induction generators – as well as materials like cast-iron products, tower materials, and glass-fiber products – for the main wind turbine manufacturers. The total turnover is estimated to be about 200 million euro in 2003. The industry has been successful in supplying components to medium-sized wind turbines up to 2 MW. This has required some investments in new production facilities.

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.

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

7.8 GOVERNMENT-SPONSORED R,D&D

Since 1999, there has not been a national research program for wind energy in Finland. Individual projects can receive funding from 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.

A new technology program DENSY (Distributed Energy Systems) was launched in 2003. Ongoing research projects within the DENSY technology program have been divided into five project groups, which are as follows:

1. Information technology and automation
2. Business models
3. Heat and combined heat and power (CHP) systems
4. Electrical systems
5. Industrial manufacturing

The project group on electrical systems includes some projects related to the grid connection and energy storage of distributed energy systems, including wind and technology development projects.

Offshore Siting

There is a drive towards offshore locations of turbines. The foundation and installation of turbines in the icing waters require careful design of the support structure. Projects to develop foundation and installation technologies suitable for Finnish offshore conditions have been initiated in a co-operation between research bodies and industry.

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

Chapter 8
Germany

8.1 INTRODUCTION

The Deutsche Windenergie Institut (DEWI) or the Bundesverband WindEnergie e.V. collected most of the data presented in this report, which is presented by the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety. All data are based exclusively on manufacturer information and therefore depend on manufacturer exactness and reliability.

8.2 NATIONAL POLICY

General national policy guidelines are fixed in the coalition agreement of the German government and outlined on page 38 of the Coalition Agreement 2002-2006, dated 16 October 2002. These guidelines can be found online at http://www.bundesregierung.de/-,414/bundesregierung.htm.

Strategy

In general, the German strategy in wind energy for 2003 has not changed significantly since 2002. One of the general goals in German energy policy is to double the share of renewable energies in the total electricity consumption by the year 2006. One major part of renewable energies is wind energy.

The federal government's goal for the erection of offshore wind turbines is to reach 500 MW by the year 2006 and 3,000 MW by the year 2010. *The Renewable Energy Sources Act,* or *Erneuerbare Energien Gesetz* (EEG) from 1 April 2000 will be adjusted to these goals. However, some details remain under discussion, and a draft for an amending law of the EEG was prepared by the German government on 17 December 2003.

8.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Support from the EEG and German wind turbine producers has grown for programs such as the 250-MW. By the end of December 2003, the number of installed wind turbines in Germany reached 15,387, with a total rated power of 14,609 MW. The number of turbines installed in 2003 was 1,703 with a total rated power of 2,645 MW (Table 8.1).

Compared to total wind energy use in previous years, there was an increase in newly installed turbines of approximately 6% and an increase in new power of approximately

Year 2003	Total number of wind turbines	Total rated power [MW]
January	84	132
February	161	254
March	230	358
April	310	486
May	403	631
June	535	835
July	635	998
August	754	1,188
September	888	1,401
October	1,073	1,696
November	1,328	2,091
December	1,703	2,645

Table 8.1 Number of wind turbines and total rated power in Germany in 2003

Date	Number of wind turbines	Number increase [%]	Rated power [MW]	Power increase [%]
31.12.1989	256	--	20	--
31.12.1990	506	97.6	60	200.0
31.12.1991	806	59.3	111	85.0
31.12.1992	1,211	50.2	183	64.7
31.12.1993	1,797	48.4	334	82.5
31.12.1994	2,617	45.6	643	92.5
31.12.1995	3,528	34.6	1,120	74.2
31.12.1996	4,326	22.6	1,546	38.0
31.12.1997	5,102	17.9	2,033	31.5
31.12.1998	6,205	21.6	2,874	41.4
31.12.1999	7,874	26.9	4,430	54.1
31.12.2000	9,369	19.0	6,095	37.6
31.12.2001	11,438	22.1	8,754	43.6
31.12.2002	13,759	20.1	12,001	37.1
31.12.2003	15,387	11.8	14,609	21.7

Table 8.2 Total number of wind turbines and total installed rated power (MW) in Germany from 1989 to 2003

28%, as shown in Table 8.2. The increase of newly installed turbines and newly installed power was a little bit lower than the increases in previous years.

The average rated power per wind turbine went up 11%: from 1,395 kW in 2002 to 1,552 kW in 2003. That means wind turbines with more than 1,500 kW rated power are playing a dominant role in the German market. The 2002 trend towards larger wind turbines has continued in 2003.

The share of the calculated annual wind energy yield to the electric energy consumption of Germany amounted to about 6% in 2003. In 2002 it was about 4.7%.

8.4 MARKET DEVELOPMENT AND STIMULATION

Does not apply.

8.5 DEPLOYMENT AND CONSTRAINTS

Within the Energy Research and Technology Program, the German government supported the design and construction of the first 4.5-MW wind turbine in the world. It is named E-112 and was erected by ENERCON with a 120-m high concrete tower in August 2002 at a test site close to Magdeburg. Due to its weight of 500 tons, the generator-cabin had to be mounted in several steps at the top of the tower. Since October 2002, the wind turbine has been connected to the local grid.

In 2003, the behavior of the E-112 wind turbine was investigated, especially in comparison to existing computer simulations. It has been shown that the E-112 wind turbine is running successfully. In 2003, the erection of a second and third E-112 began.

8.6 ECONOMICS

Does not apply.

8.7 INDUSTRY

Table 8.3 provides an overview of manufacturer market share in 2003.

8.8 GOVERNMENT-SPONSORED R,D&D

Offshore Siting

In 2001, the government's Future Investment Program (ZIP) was set in force. Part of this program is a fundamental measuring program for the implementation of offshore wind utilization in Germany.

Offshore Measuring Platform

The first German Offshore Measuring Platform, FINO 1, was erected in July 2003 in the North Sea, about 45 km north of the coast of the island Borkum (at a water depth of 28 m), adjacent to the location of the first planned German pilot wind farm.

Manufacturer	Share of the total rated power [%]
ENERCON GmbH, Aurich	34
VESTAS Germany GmbH	23
GE Wind Energy GmbH, Salzbergen	11
Repower Systems AG, Hamburg	11
NEG Micon Germany GmbH, Ostenfeld	8
AN Windenergie GmbH, Bremen	5
NORDEX AG, Norderstedt	5
DeWind AG, Lübeck	1
Fuhrländer AG, Waigandshain	1
OTHERS	1

Table 8.3 Shares of newly installed rated power by manufacturer

Hydrological, meteorological, oceanographic, and physical data relevant for the construction of offshore wind plants and their foundations are recorded. Environmental, especially biological, parameters will be monitored for the next few years and will gather basic data and information about the environmental impact of offshore wind farms. Results of the environmental monitoring are urgently needed for the permission procedure of wind farms in the German Exclusive Economic Zone.

A mast up to 101 m above sea level enables the measurement of wind profiles with anemometers and ultrasonic sensors. Four containers house living/working space (emergency accommodations), data storage and communication systems, a diesel-generator set, and batteries and radar equipment. A telescope-crane is used to take seabed samples for biological investigation. The platform is equipped with a helicopter pad for maintenance operations.

Measurements can be done in a fully remote-controlled modus. Data collected are transferred onshore by directional radio and are available publicly after validation by the contributing research institutes. First results will be published under http://www.fino-offshore.de.

Hydrographic data are collected in the MARNET database of the Federal Maritime and Hydrographic Agency (see www.bsh.de/de/Meeresdaten/Beobachtungen/MARNET-Messnetz/Stationen/fino.jsp). Many users from industry and from public research institutes request the FINO 1 data.

Figure 8.1 shows the FINO 1 platform deck and the lower part of the measuring mast. The arms for the wind sensors and the antenna of the directional radio transmission

Photo credit: Neumann, DEWI

Figure 8.1 Top view to the FINO 1 platform deck and the lower part of the measuring mast

can also be seen. Below the helicopter deck, the telescope crane of the sea bottom benthos sampler is sticking out.

References

- Bundesverband Windenergie e.V., http://www.wind-energie.de
- http://www.bund.de/files/windenergiedaten
- Coalition Agreement 2002-2006 for the German government, 16 October 2002, p. 38, http://www.bundesregierung.de/-,414/bundesregierung.htm
- *DEWI-NEWS*; Aufstellungszahlen der Windenergienutzung in Deutschland – Stand 31.12.2003, Press release DEWI/VDMA/BWE from 27.01.2004, http://www.dewi.de
- ISET, IWET last update December 2002, http://reisi.iset.uni-kassel.de
- ENERCON, *Wind Blatt*, No. 6, 2003, page 2, http://www.enercon.de
- T. Neumann et.al., Errichtung der ersten deutschen Wind-Messplattform in der Nordsee, *DEWI Magazin*, No. 23, 2003, p. 32, http://www.dewi.de
- K. Scholz, Technische Ausstattu

Author: Volker Monser, Forschungszentrum Jülich, GmbH, Germany

Chapter 9
Greece

9.1 INTRODUCTION

Greece is making profound institutional, regulatory, engineering, and funding efforts in order to meet the indicative target set by *Directive 2001/77/EC*. This is difficult because of the yet fluid state of liberalization of the utility market that was dominated for more than a half century by the single utility company in the nation. One of 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 wind potential. Government support for wind energy exploitation is part of its policy concerning renewable energy sources.

9.2 NATIONAL POLICY

Strategy

In Greece, *Law 2773/99, Liberalization of the Electricity Market – Regulation of Energy Policy Issues and other Provisions*, constitutes the basic legal background. Also, according to this law, two companies – the Regulatory Authority of Energy (RAE) and the Hellenic Transmission System Operator (HTSO S.A. or "the Operator") – have been created. These two companies are the basic factors of the free electricity market.

RAE is an independent, public authority that manages, suggests, and promotes the existence of equal opportunities and fair competition. It gives operation licenses to producers, providers, and all others related to the market.

In addition, RAE formulates suggestions to the Minister of Development with regard to the issue of power generation authorizations. Thereafter, RAE monitors the implementation progress of the renewable energy sources (RES) projects through quarterly reports and recommends which investors to remove from the sector due to unjustifiable slowness. RAE also recommends legislative measures for further deregulation of the electricity market within which critical RES issues can be addressed (as is the case of hybrid plants). On a more long-term basis, RAE considers the introduction of green certificates and the establishment of a network of large-scale, dispersed energy production.

HTSO is the company that handles the Hellenic Transmission System of Electric Energy. HTSO S.A. has a double role. The first role is the one being played by Public Power Corporation in respect to the transmission system: it always looks for a balance between production and consumption, and it ensures that quality electric energy is provided reliably and safe.

The second role of HTSO is to settle the market – in other words, to act like an energy "stock market" that arranges on a daily basis who owes to whom, according to *Law 3175/2003*. HTSO does not provide electric energy, and whatever basic exchanging relations exist are bilateral ones between producers/providers and their customers.

Prior to 1 February 2003, RAE approved a number of applications for power production from wind energy – 304 wind turbines with a total installed capacity of 3,533.9 MW. More specifically, 2,967.25

MW (from 195 turbines) have been approved for the interconnecting system of the mainland, 166.7 MW (from 31 turbines) have been approved for Crete Island, 229.36 MW (from 70 turbines) have been approved for the islands of the Aegean Sea, and 70.6 MW (from 8 turbines) have been approved for the islands of the Ionian Sea.

An optimistic estimation of wind-energy penetration up to the year 2010 is 2,170 MW. This estimate takes into account the 30% restriction on penetration of wind energy into the electric network. More specifically, 700 MW for Evia (Andros, Tinos islands); 350 MW for Thraki; 280 MW for Lakonia, East Arkadia; 240 MW for Crete, Rhodes, and other non-interconnected islands; and 600 MW for the rest of the country.

According to *Law 2773/99*, HTSO uses wind energy as first priority during generation unit dispatching. The price paid to the producer is a percentage of the tariff paid by the medium- and low-voltage consumers, the same power use as defined by the older *Law 2244/94* until *Law 2773/99* came in effect. The difference is that the Minister of Development is allowed to ask the producers from renewable sources for a discount on price.

Progress Towards National Targets

In 2003, the installed capacity of wind turbines reached 424.4 MW (from 772 wind turbines). The current national target for wind energy is now 2,000 MW for the year 2010, following EU directives.

The new *Law 2773/99*, introducing electricity market liberalization, maintains energy support from renewable sources in the framework of the competitive market, yet the effect of liberalization on the development of wind energy is not obvious.

Figure 9.1 Mavromihali, Evia, 11.4-MW wind park
Source: ROKAS AIOLIKI EVIA

Figure 9.2 Tsilikoka, Evia, 10.2-MW wind park
Source: TERNA ENERGY SA

9.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 18 separate projects, a total of 100 wind energy conversion systems with an installed capacity of approximately 75.5 MW, were connected to the electricity supply network during 2003. This brings the total installed wind energy capacity to 424.4 MW (772 machines).

Rates and Trends in Deployment

The development of wind energy within the last ten years is shown in Figure 9.3, which depicts the total installed capacity per year.

Contribution to National Energy Demand

The energy produced from wind turbines during 2003 was approximately 850 GWh, while the energy produced in 2002, 2001, 2000, 1999, 1998, and 1997 was 650 GWh, 756 GWh, 460 GWh, 160 GWh, 71 GWh, and 38 GWh, respectively. The total energy consumption in the country is on the order of 50 TWh, so the energy produced from wind turbines accounts for about 1.5 % of the energy demand.

Figure 9.4 shows the electricity produced from wind turbines for the last ten years and the corresponding capacity factor. For the year 2010, the total energy consumption in the country is expected to reach 72 TWh.

9.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The Operational Program Competitiveness (OPC) supports the development of wind energy projects. OPC raises resources from

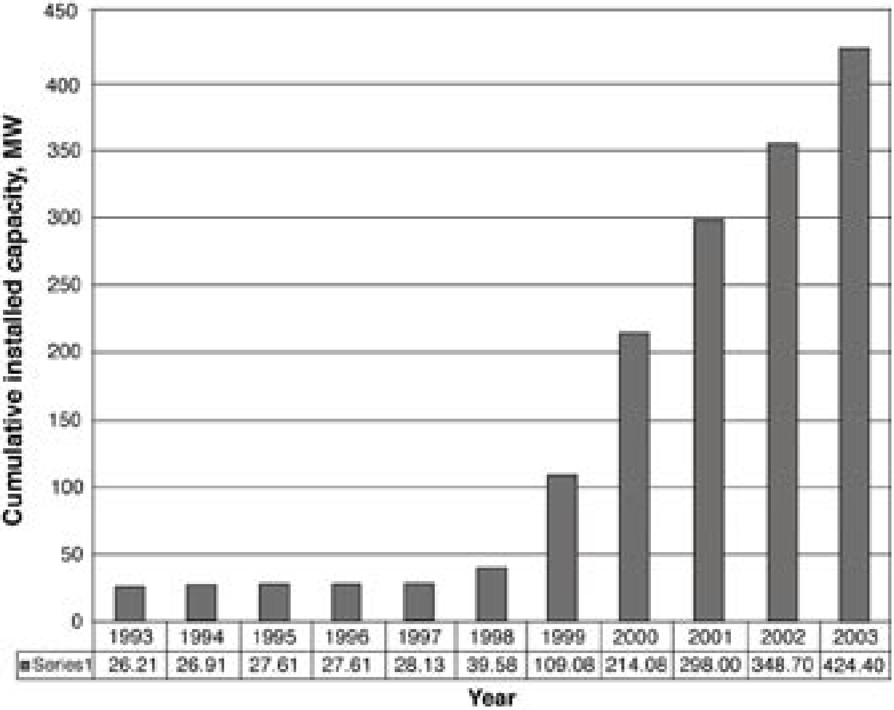

Figure 9.3 Cumulative installed wind capacity in Greece

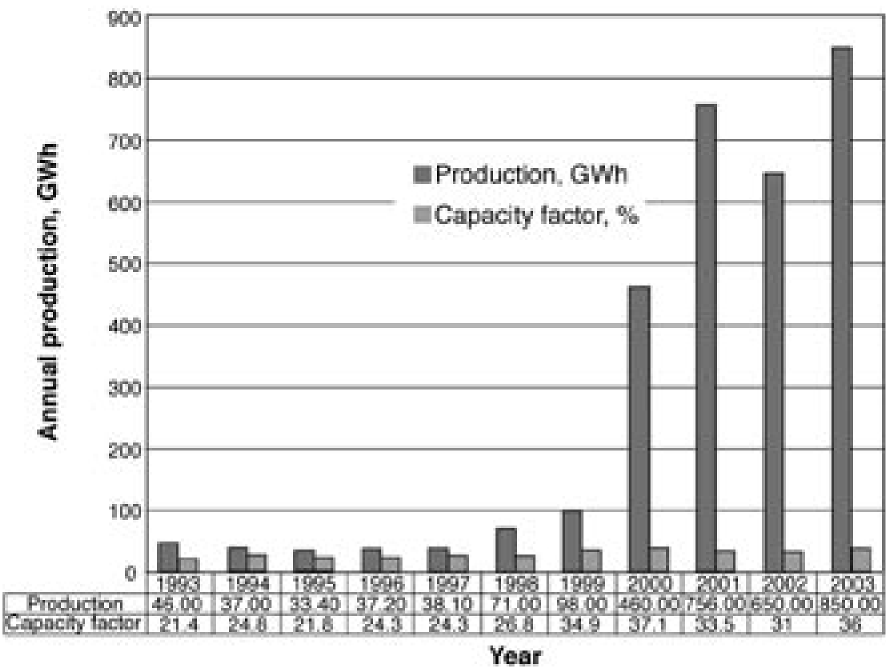

Figure 9.4 Electricity produced and capacity factor for wind turbines in Greece

the 3rd Community Support Framework, which provides public aid to RES and energy-saving, substitution, and other energy-related actions as high as 1.02 billion euro. 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 plant with 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.

The relevant budget is up to 650 million euro. An installation permit is necessary in order to finance a project. The eligible cost for financing a wind farm is up to 900.00 euro/kW, without including the cost for electrical grid connection.

Unit Cost Reduction

No data available.

9.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The average capacity of the wind turbines installed in 2003 was 755 kW, while the average capacity of all the wind turbines operating in the country is 549 kW. The market share per manufacturer is depicted in Figures 9.5 and Figure 9.6.

Operational Experience

Due to relative short operation periods of most wind-energy projects, limited malfunctions have been reported since their commissioning. However, CRES has developed, and continuously updates, a database with related information for the operation and performance of all the wind parks around Greece.

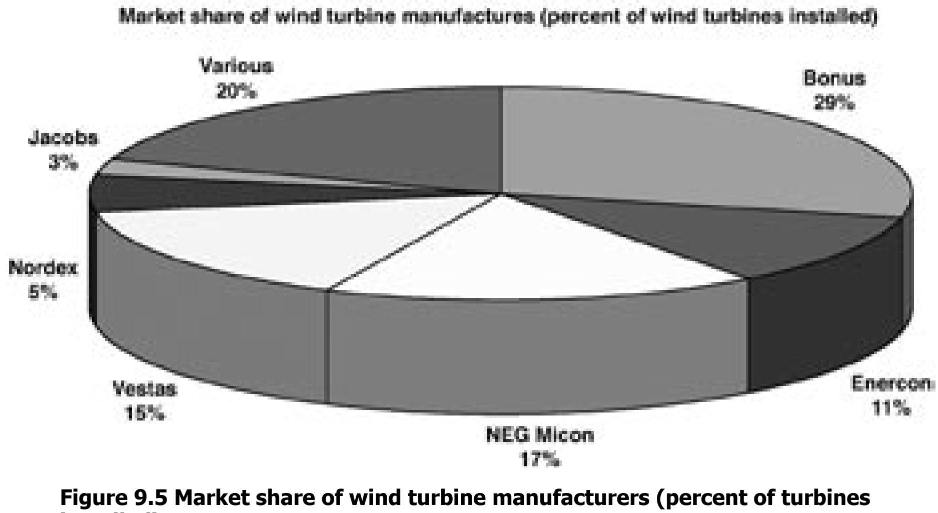

Figure 9.5 Market share of wind turbine manufacturers (percent of turbines installed)

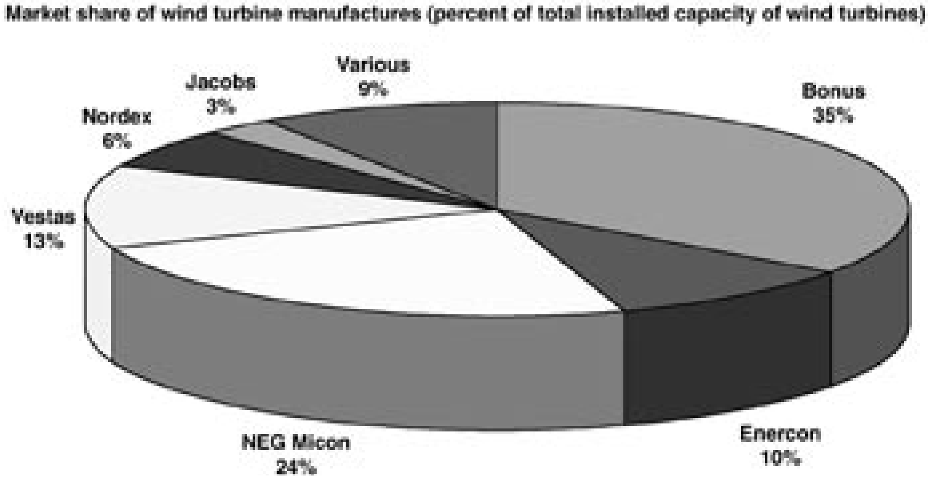

Figure 9.6 Market share of wind turbine manufacturers (percent of installed capacity)

Main Constraints on Market Development

The two main constraints for the installation of new wind farms remain (1) the complicated procedures for the acquisition of generation authorization, and (2) the inadequate electrical network to absorb the energy produced.

9.6 ECONOMICS

Trends in Investment

The total cost of wind power projects depends on wind turbine type, size, and accessibility. This cost varies between 970.00 euro/kW and 1,170.00 euro/kW. The generated wind-power cost could be assumed to be between 0.026 euro/kWh and 0.047 euro/kWh, depending on the site and project cost. The typical interest rate for financing wind energy projects is on the order of 7% to 8%.

Trends in Unit Costs of Generation

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 charging price exists in both systems, depending on the identity of the consumer and the voltage class.

This price list concerns the tariffs of electricity purchased since 1 September 2003 by HTSO according to *Law 2244/94*; the decision of the Minister of Industry, Energy, and Technology numbered Δ6Φ1/ OIK.8295/19.4.95 (ΦEK 385/10.5.95); and *Law 2773/99*. This electricity is either 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.

9.7 INDUSTRY

Manufacturing

There have not been any significant manufacturing developments in 2003 except for a couple of small wind turbine manufacturers in a typical range of 1 kW to 5 kW. However, an important involvement

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	0.06449	Peak	0.03275
			Interim Load	0.02269
			Low Load	0.01684
	Capacity	1.65565		-
Medium	Energy	0.06449		0.05016
	Capacity	1.65565		-
Low	Energy	-		0.06201
	Capacity	-		-

Table 9.1 Interconnected systems and interconnected islands (in euro/kWh and euro/kW)

Connection voltage	Magnitude with tariffs	Independent production	Auto-producers surplus
		a) From RES b) From CHP through RES	a) From RES b) From CHP through RES
ALL	Energy	0.07973	0.06201

Table 9.2 Islands non-interconnected (in euro/kWh)

in the manufacturing of tubular towers by the Greek steel industry has been considered. One Greek company that has been involved in blade manufacturing has not yet managed to commercialize its products.

Certification

Greece requires installation permission for a wind turbine with more than 20 kW of capacity. With the new Law, *Procedures for the Installation and Production Permits*, a type approval certificate and a power quality certificate are required for each wind park. CRES is, by law, the certifying authority for wind turbines in Greece and is responsible for issuing the certificates.

CRES accepts type certificates and reports of power quality measurements issued by authorized institutions – such as Germanischer Lloyds, TUV and DNV, or any other organization accredited according to EN45011 for certifying wind turbines – according to the following standards and criteria:

- Germanischer Lloyds Regulations
- Danish standards and criteria
- Dutch standards and criteria
- International Electrotechnical Commission (IEC) 61400-1 standard

Additionally, CRES's Wind Energy Department participates in the standardization work carried out by the Hellenic Organization for Standardisation (ELOT), in the framework of European and international organizations working on certification procedures and standards to be followed nationwide, taking into account the climatic characteristics of Greece.

In 2003, active involvement in the activities of IEC TC-88, CLC/BTTF83-2, and their working groups continued.

9.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The Ministry for Development promotes all R&D activities in the country, including applied and basic R&D as well as demonstration projects.

Key areas of R&D in the field of wind energy in the country are: wind assessment and characterization, standards and certification, wind turbine development, aerodynamics, structural loads, blade testing, noise, power quality, wind desalination, and autonomous power system integration. There is limited activity in Greece concerning megawatt-size wind turbines or offshore deployment.

CRES is the national organization for the promotion of renewable energy in Greece mainly involved in applied R&D in the fields of aerodynamics, structural loads, noise, power quality, variable speed, wind desalination, standards and certification, wind assessment, and integration. CRES developed and operates its Laboratory for Wind Turbine Testing, which has been accredited under the terms of ISO/IEC 17025:2000.

CRES, in co-operation with a Greek company, designed and developed a pilot autonomous hybrid (wind turbine/ photovoltaic) reverse osmosis system for seawater desalination, within the National Programme PAVET, of the Greek Ministry for Development, for further research on technologies coupling. The system has been installed at the CRES Wind Park at Lavrio, Attiki.

New R,D&D Developments

Several research projects were running at CRES during 2003, co-funded by the European Commission and the Greek Secretariat for Research and Technology. These research projects had the following goals:

1. Characterizing the main features of complex or mountainous sites (most sites favorable for wind energy development are of such topography) and identifying the crucial parameters affecting both the power performance and the loading of different types of wind turbines operating at such environments (new techniques are under development for power-curve measurement of wind turbines operating in complex terrain)
2. Developing wind turbines for installation in hostile environments
3. Improving the damping characteristics of wind turbine blades
4. Developing new techniques for power-quality measurement and assessment
5. Increasing understanding of wind turbine standardization procedures
6. Developing blade-testing techniques within the in-house experimental facility
7. Understanding generic aerodynamic performance of wind turbine blades through computational fluid dynamics (CFD) techniques
8. Developing cost-effective, micro-siting techniques for complex terrain topographies

Basic R&D on wind energy is mainly performed at the country's technical universities. The National Technical University of Athens (NTUA) is actively involved in two research areas concerning wind energy: (1) rotor aerodynamics and (2) wind-energy integration in 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, and wind farm design. Work conducted during 2003 included applied research on rotor aerodynamics for wind turbines.

More specifically, in terms of prediction/ design codes, NTUA participated in a European Community (EC)-funded benchmark exercise concerning the verification of design tools for wind turbines. Within this activity, NTUA upgraded the free-wake model, GENUVP, developed in-house into a complete aeroelastic tool. In particular, a new hybrid wake model was implemented that allows the simulation of complete, ten-minute time series with turbulent wind inflow. The code was successfully validated against measured data.

The new viscous-inviscid interaction model for airfoils, FOIL2W, was validated against wind tunnel measurements in cases of light as well as deep stall for pitching airfoils.

In terms of design, NTUA further developed the computational procedures concerning the optimum design of airfoil sections and complete blades for stall-regulated machines. The family of airfoils designed has improved polars, especially in regard to roughness sensitivity and stall behavior. Application of this procedure was carried out for megawatt-scale machines within a EU-funded project. Extension of the optimization procedure to the case of pitch and variable-speed machines has been initiated, aiming at an improved design for new, large, offshore machines.

The Electrical Engineering Department of NTUA has been actively involved in the field of wind energy since the beginning of the 1980s, participating in R&D projects sponsored by the EU and other institutions and co-operating with universities and research centers from many European countries.

In 2003, 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 quality of wind turbines and wind parks, and the design of electrical components for variable-speed machines.

The technical constraints and problems with integration of wind power into electrical grids have been investigated in various regions of Greece where the transmission system is weak and there is high interest in related wind projects due to favorable wind conditions. Steady-state voltages, voltage variations, and power quality issues have been investigated. Besides work on the interconnected system, emphasis has been placed on the secure integration of increased shares of wind energy in island systems.

Work has continued on MORE CARE, the advanced control system comprising load and wind-power forecasting, unit commitment, economic dispatch, and online dynamic security assessment modules integrated within a friendly person-machine interface. The advanced control system has been installed on Crete and is currently under evaluation with promising preliminary results. In addition, various control systems of variable-speed wind turbines have been studied. A specialized code has been developed for simulation of the effect of most common wind turbine types on the steady-state and dynamic performance of weak grids. This tool allows the convenient study of relevant power quality problems.

Dispersed renewable generation is gaining considerable attention, and research in this area has continued, focusing mostly on technical issues related to the integration and control of such units, their impact on distributed grid operation, and distribution network planning in areas with high dispersed generation potential. Particular emphasis is placed on the development of microgrids, which are comprised of low-voltage grids with increased dispersed generation.

Work continues on the control of variable-speed (large- and small-scale) wind turbines, in order to reduce the mechanical stresses and achieve a more "grid-friendly" operation (i.e., improved power quality and a controlled power factor for voltage support of weak grids).

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.

Integration of wind turbines in small, stand-alone systems is being researched, with specific application in water desalination for remote areas.

Power quality issues related to the grid-connected operation of wind turbines (e.g., slow- and fast-voltage variations, flicker, and harmonics) are a central research area, and a great deal of work has been performed on the elaboration of connection guidelines.

Increasing wind power penetration in isolated island systems, with proper application of pumped storage via reversible hydropower stations, is also an important research topic and crucial for the exploitation of wind potential in many non-interconnected Greek islands. Another ongoing research area is the development of advanced control centers for the management of conventional and renewable generation in isolated island systems of this type. Within this framework, algorithms and techniques are elaborated for short-term wind forecasting for operational planning.

The applied mechanics section of the Department of Mechanical Engineering and Aeronautics, University of Patras (UP), has focused on educational and R&D activities involving composite materials and structures since 1990. Emphasis is placed on wind turbine anisotropic material property characterization, structural design, and dynamics of composite rotor blades. Participation in several national and EC-funded research projects has provided experience in these areas.

During 2003, UP contributed to the following three EC-funded research projects:

1. Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites (DAMPBLADE)
2. Development of a Megawatt-Scale Wind Turbine for High Wind Complex Terrain Sites (MEGAWIND)
3. Reliable Optimal Use of Materials for Wind Turbine Rotor Blades (OPTIMAT BLADES)

In the DAMPBLADE project, UP is contributing with experimental characterization of anisotropic damping properties; development of a dedicated FEM code for efficient damping modeling of composite structures; and design of a 20-m GRP rotor blade, optimally damped.

In the MEGAWIND project, UP has accomplished the structural design of a modular (split) 30-m blade, which will be verified by full-scale testing at CRES. A prototype is under development by Geobiologiki SA.

In the OPTIMAT BLADES project, UP is a task group leader 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 to be assessed. Results will be available in the form of design guidelines for rotor blade manufacturers.

Other research activities of applied mechanics at UP include the following:

1. Finite element formulations and dedicated code accounting development for selective non-linear lamina behavior (e.g., in shear and in the laminate, as well as modeling of property degradation due to damage accumulation so as to predict life of large rotor blades under spectrum loading)
2. Probabilistic methods in the design of composite structures
3. Residual strength and fatigue damage characterization of composite materials using wave propagation techniques
4. Smart composites and structures
5. Structural damping and passive and active vibration control

No new demonstration projects were initiated in 2003. Performance results on the previously reported demonstration project titled, CRES 3.1 Megawatt Wind Farm in Complex Terrain can be found at http://www.cres.gr/windfarm. The monitoring software has the ability to periodically update the contents of the Internet site, presenting the latest operational data of the wind farm.

Offshore Siting

Does not apply.

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Chapter 10
Ireland

10.1 INTRODUCTION

For several reasons, 2003 was a year of high wind-energy activity in Ireland. The year set a record for new wind-power capacity addition in Ireland, with complete construction of new wind farms totaling more than 70 MW of capacity. However, while the capacity constructed in the previous record year was exceeded, this still falls short of the construction rate required to meet the national renewable energy deployment target of 500 MW of additional renewable generating capacity by 2005.

Other high points for the year include a continuing increase in wind farm size, with the 25-MW Kings Mountain wind farm, commissioned in 2003, being the largest completed to date, and construction starting on the 60-MW Derrybrien wind farm. Construction of the first 25-MW phase of the Arklow Bank project – Ireland's first offshore wind farm – was also completed in 2003.

A report titled, *The Impacts of Increased Levels of Wind Penetration on the Electricity Systems of the Republic of Ireland and Northern Ireland* – commissioned by the island of Ireland's two energy regulators, on the possible limits to penetration of wind power in the Irish electricity grid – gave a generally positive outlook. In June 2003, the results of the last tender round in the current government price support scheme for renewable electricity were announced. Support for two offshore wind farms of 25 MW each was included for the first time.

An initiative to develop a special section of the electricity transmission system code for wind turbine generators commenced in late 2003. A consultation group was set up to provide the wind power industry with opportunity to influence the code requirements. The new grid code section will be completed early in 2004.

The year 2004 ended with two notable events for the wind industry. At the end of November, the transmission system operator for the Republic of Ireland, ESBNG, wrote to the energy regulator requesting that a moratorium be placed on pending wind farm connections. The reasons given mainly concerned the unknown possible effects of a rapid near-term growth in wind power penetration on grid stability and security. The need for the new grid code section for wind turbines to be implemented, and a poor response from manufacturers in providing dynamic models for turbines, were cited as key factors. The regulator acceded to extending the moratorium until April 2004.

The government also published a consultation document, *Options for Future Renewable Energy Policy and Programmes* in December 2003. Need for a replacement scheme exists because the current price support scheme for renewable energy has allocated all the capacity for which state aid approval has been received.

10.2 NATIONAL POLICY

Strategy

The key national policies relating to wind power in the Republic of Ireland are: (1) a target, detailed in the *Green Paper on Sustainable Energy 1999*, to install 500 MW of additional renewable electricity generating capacity between 1999 and

2005; (2) an indicative target, committed to in *EU Directive 2001/77/EC*, to increase national renewable electricity consumption to 13.2% of total demand by 2010. While neither of these targets relates specifically to wind power, it is anticipated that, in each case, wind power will ultimately contribute in excess of 90% toward achieving these targets.

In December 2003, the government published a consultation document titled, *Options for Future Renewable Energy Policy, Targets and Programmes*. As a result of this consultation, plans exist for a new renewable support mechanism to be decided upon and implemented. This is required to replace the current Alternative Energy Requirement (AER) competitive tendering scheme, which has run its course. Renewable energy targets will also be set for the period between 2010 and 2020, which is not covered by any current renewable energy policy.

Progress Towards National Targets

Progress towards achieving the national renewable energy capacity target for 2005 has, to date, been below the rate required. This has been due to extremely slow progress in the early years when unanticipated difficulties were encountered in implementing the renewable energy support schemes. The rate of deployment increased significantly in 2003 but is still below the rate required to achieve targets.

The 2010 target should not pose a similar challenge, as its achievement does involve an increase in the rate of deployment beyond 2005. The government has indicated a commitment to exceed the target of 13.2% national renewable energy consumption by 2010, committed to under the EU RES-E directive.

10.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The installed and commissioned wind generating capacity at the end of 2003 was 190 MW. This is an increase of 52 MW in the year 2003 and marginally exceeds the previous record in 2000. Construction has been completed on several other projects, including the 25-MW Phase 1 of the Arklow Bank offshore wind farm, but these await commissioning.

Rates and Trends in Deployment

Grid connection agreements committed to by wind farm developers, if acted upon, will result in 326 MW of wind generation capacity being connected in 2004. It is to be expected that a majority of connection agreements will be taken up because they include financial penalties for non-performance.

Onshore wind farms totaling 75 MW in capacity are currently under construction. As previously mentioned, the largest wind farm to date, the 60-MW Derrybrien project, is among these. This project received a setback late in 2003 when a significant peat-slide occurred on the site, infiltrating a local watercourse and giving rise to serious local disquiet. As a significant number of wind projects in Ireland are being developed on upland blanket bog sites, this incident may have repercussions for future permitting of wind farms within the planning system.

Construction of 25-MW Phase 1 of the Airtricity Arklow Bank wind farm was completed in 2003 and is in the final stages of commissioning at the time of writing. This is the first such development in Ireland, and it is also the first offshore deployment of the GE Wind 3.6-MW wind turbine. The ultimate capacity for this wind farm is 520

MW under the terms of its foreshore lease. The 60-MW Phase 2 has a scheduled grid connection date of 2005.

Two other offshore wind farms, the Kish Bank and the Bray Bank, both being developed on the east coast of Ireland by the Kish consortium, each won price support contracts, at a tendered price of 0.08 euro/kWh, for 25 MW of capacity apiece under the AER VI competitive tendering round in July 2003. These will have to be commissioned by 2006 in order to avail of the AER VI power purchase agreement.

All of this points to a significant increase in the rate of deployment of wind power in Ireland in the immediate future. However, the possible effects of the moratorium, detailed in Section 10.1, on wind farm connections, cannot yet be quantified. This moratorium is based solely on signing new connection agreements and so should not seriously affect the wind farms totaling 575 MW capacity with existing connection agreements. This will give some room for development to continue while the issues that led to the moratorium being imposed are resolved.

However, the moratorium does create an uncertain environment for investors because its effects on the cost of implementing current and future wind connections are not quantifiable until possible new technical requirements are defined. Uncertainty regarding ultimate wind penetration level also contributes to an uncertain environment for growth.

Contribution to National Energy Demand

The estimated contribution from wind power to national electricity demand in the year 2003 was 465 GWh. This represents a 20% increase on 2002 production. A preliminary estimate for the total electricity demand in Ireland in 2003 is 25,270 GWh, an increase of 1% on 2002. The percentage contribution of grid-connected wind power to gross national electricity demand was therefore 1.84%.

10.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The primary market support mechanism remains the 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 contracts for wind generation capacity totaling 334 MW, which were announced for the AER VI tender round in July 2003, may be the last in the scheme.

This tender round was the first to include a category for offshore wind power for which two projects, of 25 MW each, were approved for award of contracts. A reserve list of projects was included for allocation of any remaining generating capacity for which EU state aids approval has been obtained in the event that some contracts in the scheme are not acted upon.

A high-level indication of the effectiveness of the AER scheme can be obtained from its performance in delivery of generating capacity. Of a total of 807 MW wind power capacity announced in the tender rounds to date, only 110 MW has been delivered. The competitive process tended to favor over-optimistic, uninformed tenders. It could be concluded that, while competitive tendering is an appropriate mechanism for obtaining generating capacity in a mature market sector, it is not as appropriate to a nascent market sector where there is little operational experience and market participants have varying levels of sophistication.

In recognition of the necessity to review Ireland's policies on renewable energy and the associated support mechanisms, the responsible government minister published a consultation document in December 2003. This document was titled, *Options for Future Energy Policy, Targets and Programmes*, and outlines the possible practical choices for Ireland in renewable energy technologies, support mechanisms, and targets up to the year 2020. Responses to the consultation document are invited from all relevant stakeholders, and the decision on the design of the future support mechanism and setting of future targets will take account of the responses.

In the liberalization of the electricity market in Ireland, in accordance with the requirements of the *EU Directives 96/92/EC* and *EU Directive 98/30/EC*, special consideration was given to renewable electricity suppliers in granting them access to all consumers in advance of full-market opening. Renewable electricity generators and suppliers are also advantaged in that they only have to balance aggregated annual renewable electricity supply and demand to qualify as "green" electricity suppliers, rather than that for each half-hour metering and trading period.

Approximately 30% of the wind generation capacity installed to date in Ireland trades electricity within these trading arrangements without the benefit of government price support or green credits. The majority of companies, which have developed projects in this manner to date, have been integrated generation-and-supply businesses that gain access to a significant portion of the electricity supply market prior to it being fully deregulated for "brown" electricity suppliers. As the deregulated portion of the market increased from 40% to 56% at the beginning of 2004, the sector in which green generation does not compete with other new market entrants decreased by 16%.

This advantage for green electricity suppliers will end when the market is fully deregulated in 2005. However, it is planned that, upon full-market opening, new trading arrangements – involving a single-pool market with marginal pricing for generators based on location – will replace the current interim, bilateral market. In general, these arrangements will be more favorable to wind generation because generators can obtain the pool price for any electricity they generate, without entering into a power purchase agreement with a supplier. However, wind power operating will therefore be exposed to the volatility of market prices and larger wind farms will be subjected to pricing based on location.

It therefore remains to be seen whether financing of wind farms based on merchant operation will become commonplace. Those companies involved with both generation and supply are likely to remain the most active in this area. It is noteworthy that, due to the wind regime in some areas of Ireland, wind generation can profitably supply electricity to certain mid-tariff customers with no external support other than fiscal measures that are available to conventional generation.

The main fiscal incentives, from which investors in wind farm projects can benefit, are: (1) the Business Expansion Scheme (BES) and (2) tax relief under Section 486b of the *1998 Finance Act* on capital directly invested in wind farm assets. Under the first incentive, 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 750,000.00 euro and is therefore of limited value to larger wind energy projects. Under the second incentive, corporate investors in renewable energy projects can claim tax relief on equity investment in capital assets. This fiscal incentive will have limited future attraction because the corporate tax rate has been reduced to 12.5%.

A 2002 amendment to the finance act also restricted eligibility for tax relief on capital assets to active participants in projects. This measure effectively eliminated a commonly used investment vehicle for private investment in wind farms.

Unit Cost Reduction

Does not apply.

10.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The number of operational, grid-connected wind turbines in Ireland at the end of 2003 was 269. The size of operational wind turbines ranges from 225 kW to 2.5 MW onshore, and the single offshore wind farm uses 3.6-MW turbines. The largest wind farm currently operational is 25 MW.

The average size of grid-connected wind turbines deployed in Ireland in 2003 was 1.23 MW. This average size lags worldwide averages; possible reasons are: (1) turbine size is generally fixed at the planning stage, but project development periods are protracted; and (2) road access limits turbine size on many sites. A wind farm with 71 Vestas 850-kW wind turbines, currently under construction and to be commissioned early in 2004, will be the largest wind farm upon completion. The largest wind turbines deployed in Ireland to date have been 2.5-MW Nordex turbines onshore and 3.6-MW GE Wind turbines offshore.

Operational Experience

Capacity factors for wind turbines installed in Ireland to date generally exceed 35%, and capacity factors exceeding 40% are not uncommon. While turbine availability will typically exceed 97%, there has been mixed experience on the reliability of turbines supplied into the Irish market.

A wind turbine users group was formed in Ireland in 2003 to provide a forum where experiences on turbine performance could be exchanged and concerted representations could be made to manufacturers. Sustainable Energy Ireland has funded a monitoring program to establish performance levels that are being obtained from wind turbines installed to date in Ireland. The results of this study should inform project developers when negotiating future contracts for wind turbine supply in Ireland.

Main Constraints on Market Development

As indicated in the 2002 report, permitting of wind farm sites has diminished as a near-term constraint on market development, and electricity system issues are likely to emerge as the primary constraint on growth. This perception has been reinforced by the moratorium that has been imposed by the energy regulator, at the request of the TSO, ESBNG, on issuing new wind farm grid-connection offers.

Prior to this, the availability of generation connection capacity in the electricity system had constrained growth. However, the moratorium has been imposed on the grounds of the unknown effects of a large increase in the number of wind farm connections on the stability and security of the electricity system. In discussions subsequent to the imposition of the moratorium, it emerged that the concerns of the TSO revolve around two key issues: (1) Most wind farms installed to date are not grid code compliant, and (2) dynamic models of wind turbines were not provided by turbine suppliers as required as a connection condition.

The pre-existing grid code took no account of wind generator characteristics, and connecting wind farms regularly required derogations to its requirements. This deficiency had been highlighted previously, and in September 2003 the TSO initiated a process to develop specific grid-code sections for wind generators in consultation with the industry. However, in November 2003, the TSO became concerned about the growth in the number of wind farm connection applications, which might lead to a significant portion of generators not being subject to the new grid code requirements. As a result, the TSO called for the moratorium to be imposed.

The lack of wind turbine dynamic models for power system simulation studies precluded the TSO modeling the effects of wind farm connections on system stability and carrying out remedial action where necessary. There are limited resources available to offset the effects of a growth in intermittent generation penetration because the electricity system in Ireland is a small, isolated island system with only weak interconnection with the United Kingdom.

The projected total – in excess of 1,200 MW of additional capacity from current connection offers and connection applications – would bring wind penetration in the electricity system to a level equaling or exceeding the highest penetration in any electricity system internationally. The TSO recommended against proceeding with connecting this wind generation capacity in the absence of measures to control it and predict its effects on system stability.

While the issues at the root of the moratorium are likely to be addressed in the near term, the capacity of the electricity system to accept wind generation is likely to remain as the limiting constraint on the growth of the wind generation sector in Ireland. Grid issues may not substantially hinder the achievement of national targets for renewable energy penetration, but the current total capacity of wind farm sites in all stages of development exceeds that required to meet government targets. Therefore, additional demand for the grid connection of wind farms beyond that in official projections is likely. Planning permits have a five-year lifetime, and delays in project execution due to non-availability of grid connection can compromise their viability.

Significant research effort will be required in the coming years if the technical issues associated with the grid connection of increasing amounts of wind generation are to be identified and solved. There has been a deficit of rigorous, in-depth research on these issues in the initial years after national targets were set.

As mentioned, the two electricity regulators on the island of Ireland commissioned a study on the possible penetration of wind energy in the Irish electricity system, and the final report of this study was published early in 2003. This report provided static load-flow simulations and indications of future limits on which penetration in the electricity network would be based. The report also identified areas in which further research would be required to facilitate this penetration level.

Since the publication of this report, Sustainable Energy Ireland has commissioned a study on the effects of higher wind penetration on electricity system reserve requirements and also a study on the implication of the proposed new electricity trading arrangements upon renewable electricity generators. Sustainable Energy Ireland anticipates that these studies will be the first in a program of work to address issues on renewable electricity integration.

10.6 ECONOMICS

Trends in Investment

The renewable electricity price support scheme divides onshore wind projects into two classes: (1) those less than 5 MW in size and (2) those more than 5 MW. Based on this demarcation, indicative average total costs for onshore wind farm construction for 2003 were: (1) 1,168.00 euro/kW installed, with the delivered cost of the turbine accounting for 830.00 euro/kW of this; balance of plant (BOP) cost accounting for 200.00 euro/kW, and miscellaneous site development cost making up the rest; and (2) 1,024.00 euro/kW installed, with turbine delivered costs accounting for 690.00 euro/MW and BOP accounting for 225.00 euro/kW. Costs for off-site grid connection assets will generally fall within the range of 60.00 euro/kW to 200.00 euro/kW, connected with the average at 100.00 euro/kW. Annual operating and maintenance (O&M) costs are estimated at 5.5% of project capital costs.

Limited cost data exist for offshore wind energy projects because only one offshore project has been built. According to Sustainable Energy Ireland (2002), *Cost Benefit Analysis of Government Support Options for Offshore Wind Energy,* estimated costs for developments in Irish coastal waters range from 1,270.00 euro/kW to 2,050.00 euro/kW installed, the lower cost probably not including grid connection. Information relating to offshore projects under development, albeit of a small scale, indicate costs at the higher end of this range. The costs for such developments are highly sensitive to project scale.

Trends in Unit Costs of Generation and Buy-Back Prices

Price caps in the sixth and final tender round of the AER prices support scheme – the results of which were announced in July 2003 – were 0.05742 euro/kWh for projects smaller than 5 MW, 0.05216 euro/kWh for those larger than 5 MW, and an indicative price cap of 0.084 euro/kWh for offshore wind farms (to a total capacity limit of 50 MW and 25 MW per site).

Contracts awarded under this support scheme have a 15-year duration and include full indexation. An accelerated capital recovery mechanism was included in this tender round whereby projects could obtain increased payments in the first seven years of the contract period, with rates reduced commensurately in the final eight years. The actual price bids by winning projects are confidential and weighted average prices were not published for this tendering round.

Average wholesale prices for comparison to wind power are unobtainable because the majority of wholesale electricity in Ireland is traded through bilateral contracts. However, the Commission for Energy Regulation does calculate annually a benchmark Best New Entrant (BNE) electricity price to be used in setting prices in the secondary balancing market, including the “top-up” price for electricity. This price, based on CCGT generating plant, was 0.0471 euro/kWh in 2003; and wind power compares favorably to it, with generating costs in Ireland ranging from 0.003 euro/kWh to 0.006 euro/kWh, according to Sustainable Energy Ireland (2002), *Renewable Energy Research, Development and Demonstration Strategy*.

10.7 INDUSTRY

Manufacturing

There is no significant wind turbine manufacturing industry in Ireland, although there have been several initiatives to set up manufacturing of specific wind turbine components and to manufacture micro-scale turbines. Sustainable Energy Ireland has funded several R&D projects in these areas, which are detailed in the following section.

Industry Development and Structure

Sustainable Energy Ireland has funded a study on offshore wind energy potential and associated industry development in Ireland. When completed, this study will serve to inform government policy on the development of this industry sector.

10.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The *1999 Irish Government Green Paper on Sustainable Energy*, along with setting renewable energy targets for Ireland, set out a program of Sustainable Energy R,D,&D with a budget of 50 million euro for the years 2000 to 2006. Sustainable Energy Ireland was charged with administering this budget. Of this budget, 16 million euro was specifically allocated to renewable energy research, while other parts of the program also contain renewable energy elements. Priorities identified within the green paper included 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 2001, the government-convened Renewable Energy Strategy Group completed a report specific to wind energy development, titled, *Strategy for Intensifying Wind Energy in Ireland*. This report identified key areas where development is required and work was initiated in these areas. As the majority of requirements initially identified have now been addressed and the wind industry in Ireland has moved from the initial deployments phase to the threshold of large-scale deployment, the priorities for facilitation of future wind energy development have also changed.

The Minister for Communications, Marine and Natural Resources, whose role includes energy policy, has announced the formation of a Renewables Development Group, chaired by his department. Within this department, the renewables industry, the Commission of Energy Regulation, SEI, and network operators will have a permanent forum to share expertise and to solve potential constraints to the development of this key sector. It is expected that this group will identify a new set of research priorities to assist the further deployment of wind energy in Ireland.

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

The Renewable Energy Research, Development and Deployment program, with an indicative budget of 16 million euro, will give priority to supporting the following:

1. Research aimed at developing policy options for enhanced deployment
2. Research to define the market structure for renewable energy technologies with high penetration potential
3. Research aimed at cost reduction, improved reliability, and/or opening new markets
4. Demonstration of non-technical innovation
5. Feasibility studies for renewable energy projects
6. Demonstration aimed at high-risk, high-reward projects
7. 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, and market and social conditions for the wider acceptance of the expanding deployment of wind energy.

New R,D&D Developments

Since its launch, the program in the previous section has had a significant number of applications. The following are among the wind energy R&D projects that have been approved for funding to date:

1. Development of a short-range ensemble prediction system for wind energy forecasting in Ireland
2. Participation in IEA R&D Wind Agreement Task XXI – Dynamic Models of Wind Farms
3. A study titled, Offshore Wind Energy Potential and Associated Industry Development in Ireland
4. A study titled, Wind Turbine Design and Method of Implementation that is Ideally Suitable for Use at Small Irish Wind Farms
5. A study titled, Define of a Monitoring Program for Irish Wind Farms
6. A study titled, Electricity Storage Technologies and their Potential to Address Wind Energy Intermittency in Ireland
7. A marketing/technical feasibility study to determine the possibility of developing a viable small vertical axis wind turbine
8. An investigation of the effects of wind turbines on MSSR radar tracking in Ireland
9. A project titled, Wind Turbine Blade Manufacture with New Materials
10. An evaluation of wind turbine foundation behavior
11. A study titled, The Influence of Mounting Booms and Towers on Wind Speed Measured by Anemometers
12. A study titled, Development of a Demonstration1 0.2-kW Domestic Wind Turbine
13. A study titled, Ownership Models and Financing of Community Renewable Energy Initiatives

Commissioned studies on specific prioritized topics affecting wind energy integration, which have been funded under the Renewable Energy R,D&D, include the following:

1. An updated wind atlas for Ireland with 200-m resolution, providing wind data at 50 m, 75 m, and 100 m for both onshore and offshore areas of the Republic of Ireland
2. A public attitudes survey titled, *Attitudes to the Development of Wind Farms in Ireland*
3. A study titled, Renewable Energy in the New Electricity Market
4. A study titled, Costs & Benefits of Embedded Generation in Ireland
5. A study titled, Impacts on Operating (and Load Following) Reserves of Increased Wind Penetration in Ireland
6. A study titled, Economic Analysis of Policy Mechanisms

Offshore Siting

The mechanism for permitting offshore wind farms is an adaptation, introduced in 2000, of the offshore exploration licensing system and comprises a "foreshore license." A foreshore license allocates exclusive rights to a single developer to allow in-depth site assessment and a "foreshore lease" that assigns exclusive site development rights to a developer.

To date, 11 foreshore licenses have been issued and one foreshore lease, the latter being for the Arklow Bank. Two projects with foreshore licenses were winning tenders, for 25-MW capacity each, in the AER VI competitive tendering round. These, and the Arklow Bank project, are all located on the east coast of Ireland, which is less exposed to Atlantic sea conditions.

References

- Department of Public Enterprise, 1999, *Green Paper on Sustainable Energy*, p. 123, ISBN: 0707 66263 X, http://www.dcmnr.gov.ie/display.asp?pg=557
- Commission for Energy Regulation, 2003, *The Impacts of Increased Levels of Wind Penetration on the Electricity Systems of the Republic of Ireland and Northern Ireland*, Garrad Hassan & Partners Ltd., http://www.cer.ie/cerdocs/cer03024.pdf
- ESBNG, 4 December 2003, Letter to CER re: Wind Generation System Security Issues, http://www.eirgrid.com/EirGridPortal/uploads/Regulation%20and%20Pricing/Letter%20to%20CER%20re%20Wind%20Gen.pdf
- ESBNG, 4 December 2003, *Interim Policy on Wind Connections*, http://www.eirgrid.com/EirGridPortal/uploads/Regulation%20and%20Pricing/Letter%20to%20CER%20re%20Wind%20Gen.pdf
- Department of Communications Marine and Natural Resources, 2003, *Options for Future Renewable Energy Policy and Programmes*, http://www.dcmnr.gov.ie/files/Cosultation%20document%20final%2019%20Dec%202003.pdf
- Commission for Energy Regulation, *Market Arrangements for Electricity (MAE) – An MAE Consultation by the Commission for Energy Regulation under SI 304 of 2003*, 12 September 2003, http://www.cer.ie/cerdocs/cer03230.pdf
- Sustainable Energy Ireland (2002), *Cost Benefit Analysis of Government Support Options for Offshore Wind Energy*, p. 41.
- Sustainable Energy Ireland (2002), *Renewable Energy Research, Development and Demonstration Strategy*, p. 16
- Government of Ireland (2001), *Strategy for Intensifying Wind Energy Deployment*, Government Publications ISBN 0-7076-9225-3
- Sustainable Energy Ireland (2003), *Republic of Ireland Wind Atlas 2003*, http://www.sei.ie/content/content.asp?section_id=1049
- Sustainable Energy Ireland, (2003), *Attitudes Towards the Development of Wind Farms in Ireland*, http://www.sei.ie/../uploads/documents/upload/publications/Attitudes_towards_wind_.pdf

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Figure 10.1 Tower construction offshore in Ireland (Courtesy of Airtricity)

Chapter 11
Italy

11.1 INTRODUCTION

Following the 2002 trend, initial forecasts about new wind energy installations in Italy for 2003 were pessimistic. But in the last three months of 2003, almost 100 MW were installed, and several new initiatives have begun. Another important step toward achieving the 2,500-MW-by-2010 target is the approval of the *Decree for Implementing EU Directive 2001/77/EC,* which establishes, among others, an increase in the quota of renewables to be put into the electricity system, beginning in 2004. Finally, new investors have been approaching wind energy and bringing new ideas and money to the sector. Financial institutions are more confident about new incentive schemes.

11.2 NATIONAL POLICY

With the approval of *Legislative Decree No. 387 of 23 December 2003 for Implementing EU Directive 2001/77/EC*, Italy is strongly committed to significantly increasing the share of renewable sources in the feeding of the electricity system, from 16% to 22% by 2010. In order to reach this goal, a large contribution is expected from wind, biomass, sun, and waste.

Previously, the Italian parliament, through Law 120 of 1 June 2002, ratified the *Kyoto Protocol on Climate Changes*. The Ministry of the Environment has implemented a National Plan for Greenhouse Gas Reduction, which was approved by the Interministerial Committee for Economic Planning (CIPE) in December 2002, with the aim of complying with the planned objectives on gas emissions.

According to *EU Directive 2001/77/EC* on the promotion of renewable energy sources (RES) for electricity, the national indicative target is for Italy to increase the contribution of RES electricity to gross electricity consumption from 16% in 1997 to 25% in 2010. In a footnote, however, Italy stated that this target is contingent upon the national demand in 2010 – assuming a gross national electricity consumption of 340 TWh in 2010, 22% would be a realistic figure. The latter target would correspond to production of up to 76 TWh/yr from RES.

The same 76-TWh/year target was already set forth for 2008 through 2012 in the Italian white paper for the exploitation of RES approved by CIPE in 1999, with an eye to Italy's Kyoto engagements for 2008 through 2012 (6.5% reduction of greenhouse emissions from the 1990 level). In this connection, the 2008 through 2012 contribution from wind should be approximately 5 TWh/yr, corresponding to capacity of approximately 2,500 MW (1,400 MW is the intermediate target for 2006).

Legislative Decree No. 387 for Implementing EU Directive 2001/77/EC is coming into force early in 2004. Its main highlights are as follows:

1. All the main principles of the EU directive have been considered. The definition of RES is in agreement with the directive to include wind, solar, geothermal, wave and ocean, hydropower, biomass, landfill gas, and biogas. Biomass and hydro-power plants (with the exception of run-of-river plants) are defined as dispatchable RES plants; all the others (including wind) are non-dispatchable and unfit for peak service.

2. No specific percentage target for any type of RES electricity has been set, but reference is made to national targets that will be established by the Minister of Production Activities in his periodic reports to the European Commission, pursuant to Article 3 of the directive.

3. The main RES supporting measures have been confirmed to be those already provided for in *Legislative Decree No. 79/99* of 16 March 1999 ("the Bersani Decree") and subsequent legislation (namely, the RES quota obligation with green certificate system).

4. The current 2% RES obligation is to be increased annually with a 0.35% step from 2004 to 2006.

5. There are special provisions about enhancing production and exploitation of biomass and biogas, about electricity from RES plants not exceeding 20 kW (to be fed into networks only on an exchange — i.e., net-metering basis), about solar energy (to be supported by further legislation fixing special prices for electricity fed into networks), and about hybrid plants (using both renewable and non-renewable fuels).

6. National targets are to be allocated among regions, depending on their resources, and regions may adopt additional measures for promoting RES.

7. Electricity from RES plants is entitled to a Guarantee of Origin issued by GRTN, the Italian transmission system operator. This Guarantee of Origin is intended only to testify that electricity has been produced from RES and has nothing to do with the green certificates related to fulfill the RES quota obligation.

8. Work on construction of RES plants and related infrastructures is to be considered in the public interest, urgent, and not deferrable. The whole plant construction must be authorized by a single permitting act, to be released by the region concerned after a single procedure and within 180 days.

9. RES electricity is granted the right of priority in use and dispatching as per *Decree No. 79/99* of 16 March 1999, and can take part in the free market in electricity according to given rules.

10. The Regulatory Authority for Electricity and Gas shall issue technical and cost-sharing instructions for the connection of RES plants to networks.

11. All waste, including that which is non-biodegradable, is entitled to the same benefits as RES, provided it is used in compliance with EU waste management legislation. The non-biodegradable fraction is only excluded from the Guarantee of Origin. This provision has raised some concerns among RES plant operators, as it could affect the deployment of real RES plants, to some extent.

Strategy

In accordance with *Legislative Decree No. 112/98* for the decentralization of administration, the decision on RES plants to be installed must be taken at the regional and local level. As a consequence, regions have been involved in determining wind energy capacity contribution to the electricity system in their regional energy plans. Moreover, regions are in charge of evaluating wind projects in terms of environmental impact and all other relevant aspects, before authorizing the building of wind plants.

Currently, after a long decision-making process, only a few regions have approved their energy plans. In particular, Sardinia and Tuscany have fixed wind-energy limits of 2,000 MW and 300 MW, respectively, by 2012, and at the same time have issued guidelines for wind investors. All other Italian regions are in the preparation and approval stages of their energy plans. The Campania region, with the aim of overcoming its electricity deficit, intends to improve regional renewable exploitation, with 25% of new energy plants (corresponding to 1,000 MW) fed by wind and biomass by 2010.

Progress Towards National Targets

After the achieving of 700 MW by 2002, as defined by the Italian white paper for the exploitation of RES, approved by CIPE in August 1999, the next target is 1,400 MW by 2006, and the final target is 2,500 MW by 2008 through 2012. In 2002 and 2003, the growth rate in wind capacity was not satisfactory, particularly if compared with the excellent result obtained in 2001, and it was not enough to comply with the second and final targets. In fact, in the last two years, only 222 MW were installed, of which almost 100 MW was installed between October and December 2003.

In spite of these results, there is nevertheless a good chance of achieving the second milestone, since a lot of projects are close to completion and other ones are in progress or under evaluation by local administrations. In 2004, 300 MW is a rough estimate of the new wind capacity that will be added, bringing total cumulative capacity to 1,200 MW.

Regional energy plans and their application, and in particular their acceptance by the local population, will play a decisive role in the achievement of national targets.

11.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 2003, Italy added new wind capacity, corresponding to 116 MW, to the pre-existing 788 MW, making a total cumulative wind power of 904 MW by the end of the year. Figure 11.1 shows the installed capacity (annual and cumulative) and the annual energy production.

Enel GreenPower was the most active company during the year with a very strong involvement in the two biggest Italian islands: Sardinia and Sicily. On these two islands, Enel GreenPower installed 24 MW and 39 MW, respectively. This company alone put more than 50% of new wind capacity into the grid. Enel Green Power is still working in Sicily on connecting two wind farms to the network,

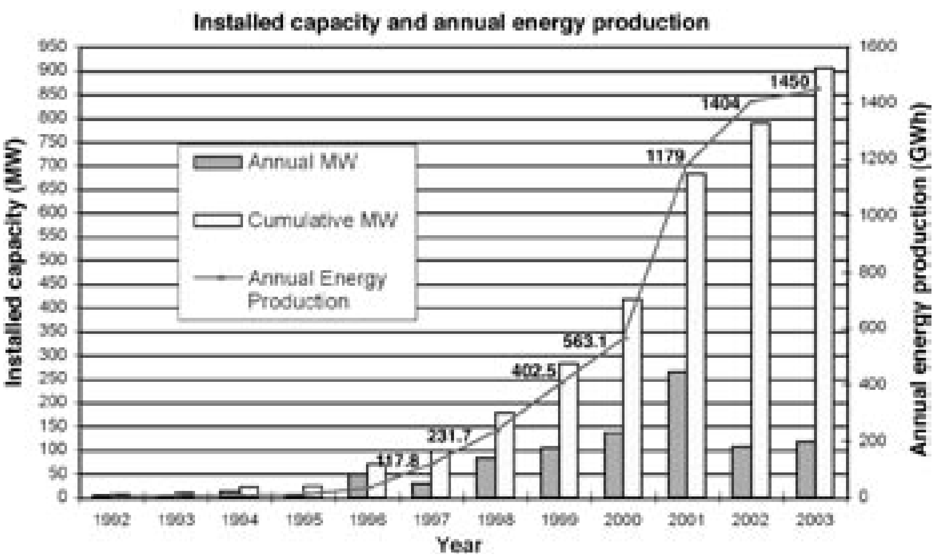

Figure 11.1 Installed capacity (annual and cumulative) and annual energy production

and thus completing one step towards an increasing quota of renewables in electricity production.

Harpen, a German company, has almost completed the installation and connection to the grid of 13 Fuhrländer 1-MW turbines, in the Campania region. The tower, which is 70 m high, is the tallest one in Italy to date.

Edison Energie Speciali (Edens) has finally completed its 12.3-MW wind farms in the Basilicata region, after years of involvement in the authorization processes. The company plans to achieve 500 MW of wind capacity in Italy by 2010.

A new private developer, Eolo-Utilità, has installed ten Vestas V52 machines in the province of Salerno.

So far, total wind capacity has reached 904 MW, with little growth (20 MW) between January and September 2003. But in November and December, approximately 100 MW were added, bringing the total increase in 2003 to slightly more than the previous year.

IVPC opened five new sites in Sicily, where the installation of 114 MW by year-end 2004 is planned. Through the opening of two other sites in Sardinia, 13 MW will be brought into service soon at Nulvi, and 35 MW later at Ploaghe. All these IVPC wind farms will be set up with Vestas V52 turbines.

Spain's Gamesa is completing work on the 20-MW Florinas wind plant in Sardinia. The plant will also mark the first large-scale installation of Gamesa's 2-MW machine in Italy. Gamesa Energia, the project developer, has about 200 MW under development in Sardinia and other Italian regions.

ICQ is enlarging its plant at Ginestra degli Schiavoni, adding eight Vestas V52 turbines of 850 kW each.

Energia Sud, a new wind developer, is working in the Basilicata region on installing 11 Vestas V52 turbines.

Fri-el is going to install 26 Vestas V52 turbines at Nurri in Sardinia.

Another private company, Eolo, is in the process of completing its wind farm at Viticuso, the first one in the Lazio region, adding seven Enercon E-40 turbines to the eight already installed.

Italian wind farms installed in 2003 and those under construction are both listed in Table 11.1.

Rates and Trends in Deployment

Deployment rates showed only a small increase in 2003, with only 116 MW installed. This is mainly due to financial and bureaucratic difficulties and a strong campaign against wind energy. The annual average growth necessary to comply with the national targets is approximately 200 MW, but this figure is likely to be overtaken by about 100 MW in 2004 when wind farms currently under construction are taken into account.

In conclusion, rates and trends in wind energy deployment are still not steady, owing to their strong dependence on factors such as grid connection as well legislative, economic, social, and environmental issues.

Contribution to National Energy Demand

Given that a limited number of new wind farms began operation in 2003, and taking into account that 2002 was the worst year of the decade in regard to wind resource

Wind farms installed in 2003 in the Italian regions				
regions	**number**	**Wind power capacity (MW)**	**Energy producers**	**Wind turbines**
Sicily	**2**	**39.1**	**Enel GreenPower**	**Vestas V52**
Sardinia	**1**	**23.8**	**Enel GreenPower**	**Gamesa G52**
Campania	**3**	**23.3**	**Harpen eolica, Eolo-Utilità, Edens**	**Vestas V52, Fuhrlander SL, Enercon E40**
Basilicata	**2**	**14.85**	**Edens, Enel GreenPower**	**Vestas V52, Enercon E40**
Apulia	**1**	**7.92**	**IVPC4**	**Vestas V52**
Lazio	**1**	**3.6**	**Eolo**	**Enercon E40**
Molise	**1**	**2.55**	**Enel GreenPower**	**Gamesa G52**
Wind farms under construction or completion in the Italian regions				
regions	**number**	**Wind power capacity (MW)**	**Energy producers**	**Wind turbines**
Sicily	**7**	**167**	**IVPC, Enel GreenPower**	**Vestas V52**
Sardinia	**4**	**80**	**Fri-El Green Power, Gamesa, IVPC**	**Vestas V52, Gamesa G82**
Abruzzo	**2**	**18**	**Edens**	**Vestas V52, Enercon E40**
Apulia	**1**	**12**	**Edens**	**Vestas V52, Enercon E40**
Basilicata	**1**	**9.3**	**Energia Sud**	**Vestas V52**
Lazio	**1**	**4.2**	**Eolo**	**Enercon E40**

Table 11.1 Italian wind farms installed and under construction in 2003

contribution in Italy, the wind share in national energy demand was roughly the same as 2002, corresponding only to about 0.5%.

Domestic electrical energy demand was about 319.7 TWh (including transmission and distribution losses) in 2003, with an increase of 2.9% from 2002. To meet this demand, 50.9 TWh, 0.7% more than in 2002, were imported from neighboring countries. In 2003, the gross electrical energy produced in Italy was 292.8 TWh, 3.0% more than the previous year.

Thermal plant production grew by 4.7% as compared to 2002, with a total gross production of 241.8 TWh, while the gross contribution of all renewable sources, including large and small hydro, was 51.0 TWh, with a 5% drop in respect to 2002 due to hydropower. Total gross production of hydropower plants was 44.2 TWh in 2003, a 6.4% decrease from 2002.

In 2003, wind energy's contribution to electricity generation was estimated at 1,450 GWh, while in 2002, the total wind energy production was 1,404 GWh. Wind energy's share of the country's overall electricity demand therefore remained at less than 0.5%.

11.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

In Italy, most of the RES plants that began operation in the last few years are still benefiting from the former mechanism of premium energy feed-in prices established by *CIP Provision No. 6* of 29 April 1992. *CIP 6/92* feed-in prices are allowed only in the first eight years of grid-connected operation. Therefore, the peak of RES capacity getting these prices should be reached by about 2006; then this capacity should be declining.

The premium prices currently fixed for wind energy produced in 2003 range from 0.0952 euro/kWh to 0.0680 euro/kWh, depending on the date of entry into operation and other parameters. Wind energy plants that have already exceeded the term of eight operating years get only 0.0576 euro/kWh to 0.0499 euro/kWh.

Currently, *CIP 6/92* feed-in prices are no longer available to new RES projects. In the meantime, a new RES support framework has been introduced by *Legislative Decree No. 79/99* of 16 March 1999 (the "Bersani Decree"), which restructured the electricity market in line with *EU Electricity Directive 96/92/EC*. Since 2002, the support system has therefore been changing from a feed-in-price mechanism to an RES-quota mechanism based on green certificates.

According to the new mechanism, all those producing or importing more than 100 GWh per year of electrical energy from conventional (non-renewable) sources are obligated to feed into the grid, or to acquire, a given percentage of energy from RES. This percentage has initially been fixed at 2% and must be produced by new or repowered plants that came into operation after 1 April 1999.

Another decree, issued on 11 November 1999, regulates how the electricity produced by these RES plants is to be labeled with green certificates granted by the transmission system operator (in Italy, GRTN). A plant can be granted green certificates over its first eight years of operation. It is allowed to combine green certificates with other subsidies, except the *CIP 6/92* feed-in prices.

In addition to selling energy at market price (between 0.05 euro/kWh and 0.06 euro/kWh in the last two years), RES electricity producers can get an additional income by selling their certificates to those who are subject to the 2% RES obligation and have to submit enough certificates to GRTN to demonstrate their compliance every year. This mandatory 2% quota can be achieved by conventional energy producers in two ways: by directly producing energy from renewables, or by acquiring green certificates in an exchange organized by the Electricity Market Operator (GME), as well as through bilateral contracts between conventional and renewable energy producers.

The green certificates for electricity produced by those RES plants that are also entitled to *CIP 6/92* prices are retained by GRTN, which must sell them out at a fixed price. This price was 0.08418 euro/kWh for 2002 production and was recently set at 0.08240 euro/kWh for 2003 production. Since the certificates held by GRTN currently outnumber cumulative demand, GRTN may fix a price cap to marketed certificates. For instance, the demand for 2002 green certificates (to be submitted by 31 March 2003 to show compliance with the 2002 RES obligation) corresponded to about 3,300 GWh and was mostly covered by GRTN certificates (potentially up to

4,300 GWh). The contribution from entitled RES producers was only 1,200 GWh. The latter had to sell their certificates at a price not exceeding 0.08418 euro/kWh.

Prospects for RES producers are going to improve in the future, as *CIP 6/92* incentives expire and GRTN certificates become fewer. However, the new mechanism raised some mistrust among RES investors and banks, which saw more income uncertainty compared to former *CIP 6/92* feed-in prices. But according to the main RES producers, financial institutions are now more confident of the new incentive scheme, which is based on green certificates, and some large wind projects have been financed since the end of 2003.

The new Decree for Implementing *EU Directive 2001/77/EC*, starting in 2004, increases the mandatory 2% renewables quota by 0.35% per year until 2006. At the national level there are laws – not specific for RES but including them – that grant a different kind of support to RES initiatives. One initiative, *Law 488/92*, has as its main national objective increasing and improving production, the economy, and employment (particularly in depressed areas). This law provides for subsidies on investments to enterprises in various sectors, including electricity.

RES in southern Italian regions have access to another financial instrument. In particular, Sicily's energy plan has granted financial support to wind projects for approximately 37 million euro. Onshore wind farms that are entitled to financing can obtain up to 25% of eligible cost, while offshore wind farms can obtain up to 42%. These percentages are only granted to small- and medium-sized enterprises. Larger enterprises submitting to the region onshore and offshore projects could be entitled to financial support of 17% and 29%, respectively.

11.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

In 2003, 145 wind turbines were installed, just eight more than 2002, corresponding to 116 MW. The average size of the turbines

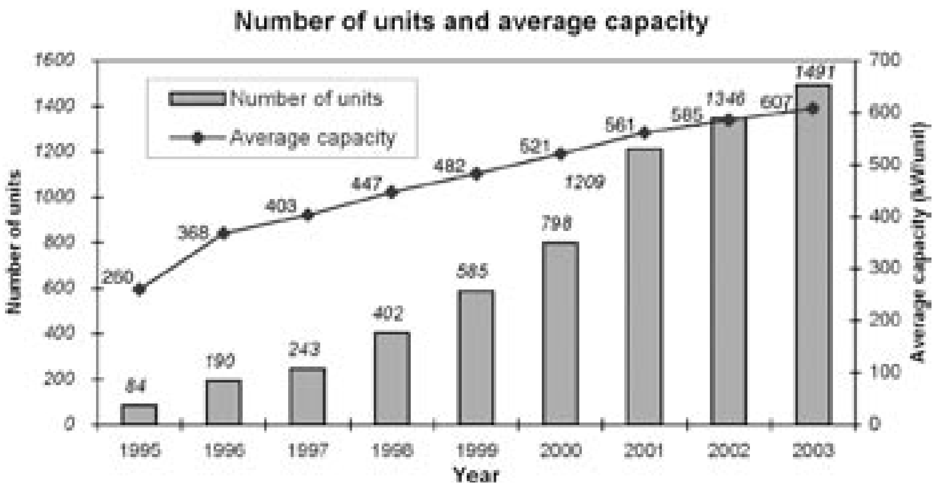

Figure 11.2 Number of units installed and corresponding average capacity

erected during the year increased from 774 kW to 800 kW. This is due to a substantial contribution from 850-kW turbines, currently the most commonly erected turbine size in Italy. At the end of 2003, the average capacity of the total 1,491 turbines installed, rose to 606 kW (Figure 11.2). Figure 11.3 and Figure 11.4 show the 2003 market shares for wind turbine manufacturers and the 2003 wind contribution by electricity producers, respectively.

IWT-Vestas is still the leading constructor in the Italian market, with a 63% share. Enercon maintains the second position with a little more than 200 MW installed (and a corresponding 21% share), due in great part to its E40 600-kW model.

In 2003, Gamesa 850-kW and Fuhrländer 1-MW turbines were erected in Italy for the first time. In February 2004, ten 2-MW G82 Gamesa turbines are expected to be connected to the grid at Florinas. This is the country's largest turbine installation to date. During 2004 some other Vestas and Gamesa 2-MW class turbines are expected to be put up in the Abruzzo, Campania, and Sardinia regions.

IVPC4 and IVPC – despite their lack of contribution to the 2003 market, in the sense that only eight megawatts were installed in the Apulia region – are strongly maintaining their role as leading wind electricity producers, with a 50% share. Enel GreenPower made significant progress, with a 14% share at the end of 2003, while Edens, with a 23% quota in the Italian wind market, is still in second position.

Operational Experience

Detailed information about operational experience is difficult to obtain from developers, but it is known that, from a meteorological aspect, 2003 was one of the worst wind years in Italy. During the summer, there were three months of extremely low wind. As a consequence, the capacity factor decreased significantly, with an average value of 0.23 and a peak value of 0.30.

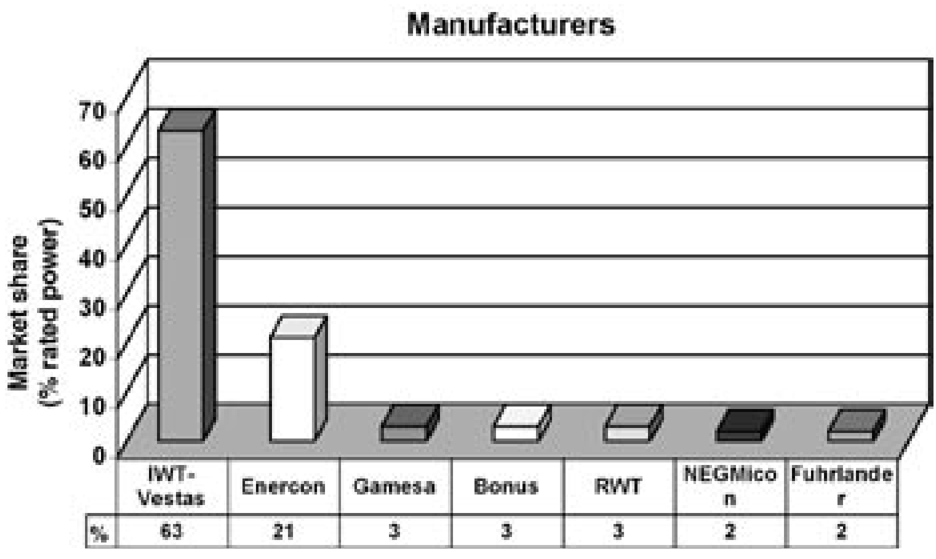

Figure 11.3 Market shares of wind turbine manufacturers at the end of 2003 (as a percentage of total online capacity)

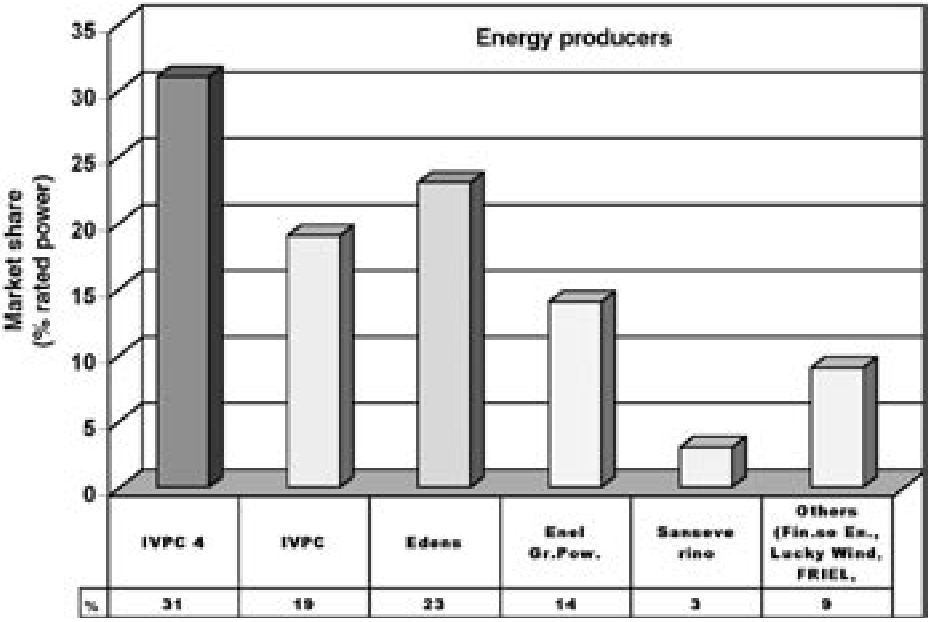

Figure 11.4 Contribution by electricity producers from wind at the end of 2003 (as a percentage of total online capacity)

The 2003 average availability of wind turbines was the same as in 2002, around 98%. In the best cases, an availability of 99% was reported, but sometimes (at the beginning of grid connection) the related availability was quite low.

Main Constraints on Market Development

Developers and industry were facing the same difficulties as in previous years with the addition, in certain cases, of further problems arising with grid connection, owing to technical and social constraints. Social constraints were a primary concern and were raised by local populations in the process of planning new high voltage lines.

A minority of environmentalists is still strongly against wind energy deployment in mountainous areas, both for its visual impact and bird collisions (despite the lack of figures about bird deaths until recently along the Apennines and other mountain ridges).

Strangely, one of the agricultural associations is against wind energy, too, seemingly forgetting the economic advantages obtained by farmers, rural communities, and landowners. Besides, it is quite usual to have better access to agricultural farms through improvement and, sometimes, construction of new roads for transportation and maintenance of wind plants.

Another great problem, which has been creating difficulties to developers, is the authorization process for building wind farms. The inclusion in Italian legislation of the principles of *EU Directive 2001/77/EC*, as mentioned before, should be, to a certain extent, a positive response to this type of problem. This aspect has been managed in different ways by the Italian regions, depending on their approach in favor of or against wind energy.

11.6 ECONOMICS

Trends in Investment

For reasons already explained, in 2003 (especially in the first nine months of the year), the capacity of plants that entered into operation was below expectation. The corresponding investment was lower as well. It has not been easy to obtain precise figures from wind turbine manufacturers and investors; on the other hand, selling prices may well have been different from one wind turbine supplier to another, depending on the number of units in each batch. As a rough estimation, however, the 2003 total investment in new, completed wind plants could be put at the same amount as 2002, namely about 100 million euro.

As already stated, by the end of the year, several additional projects began, which means that investments improved as well. Since the related plants will begin operation in 2004, these later investments have not been taken into account for 2003. The 2004 investments are therefore likely to be about three times the amount given for 2003.

Trends in Unit Cost of Generation and Buy-Back Prices

Most wind plants currently operating in Italy still benefit from *CIP Provision No. 6/92*, which grants them premium prices for the energy generated during the first eight years of operation. In 2003, the energy buy-back price for wind plants ranged between 0.0952 euro/kWh and 0.0680 euro/kWh, depending on start-up year and other parameters. Since the 2002 buy-back price for wind was around 0.012 euro/kWh, there has actually been a downward trend in *CIP 6/92* buy-back prices.

As for the new quota/green certificate system (see the section, *Main Support Initiatives and Market Stimulation Incentives*), in late 2003, following a method set out by the legislation, GRTN again fixed the selling price of its own green certificates relating to 2003 production (namely those certificates that should have belonged to RES plants that are also getting *CIP 6/92* buy-back prices) at 0.0824 euro/kWh.

These certificates must be traded before 31 March 2004, the deadline for proving compliance with the 2003 RES quota obligation. In this case, there has also been a downward trend from the 2002 price of 0.08418 euro/kWh. This trend will also affect the certificates actually assigned to RES electricity producers, since GRTN certificates set a price cap in the green certificate market, owing to their prevailing quantity. However, even the 2003 GRTN green certificate price can be deemed as fair, considering that the annual average price of wholesale traded electricity rose in 2003 to 0.0626 euro/kWh.

11.7 INDUSTRY

Manufacturing

Italian Wind Technology (IWT), a subsidiary of Vestas Wind Systems A/S, has been manufacturing wind turbines since 1998 and is the only commercial wind turbine manufacturer in Italy. Since the year 2000, when IWT became a 100%-owned subsidiary, its production has been delivered not only to the Italian market but also to Vestas's clients throughout the world, guaranteeing both the quality and the technology of the mother company.

IWT's facility occupies an area of 75,000 square meters, split between a nacelle assembly area and a blade factory, with a total covered area of 18,000 square meters. The production facility in Taranto is dedicated to the Vestas V47 660-kW and V52 850-kW turbines and has an annual production capacity of approximately 500 wind turbines. In addition to production IWT operates sales, technical support, service, and erection throughout the country.

IWT is now delivering complete, operational wind farms. In order to fulfill this type of commitment, it engages local companies for the supply of civil works, electrical works, substations, and grid connection, while maintaining full responsibility and supervision.

As of 30 June 2003, IWT had installed 553 MW in Italy. As for now, kilowatt turbines have been dominating the market, but an interest is growing in megawatt turbines. This makes the performance of a turn-key contract even more complicated and challenging.

IWT is certified according to UNI EN ISO 9001 and 14001, confirming the total commitment towards developing products in respect to quality and the environment.

Despite a slow start to 2003, when production activity was significantly reduced, the end of the year has, on the other hand, been characterized by a growing interest in the wind market, which could lead to a significant impact on production for 2004.

The following component suppliers carry out additional activities in the wind sector:

- ABB-ASI for engines and generators
- Brevini-Bonfiglioli for reduction gears
- Ring Mill for forging
- Colombo-Ariotti for casting
- Magrini-Schneider for transformers
- Pirelli for cables
- Monsud-Leucci-Pugliese for towers

Industry Development and Structure

After experiments on the GAMMA 1.5-MW prototype in the 1990s, a new, Italian-made, large machine was developed and installed by Leitner AG in 2003.

Leitner is an Italian company from Vipiteno/Sterzing in the northern Italian province of South Tyrol/Alto Adige (where Italian and German are both spoken). The company has long been constructing cableways and other lifting plants in many countries and has just entered the wind sector as well, drawing on such expertise.

The wind-power generator, Leitwind 1.2 MW, is a prototype of the megawatt class (Figure 11.5). The turbine has three blades, a horizontal axis, and a rotor diameter of 62 m. Leitwind is designed for Wind Class I (IEC 61400-1 standard) and for a life of 20 years. Leitwind is now in the certification phase, carried out by *TÜV Süd* (Munich). With the omission of the gearbox, Leitwind is more efficient, emits less noise than conventional plants, and has easier maintenance.

The Konsortium Windkraft Marein is the operator of the prototype installed at Malles/Mals in South Tyrol/Alto Adige at the end of August 2003. This consortium consists of the communities of Glurns, Graun, Mals, and Schluderns; the utilities of Prad and Stilfs; the energy co-operative of Oberland; and the Vinschgauer Elektrizitätskonsortium. The inhabitants of the four communities have been informed about the project in assemblies. The test phase of the prototype will last for two years, and there will be an information center close to the site for people interested in wind power.

For three years, a team of 16 persons was occupied with the development of the prototype, representing a total investment of 8 million euro. Leitner expects a wind-power share in its yearly turnover of 30% over the next four years. In the last financial year, the Leitner-Group achieved a turnover of 372 million euro.

Figure 11.5 Prototype Leitwind 1.2 MW, installed at Malles/Mals in South Tyrol/Alto Adige

11.8 GOVERNMENT-SPONSORED R, D&D

Priorities

Government support to R,D&D programs has been dramatically cut back in recent years. In 2003, about 500,000.00 euro were allocated for scientific research. Part of this money was devoted to the completion of the *Wind Atlas of Italy*, finally ready to be utilized by regional and local administrations.

Some Italian universities are engaged in aerodynamics, siting, offshore foundations, and electrical systems, but with poor resources both in terms of personnel and money.

New R,D&D Developments

By mid-2003 the company CESI S.p.A., which is owned by companies of the Enel Group, GRTN (the Italian transmission system operator), and several other utility and industrial companies, completed a three-year research project on wind energy with support from the Fund for Research on the Electrical System, established by the Italian Minister of Industry, Trade and Handicraft (now Minister for Production Activities) on 26 January 2000.

As described in more detail in the *2002 IEA Wind Energy Annual Report*, the main activity was aimed at publishing the *Wind Atlas of Italy*, which is a full general atlas of Italy's wind resources. The atlas can provide a framework for singling out the most promising areas for purposes of regional energy planning and wind farm siting. In fact, such a comprehensive, basic tool was still lacking in Italy, even though much wind data had been collected by ENEA, Enel, CNR, and some industrial companies over the past two decades.

The work started with the simulation of wind flow all over Italy in co-operation with the University of Genoa. An up-to-date wind-flow model was used to obtain preliminary wind maps at various heights above ground from geostrophic wind data provided by meteorological institutes

(ECMWF of Reading, the United Kingdom). Subsequently, these maps were adjusted by comparison with data recorded by more than 240 wind-measuring masts throughout Italy.

The atlas was published in both paper and electronic form. In addition to synthesis maps, it comprises three series of 27 maps, each showing wind speeds at heights above ground of 25 m, 50 m, and 70 m, respectively. A further series of 27 maps shows the theoretical specific annual electrical energy yield at 50 m above ground (namely, the production in megawatt-hours per megawatt of a notional wind turbine with a 50-m hub height). By the terms of the contract to the Italian government, the wind atlas will be available to all local authorities and other interested entities.

In 2003, CESI also developed further its methodology for assessing the feasibility of wind farms in mountain areas above 1,000 m altitude and applied it to the whole country, in order to get a picture of Italy's usable potential up to elevations of 2,000 m. Unlike former investigations concerning a few sample areas, this last phase could rely on the newly made wind atlas.

In addition to windiness, account was taken of factors (e.g., terrain slope and roughness, soil use, distance from the electrical grid and roads, environmental, and other constraints) that can heavily affect the feasibility and production costs of a wind farm. It was found that Italy does, in principle, have an economically exploitable wind potential in the 1,000 m to 2,000 m altitude range. However, the estimated wind capacity that could be installed at such heights turned out to vary considerably, albeit always in the order of hundreds of megawatts, depending on the assumptions and criteria that were taken into account.

As for the future, CESI's wind energy research is now likely to aim mainly at evaluating the role of wind plants within the framework of studies on future energy scenarios.

Figure 11.6 shows an overall synthesis map of annual mean wind speeds at 50 m above ground, taken from the *Wind Atlas of Italy*.

Offshore Siting

After the conclusion of a European project called WEMSAR, ENEA is now involved in the project, Net for Offshore Sustainable Technologies, Resources, and Use in the Mediterranean Sea (NOSTRUM), jointly with Besel (as project leader), CRES, and Espace Eolienne Development. The objectives of this work are to facilitate the sustainable deployment of offshore wind power in the Mediterranean Sea, and to remove legal and administrative barriers and gaps that hamper or impede the development of this type of energy industry.

In April 2003, the fourth OWEMES seminar for the promotion of offshore wind energy development in the Mediterranean was held in Naples with qualified international participation.

Authors: L. Pirazzi, ENEA; C. Casale, CESI, Italy

Figure 11.6 Overall synthesis map of annual mean wind speeds at 50 m above ground, taken from the *Wind Atlas of Italy*

Chapter 12
Japan

12.1 INTRODUCTION

At the end of 2003, the total wind-power capacity in Japan was 506 MW, which corresponds to one-sixth of the national target for wind-power capacity by 2010. Japan's wind power was severely impacted in September 2003 when a huge typhoon attacked Miyako Island. All seven wind turbines on the island were heavily damaged.

2.2 NATIONAL POLICY

Strategy

At the United Nations (UN) Climate Change Conference in Kyoto in 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 has changed the target of wind power for 2010 from 300 MW to 3,000 MW in the latest Primary Energy Supply Plan.

Progress Towards National Targets

In 1995, the government and the New Energy and Industrial Technology Development Organization (NEDO) started a promotional policy with subsidy-programs. In June 1997, the *Law on Special Measures for Promotion of Utilization of New Energy (New Energy Law)* was enacted, which encouraged wind-generation businesses in Japan. As a result, some large-scale commercial wind farms ranging from 20 MW to 30 MW were developed, and a rapid increase in wind-power capacity in Japan was recorded in the last three years.

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 the 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 1.1% of their total electricity supply from renewables by 2010.

12.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Japan's cumulative wind-power capacity was 506 MW at the end of 2003. Figure 12.1 shows the history of wind turbine development in Japan. Every value of capacity was taken at the end of the year.

Rates and Trends in Deployment

At the beginning of 2004, the increase in cumulative wind-power capacity was recorded as 7.5 times that at the beginning of 2000. The average increase late in this period was 71.3%. Many commercial wind farms have been developed with support from government promotional subsidy programs. However, wind capacity has had limitations due to some regional utilities' grid problems.

Contribution to National Energy Demand

Wind power generation from April 2002 to March 2003 was 569.4 GWh. The national energy demand in the same period was 841.4 TWh, and the contribution of wind power counts for 0.068%.

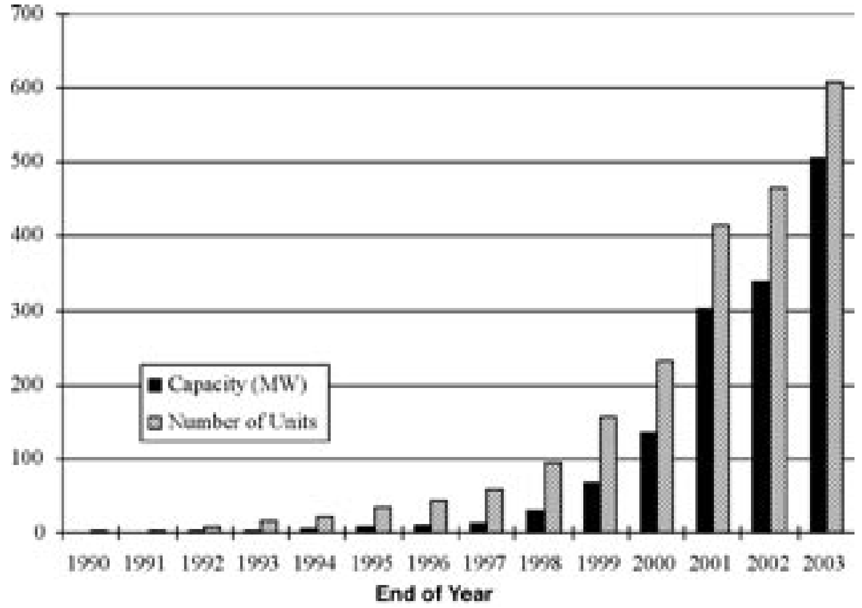

Figure 12.1 History of installed wind capacity in Japan
Data source: NEDO

12.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

NEDO has been conducting the following three subsidy programs as part of the Ministry of Economic, Trade, and Industry's (METI's) introduction and dissemination program. These programs play an important role for local governments' and private companies' wind-power developments.

1. Field test program for developing wind turbine generating systems

This program started in 1995 to stimulate the introduction of wind-energy plants into Japan. NEDO subsidizes local governments and private companies at 100% for one year of wind measurements and 50% for facility construction and operation.

2. Regional New Energy Introduction Program

This program has supported new energy projects developed by forefront developers or public sectors since1998. NEDO subsidizes up to 50% for the design and construction of each wind-power plant with a capacity of more than 1,500 kW.

3. New Energy Business Support Program

This program is for the private wind farm developers, and NEDO subsidizes up to one-third for each facility design and construction.

Unit Cost Reduction

More than 90% of installed wind turbines in Japan are imported from Europe and the United States. Therefore, the 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 to stabilize the power for grid connection – require a higher total plant cost.

12.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Commercial wind farm deployment increased in 2003. Table 12.1 lists the 20 largest wind farms. These large wind farms are located primarily in the northern part of Japan – 49% of the total capacity listed in Table 12.1 comes from wind farms in the Tohoku area, and 37% comes from wind farms in the Hokkaido area.

Most of the wind turbines in Japan are imported from Europe and the United States. There are, however, a few national manufacturers such as Mitsubishi Heavy Industries (MHI), Ltd. for large-scale wind turbines and Fuji Heavy Industries (FHI), Ltd. for small-scale wind turbines. The share in capacity of the national manufacturers is only 7.3%, as shown in Figure 12.2.

Operational Experience

In Japan, the outstanding technical issues related to wind power are power quality, the risk of typhoon attacks and lightening strikes, and high turbulence at hilly sites. Many turbines have been hit by lightning, and winter lightning poses a specific threat due to its intense power and electric current that is much higher than the world average.

In September 2003, a huge typhoon attacked Miyako Island. All seven wind turbines on the island were severely damaged: three fell down, three lost blades, and one had its nacelle cover broken. The destroyed turbines were all imported from Denmark or Germany. The maximum (extreme) wind speed recorded was 74.1 m/s, which means the typhoon is the seventh largest in the history of observation.

In principle, the typhoon accident is considered a natural calamity because the wind-gust speed at hub height was likely more than 90 m/s. Typhoons are not uncommon on Miyako Island – the first, third, fifth, and seventh highest wind speeds have been recorded there. The Japanese government recently set up a committee of investigation to explore typhoons incidents on the island.

Main Constraints on Market Development

Grid capacity, or power quality, has become one of the most important issues in Japan. The regional utility has limited available capacity for wind generation to 250 MW in the Hokkaido area and 150 MW in the Tohoku area. Even without these limits, the national target by 2010 will be difficult to attain.

Complex terrain affects mechanical strength and electrical quality due to gusty and turbulent wind. It also increases the cost of transportation, erection, and grid-connection. NEDO conducted a demonstration program on a power stabilization technique using battery-back-up.

12.6 ECONOMICS

As large-scale, commercial wind-power plants ranging from 20 MW to 30 MW are developed, the economics are getting more competitive. The cost of energy (COE) is 9.00 yen/kWh to 11.00 yen/kWh for medium-scale wind turbines with capacities between 500 kW and 1,000 kW. The COE is 7.00 yen/kWh to 9.00 yen/kWh for large-scale wind farms comprised of wind turbines with capacities of more than 1,000 kW.

No.	Location	Plant capacity (kW)	Turbine capacity (kW)	Number of units	Manufacturer
1	Rokaksho-mura, Aomori-ken	33,000	1,500	22	NEG-Micon
2	Higashidouri-mura, Hokkaido	32,500	1,300	25	BONUS
3	Higashidouri-mura, Hokkaido	27,000	1,500	18	NEG-Micon
4	Nikaho, Akita-ken	24,750	1,650	15	Vestas
5	Tomamae, Hokkaido	23,100	1,650	14	Vestas
6	Horonobe, Hokkaido	21,000	750	28	Lagerwey
7	Esashi, Hokkaido	21,000	750	28	Lagerwey
8	Kuzumaki, Iwate-ken	21,000	1,750	12	Vestas
9	Tomamae, Hokkaido	20,000	1,000	20	BONUS
10	Oyamada-mura, Mie-ken	15,000	750	20	NKK-Lagerwey
11	Kitakyuushuushi, Fukuoka-ken	15,000	1,500	10	GE Wind Energy
12	Wakkanai, Hokkaido	14,850	1,650	9	Vestas
13	Noshiro, Akita-ken	14,400	600	24	Hitachi-Enercon
14	Nejima-machi, Kagoshima-ken	13,000	1,300	10	IHI-NORDEX
15	Seto-cho, Ehime-ken	11,000	1,000	11	MHI
16	Kazuno, Akita-ken	7,650	850	9	Vestas
17	Tomamae, Hokkaido	7,500	1,500	5	Hitachi-Enercon
18	Akita, Akita-ken	6,000	750	8	NEG-Micon
19	Shimamaki, Hokkaido	4,500	750	6	NEG-Micon
20	Ine-machi, Kyoto-fu	4,500	750	6	Lagerwey

Table 12.1 Japan's 20 largest wind farms

Trends in Investment

As shown in Table 12.1, nine wind farms with capacities of more than 20 MW have been developed. The current wind turbine cost is approximately 100,000.00 yen. The installation cost is decreasing as large-scale wind power plants increase. The cost differs depending on wind condition, grid condition, and plant size.

Plant cost is 130,000.00 yen/kW to 200,000.00 yen/kW for medium-scale wind turbines with capacities between 500 kW and 1,000 kW. Plant cost is 110,000.00 yen/kW to 150,000.00 yen/kW for large-scale wind farms comprised of wind turbines with capacities of more than 1,000 kW.

Trends in Unit Costs of Generation and Buy-Back Prices

The average electricity purchase price is about 18.00 yen/kWh. The wind-generated electricity purchase price has been as low as 11.50 yen/kWh, according to the utilities' purchase menus. However, since RPS

Vestas	21.4%
NEG-Micon	21.3%
Lagerwey	17.1%
BONUS	11.9%
Mitsubishi	7.0%
Hitachi-Enercon	6.2%
IHI-NORDEX	4.7%
GE Wind Energy	4.1%
TACKE	2.6%
Fuhrlander	1.1%
Etc	1.0%
DeWind	0.6%
Repower SystemAG	0.4%
Fuji	0.3%
WindWorld	0.1%
Kenetech	0.1%
Yamaha	0.1%

Figure 12.2 Manufacturer share of turbine capacity (MW)]

began, the price is often decided through tender, which results in a price reduction of up to 4.00 yen/kWh to 5.00 yen/kWh. The subsidy could keep the economic balance.

12.7 INDUSTRY

Manufacturing

MHI is the only national manufacture that supplies medium-to-large wind turbines. MHI has recently developed variable-speed, synchronous wind turbines with capacities of 300 kW, 600 kW, and 2,000 kW.

FHI is a relatively new wind turbine manufacturer. Under a national project, FHI developed a 40-kW Subaru wind turbine and a 100-kW wind turbine as a result of its 20-kW class rotor development in cooperation with the Mechanical Engineering Laboratory (MEL).

Industry Development and Structure

As shown in Figure 12.2, Vestas, Neg-Micon, and Lagerway are Japan's three largest manufacturers in terms of capacity, with a cumulative share of about 20%. MHI's share is 7%.

MHI is a national manufacturer that provides large wind turbines. The largest 2-MW wind turbines are horizontal axis, variable-pitch control, variable-speed control, and gearless, with a permanent magnet synchronous generator. MHI conducts business all over the world, in countries such as Germany, India, Mexico, Portugal, the United Kingdom, and the United States.

FHI is another national manufacturer that provides small-to-medium wind turbines with capacities of 40 kW and 100 kW.

Since 1 November 2000, Japan Natural Energy Company, Ltd., has provided power generation services mainly to corporate customers using natural energy sources such as wind power with *Certification of Green Power*. In addition, nearly 100 companies in the wind industry founded the Japan Wind Power Association in 2002.

12.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Government-sponsored R&D was closed in fiscal year 2002 (March 2003) based on the judgment that wind turbine technology has become mature enough.

Since 1978, the Japanese government – formerly the Ministry of International Trade and Industry (MITI), now METI – aims its wind energy R&D program at energy security after the oil crises. This is one part of the general R&D program for renewable

Figure 12.3 The aftermath of typhoon attack on Miyako Island
Source: Asahi-Shinbun Website

energy called the New Sunshine Project and has been directed by the New Sunshine Program Promotion (NSS) Headquarters, MITI.

After global warming was recognized, the objective of the New Sunshine Project was set to develop innovative technology to create sustainable growth while solving both energy and environmental issues.

Table 12.2 summarizes Japan's national wind energy activities, which are described in more detail as follows:

A. New Sunshine Project: R,D&D

In 1999, Japan started new R&D,D programs on new wind technologies for remote islands.

B. Technical demonstration programs on wind power stabilization

In 2000 and 2001, two new demonstration programs were undertaken by NEDO to develop techniques to stabilize wind output power.

C. Promotion of introduction with subsidies

NEDO's field test programs, the New Energy Local Introduction Supporting Program, and the New Energy Business Supporting Program, have played an important role in promoting the introduction of wind turbines among private sectors as well as local governments.

D. Integration of Japanese Industrial Standards (JIS) and International Electrotechnical Commission (IEC) standards

The national programs include co-operation in IEC standard activities in the wind energy category. METI is also promoting the policy in order to keep international consistency. In 1999, two JIS that keep conformity with IEC 61400 standards were published, and in 2001, JIS had three more standards introduced.

In fiscal year 2003, the Japan Electrical Manufacturers' Association (JEMA), and the National Institute of Advanced Industrial Science and Technology (AIST) started a new wind measurement program. The purpose of the program is to catch typical Japanese wind characteristics, such as turbulent intensity and gust, by observation with high-sampling time and then provide J-class wind models that can be used as design standards for wind turbines built in Japan.

Figure 12.4 A large wind farm in Japan

D. IEA Wind R&D

NEDO, AIST (MEL), Mie University (MU), and JEMA have started IEA international co-operations in Tasks XI, XV, XVII, and XVIII by presenting technical data.

NSS R,D&D and Demonstration Programs

Since 1999, METI has conducted two new R&D programs in order to meet the national target of 300 MW of wind power by 2010. Programs are needed partly because Japan has many severe external conditions such as typhoon attacks, high turbulence intensity, weak grids in remote areas and islands, and poor accessibility at hilly sites and islands. These two programs are as follows:

1. Advanced Wind Turbine Generating Systems for Remote Islands

Japan consists of hundreds of islands where electric power depends on expensive diesel power; however, Japan has plenty of wind resources. Since 1999, NEDO has been conducting a national R&D project titled, Development of Advanced Wind Turbine Systems for Remote Islands.

METI and NEDO developed a prototype, 100-kW turbine for remote islands where there may be severe external conditions such as typhoon attacks, high gusts, poor accessibility, lack of large cranes, and weak grids.

The following targets of this project were successfully achieved:

- Among small islands, the COE of wind can be cheaper than that of diesel, amounting to 30.00 yen/kWh to 100.00 yen/kWh

National Activities	Period	Organization/Institute
A. New sunshine project (R, D&D):	**1978-**	**METI (NSS-HQ, MITI)**
(1) Wind resources measurement	**1990-1994**	**NEDO**
(2) R&D of LS-WTGS (500kw) on tappi cape	**1990-1997**	**NEDO/MHI/Tohoku EPC**
(3) Demonstration of a mw-class wind farm on miyako island	**1991-1998**	**NEDO/Okinawa EPC**
(4) Generic, innovative R&D	**1978-**	**AIST (MEL)**
(5) Advanced WTGSS for remote islands	**1999-2003**	**NEDO**
(6) Local area wind energy prediction model	**1999-2003**	**NEDO**
B. Demonstration programs		
(1) Research on stabilization of output power from WTGSS.	**2000-2001**	**NEDO**
(2) Research on stabilization of output power from a WTGSS with storage batteries	**2000-2001**	**NEDO**
(3) Research on stabilization of output power from wind farm with storage batteries	**2003-**	**NEDO**
C. Promotion of introduction:	**1992-**	**METI (MITI)/NEDO**
(1) Field test program		
(2) New energy business support		
D. Standard: IEC, ISO, JIS	**1988-**	**METI/JEMA/AIST/ Industries**
E. IEA Wind R&D	**1978-**	**METI, AIST, MU, JEMA**

Table 12.2 National wind energy activities

• Demonstrations show that design power quality can be maintained at a maximum of 40%

• On islands where large cranes are not available, turbines can be easily constructed using a 16-ton crane and a gin pole unit

• Turbines are designed to be safe for up to 80 m/s of extreme wind speed under typhoon attacks

2. Local Area Wind Energy Prediction Model (LAWEPS)

This computational fluid dynamics (CFD) model is applied to Japanese complex terrain with high accuracy in predicting local wind flows. Figure 12.5 shows the nesting structure employed by the CFD model, and the wind atlas from the first to the third nesting stage can be seen publicly on NEDO's website. The final fifth stage has a 10-m mesh resolution, and the CFD solutions for the fourth and fifth nesting stages can be obtained by running LAWEPS code, which is also publicly available.

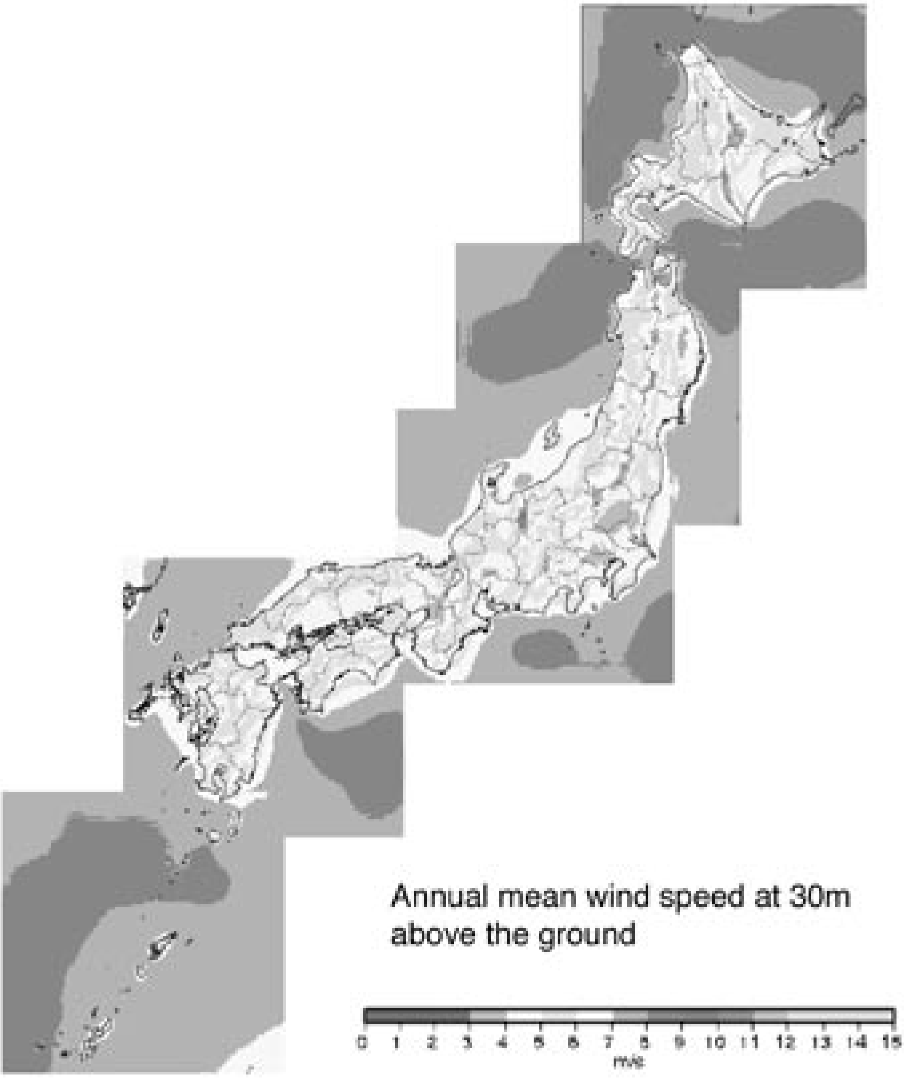

Figure 12.5 Annual mean wind speed at 30 m above ground level (first nesting level: 500-m mesh)

Figure 12.6 shows the results of a comparison between measured annual mean wind speed and those predicted by CFD models at a height of 30 m above ground level. LAWEPS gives the highest prediction.

Author: Hikaru Matsumiya, Chief Researcher, AIST, Japan

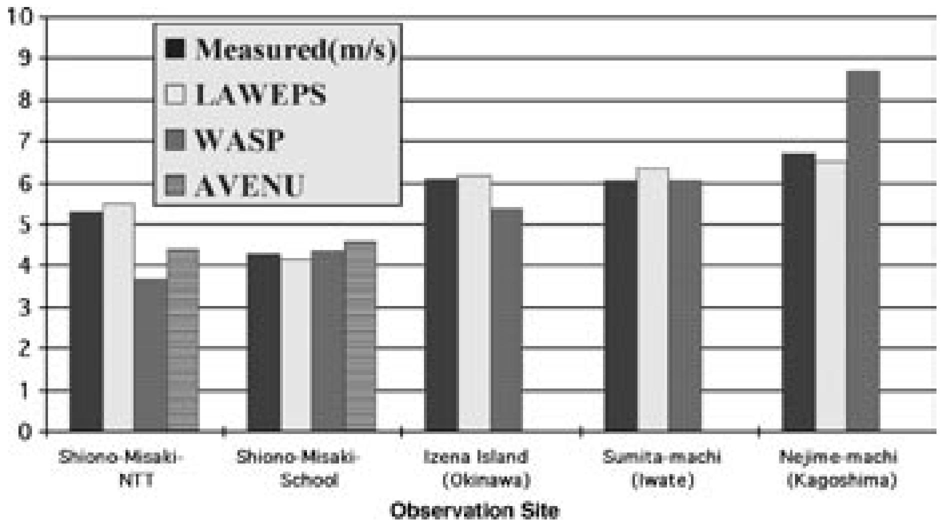

Figure 12.6 Comparison between measured annual mean wind speed and those predicted by CFD models at 30 m above ground level

Chapter 13
Mexico

13.1 INTRODUCTION

Estimates indicate that Mexico's most viable wind resources would be sufficient for the installation of 3,000 MW to 5,000 MW of wind power. These figures are based on rough regional estimates – detailed evaluations of wind resources have yet to be carried out. Other sources indicate that there are many areas in the country with moderate wind resources that could eventually be efficiently tapped using improved wind turbine technologies. Based on the experiences of other countries, it is reasonable to expect that extensive exploration and improved wind-speed measurements throughout the country will result in higher estimates of Mexico's wind energy potential.

Mexico's largest wind energy resource is found in a sizeable region (about 3,000 km^2) known as La Ventosa, located in the Isthmus of Tehuantepec in the state of Oaxaca (Figure 13.1). Average annual wind speeds in this region range from 7 m/s to 10 m/s, measured at 30 m above the ground.

Estimates show that up to 2,000 MW of wind power could be commercially tapped in La Ventosa, given the favorable characteristics of this region, particularly its topography. In fact, a 1.6-MW pilot plant, located in one of the best sites in the region (La Venta), has operated at an average capacity factor of approximately 38% for six-and-a-half years. This compares favorably to wind power plants located in the best inland sites in the world. However, implementation of wind power in Mexico remains incipient and inconsequential due to the existence of a large number of barriers.

Jointly, a number of actors from the public and private sectors are carrying out a number of actions to remove these major barriers. At the end of 2003, the Global Environment Facility, through the United Nations Development Programme (GEF-UNDP), approved a project titled, Action Plan for Removing Barriers to the Full Scale Implementation of Wind Power in Mexico.

13.2 NATIONAL POLICY

Both the energy and the environmental policy makers in Mexico consider that wind energy could be a realistic way for diversifying energy supply within a sustainable development framework. The National Development Plan and the Energy Sector Program take into account the promotion of wind energy. On the other hand, energy supply in Mexico is aimed at securing projected economic development. Therefore, both the energy and the environmental ministries are coordinating actions to establish a shared vision concerning common goals and challenges, with global climate change among the main concerns.

National consumption of electricity is expected to increase at an average annual rate of 5.6% for the period 2003 to 2012. This growth results in a projected requirement of 298 TWh of electricity generation for 2012, representing an increase of 124 TWh and equivalent to 28.2 GW of additional new generating capacity. Of this, 12.1 GW is already under construction or planned, the majority of which uses combined-cycle, gas-turbine technology, in addition to several new hydro

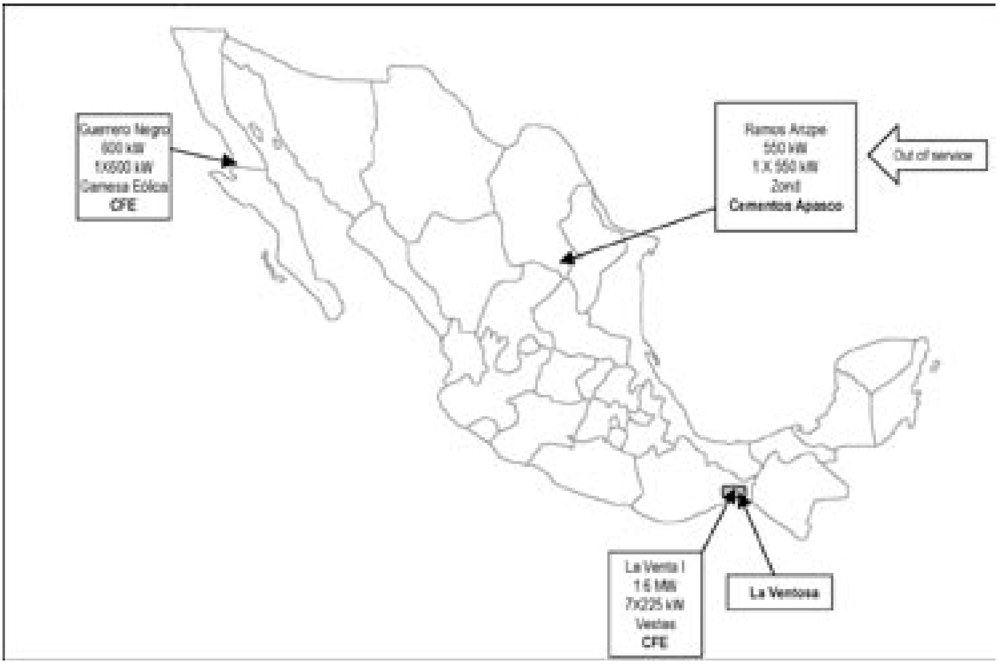

Figure 13.1 Locations of wind turbines installed in Mexico as of December 2003

and geothermal plants. The remaining 16.1 GW will come from new projects, with an expected 2.4 GW to be built for self-supply within both the private and public sector. An opportunity niche therefore exists for supplying a reasonable portion of the non-committed 16.1 GW of new capacity using Mexico's wind energy resource. Unfortunately, there are a number of barriers that have to be removed in order to have wind power development in Mexico become a reality.

Strategy

By the end of 2003, the Global Environmental Fund (GEF) approved the project Action Plan for Removing Barriers to the Full Scale Implementation of Wind Power in Mexico. This wind power action plan will begin in January 2004. Phase 1 of the project (2004 to 2005) will launch a comprehensive and systematic effort to reduce identified barriers to wind energy development, beginning with a coordinated initiative aimed at revising the institutional and regulatory frameworks affecting on-grid wind power development. An educational campaign, geared towards raising awareness of the benefits of wind energy among government officials, will be carried out simultaneously.

Technical information and human resource barriers will be addressed through the creation of a Regional Wind Technology Center. At this center, local technicians and engineers will obtain hands-on experience in the operation of wind turbines. Wind energy equipment will be assessed for operation under local conditions, and international standards and best practices will be adapted and applied for Mexico.

A preliminary assessment and mapping of wind energy resources at the most promising sites in the country will also be carried out as part of Phase 1, in order to obtain the wind resource data essential for the development of commercial projects. A set of comprehensive feasibility studies will also be completed in Phase 1, in conjunction with any required preparatory activities – all geared towards the formulation of business-demonstration wind power plants.

Matching the wind power action plan, special attention will be placed on the implementation of the Clean Development Mechanism as an important element for improving economic feasibility of wind power projects. Phase 2 of the action plan (2006 to 2008) will launch a competitive bidding process for three prototype projects that could be supported with GEF resources to emulate temporary production incentives. Next, the technical and economical performance of commercial wind power plants will be monitored and documented; suitable financial mechanisms will be established; and a national campaign – based on lessons learned, best practices, and specialized human resources – will be launched aimed at consolidating a sound wind-power market.

The action plan will be an important first step that will pave the way to a complementary project known as the Large Scale Renewable Energy Development Project, currently under the consideration of the Global Environmental Facility from an initiative of the Ministry of Energy and the World Bank.

Progress Towards National Targets

Until recently, the federal government has not stated any specific national target regarding wind power capacity to be installed. Nevertheless, officials are talking about a strategic goal of 1,000 MW to be completed within the next five years.

13.3 COMMERCIAL IMPLEMENTATION

The total installed capacity of wind turbines in Mexico remains at 2.2 MW, with no additional capacity installed during 2003. 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. Trends are unpredictable. Although a number of wind project developers are trying to move forward, several barriers are holding back the initiatives. Frequently, almost all project developers affirm that they will soon start construction of their respective projects. Starting dates, however, continue to be delayed.

13.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

In September 2001, the federal government, through the Regulatory Energy Commission, 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 certain periods can be credited to compensate for the electricity extracted from the grid during a different period. The interchange is allowed on the basis of 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 improves the economic feasibility of some self-supply wind power projects, especially those for municipal public lighting, where a considerable quantity of electricity could be generated during the daylight period when no electricity is required. Furthermore, previous to this incentive, electricity transmission charges for a renewable energy self-supply project were computed on the basis of its rated capacity; today these charges are reduced to the power plant capacity factor level. The new model of agreement is expected to facilitate some self-supply wind power projects that have been waiting for better regulatory conditions for years. Unfortunately, two years have passed since the incentive was issued, and there are still no projects under this modality.

13.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

There were no additional wind turbines installed during 2003. The number of wind turbines installed in Mexico is eight (Table 13.1).

Operational Experience

During 2003, electricity production from the La Venta wind power station was 4.97 GWh. The facility operated at an annual capacity factor of 36%, and its overall availability was 99%. (Reported by Eng. Carlos Garcia Aguilar, General Manager of La Venta Wind Power Station.)

Data from previous years revealed that the 600-kW wind turbine installed at Guerrero Negro operated at a capacity factor of 25%. Annual average wind speed at this site is around 8 m/s at 50 m above ground. However, performance data for the year 2003 was not released.

Main Constraints on Market Development

The main constraints on wind power market development in Mexico are as follows:

1. The current regulatory framework does not promote the commercial development of wind power
2. Electricity for the industrial sector is subsidized
3. 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
4. A national program for wind power implementation does not exist
5. Specialized human resources on the subject do not exist
6. Financial mechanisms do not fit

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**	**2.2**		

(1) Cementos Apasco (Cement factory).

(2) By mid 2002 this machine went into flames.

Table 13.1 Wind turbine installations in Mexico at the end of 2002

13.6 ECONOMICS

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 13.2 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.

13.7 INDUSTRY

A 5-kW 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. According to the status of Mexican industry, a number of wind turbine components – including towers, generators, gears, conductors, and transformers – could all be manufactured in Mexico using existing infrastructure.

Sector	Average price (Mexican Pesos/ kWh)
Industrial	0.539
Agricultural	0.313
Residential	0.607
Commercial	1.318
Public services	1.135

Table 13.2 Average price for electricity in Mexico by sector

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.

13.8 GOVERNMENT-SPONSORED R,D&D

In 1994, the La Venta 1.6-MW wind power plant was the first demonstrative project sponsored by the Mexican government. Next, a 600-kW wind turbine was installed at Guerrero Negro in 1998. The Federal Electricity Commission operates both of these projects. During 2003, the Mexican government did not sponsor the construction of any additional wind power facility for demonstration or local capacity building.

Under the auspices of the Ministry of Energy, the Electrical Research Institute is in charge of the formulation and execution of an Action Plan for Removing Barriers to the Full Scale Implementation of Wind Power in Mexico. This plan includes the construction and operation of a Regional Wind Technology Center, which aims to offer the following provision:

1. Support to interested wind turbine manufacturers for the characterization of their products under 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 the encounter between wind 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

Furthermore, major concerns exist because wind data currently available in Mexico is scarce (except for few sites), and therefore wind energy resources in several promising areas have not been evaluated. In addition, planning the adequate deployment of wind power at the national level is considered as a primary requisite to create a sound wind power market instead of a rushed and problematic one. Therefore, the action plan to open a wind power market in Mexico will be focused on removing regulatory and economic barriers because the Electrical Research Institute and associated parties will comprehensively address local capacity building.

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Chapter 14
The Netherlands

14.1 INTRODUCTION

In 2003, the net increase in installed capacity in the Netherlands was 227 MW, bringing the total installed capacity to 905 MW.

In 2003, various changes in the financial framework for renewable energy stimulation were announced and implemented through government legislation. Support and incentives are gradually changing from demand stimulation to production stimulation between January 2003 and January 2005.

Also in 2003, the Ministry of Economic Affairs started the project, Connect 6000. The objective of the project is to develop a vision to integrate 6,000 MW of offshore wind power into the Netherlands electricity grid and to clarify the responsibilities; tasks; and authority of the government, TenneT (the national transmission system operator), and market parties. The technical background studies include: available areas and costs for installation of offshore wind farms, consequences for the land-based electricity grid, and possibilities for an electricity grid at sea.

On 4 July 2003, the Minister of Economic Affairs – as well as sub-secretaries of state from the Ministries of Transport, Public Works, and Water Management and the Ministry of Housing and the Environment – informed Parliament about their plans for wind energy offshore. They established the main points of a concession regime for wind farms at the North Sea, after the first consultation with offshore market parties.

Baseline measurements for the environment on behalf of the government for the Monitoring and Evaluation Program of the Near Shore Wind Farm (NSW) for birds, fish, sea-mammals, and sea-bottom organisms were started and first results obtained.

14.2 NATIONAL POLICY

The government policy for renewable energy was revised in 2001. Wind and biomass energy are now priorities and are supposed to give the greatest contributions to the 2020 target. The realization of 6,000 MW installed wind capacity offshore is considered possible and necessary. The targets are summarized in Table 14.1.

Targets	2005		2010				2020			
	%	TWh	%	PJ	TWh	MW	%	PJ	TWh	MW
Energy from RE			*5*	150			*10*	300		
Electricity from RE	*6*	6.5	*9*		10.6					
Possible from wind				20	3.5	*1,500*		130	22.4	*7,500*

Table 14.1 Targets are in italic. Percentages are renewable energy of national energy or electricity; avoided fossil fuel in petajoules (PJ)

Strategy

The government will create the conditions to reach its targets through various instruments that facilitate demand for renewables. The government instruments s include fiscal incentives and financial instruments, spatial planning, research programs, a competitive green market, administrative agreements, R&D programs, carbon dioxide reduction subsidies, and joint implementation mechanisms.

Progress Towards National Targets

In 2002, about 1.5% of national energy consumption was provided by renewable energy, mainly from biomass and wind. Renewable electricity generation was 3,600 GWh, about 3.4% of the total national electricity consumption. Estimated 2003 renewable energy generation was 3.9% of the total national electricity consumption.

14.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

A total of 185 turbines were installed during 2003, with a total capacity of 234 MW – and 45 turbines, with a total capacity of 7.3 MW, were removed. This brings the total installed capacity at the end of 2003 to 905 MW. The final numbers for 2002 show a total increase in operational capacity of 192 MW. During the years 1985 through 2003, the total capacity of installed turbines was 964 MW, and the total removed capacity was about 60 MW. (Figure 14.1)

Rates and Trends in Deployment

The net increase installed capacity in 2003 of 227 MW is twice as much as in the record year, 1995. The average installed capacity per turbine decreased slightly from 1,306 kW in 2002 to 1,266 kW in 2003, mainly due to the large amount of wind turbines installed in small projects. The average hub-height decreased slightly from 66 m in 2002 to 61 m in 2003. This change is mainly due to the large amount of wind turbines installed in projects with one or two wind turbines in the range of 600 kW to 950 kW.

The installed swept-area-per-unit of power decreased slightly from an average value of 2.5 m^2/kW during the years 1994 through 2001, to 2.27 m^2/kW in 2002 and 2003. This change is mainly caused by the larger projects with Vestas V66, Enercon E66, and Nordex N80 turbines, which have a lower swept area. (Figure 14.2)

Contribution to National Energy Demand

Total national electricity consumption in 2002 was 106,815 GWh. Wind provided 910 GWh of electricity, which is about 0.8% of the total. In 2003, total national consumption is expected to be 110,241 GWh, with wind providing 1,610 GWh, or about 1.46% of the total (Table 14.2). The increase from 910 GWh to 1,610 GWh is mainly due to the large increase in installed capacity in 2002 and 2003. In a normal wind year, the installed capacity of 905 MW can generate about 1,900 GWh of electricity.

14.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The history of support initiatives and market stimulation instruments, including fiscal incentives, can be found in the Netherlands's annual reports for 1999, 2000, 2001, and 2002. Information about the competitiveness of prices can be found online at http://www.greenprices.com.
At the end of 2003, there were about 2.2

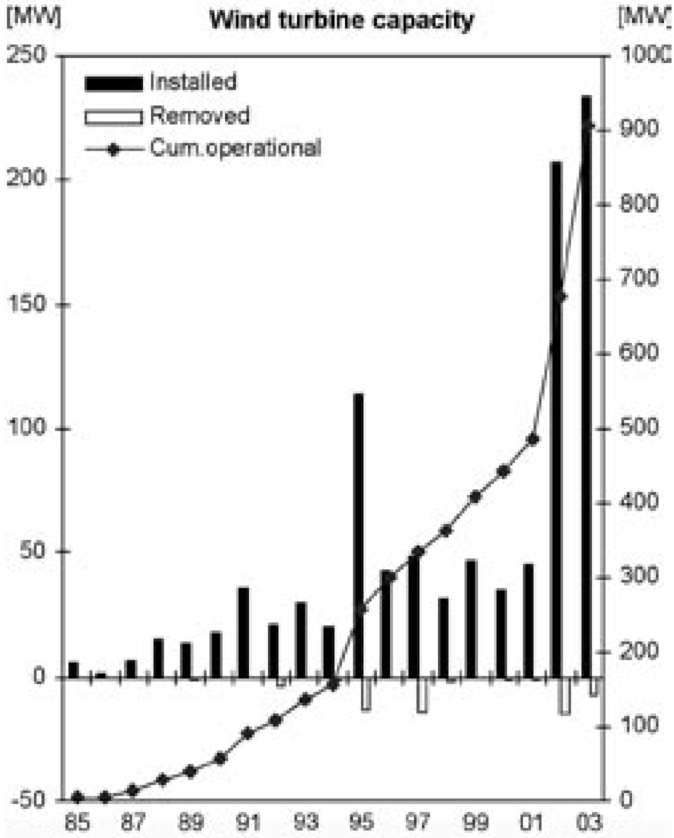

Figure 14.1 Installed, removed, and operational wind capacity in the Netherlands

million households that bought renewable electricity at the same price as grey electricity.

In 2003, various changes in the financial framework for renewable energy stimulation were announced and implemented through government legislation. Support and incentives are gradually changing from demand stimulation to production stimulation between January 2003 and January 2005. The following paragraphs summarize government legislation during this period.

Government legislation up to 1 January 2003 is outlined in the first section of Table 14.3; the information is taken primarily from the 2002 annual report.

Intermediary legislation existed from 1 January 2003 to 1 July 2003. Green energy for end users was no longer fully exempt from the ecotax of 0.0639 euro/kWh (REB 36i), but was taxed 0.029 euro/kWh. The production incentive of 0.02 euro/kWh was cancelled (REB 36o) for hydro energy, foreign wind, and biomass electricity imports. The incentive was adjusted for inflation to 0.0207 euro/kWh. The yearly budget for the Energy Investment Deduction (EIA) was decreased, but wind was still eligible. Energy investments were no longer eligible for Free Depreciation (VAMIL), and

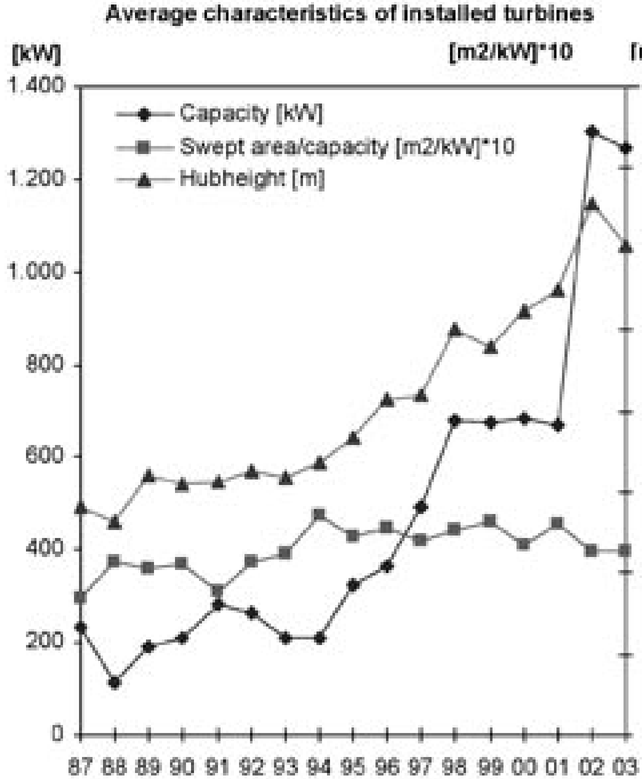

Figure 14.2 Average characteristics of installed turbines

the tax exemption for interest from green funds for investors changed slightly.

Legislation from 1 July 2003 until 1 January 2004 canceled the intermediary legislation and the production incentive of 0.0207 euro/kWh (REB 36o). A new governmental scheme, Environmental Quality Electricity Production (Milieukwaliteit Elektriciteits Productie, or MEP) was introduced.

Under MEP, producers of green electricity in the Netherlands receive a fixed subsidy per kilowatt-hour for wind for ten years, to a maximum of 18,000 full-load hours. The effect is like an investment subsidy for investors in renewable energy. The MEP subsidy differentiates between energy sources and takes into account unprofitable top-of-the-investment and avoided carbon dioxide emissions. Only "new" installations – those built after 1 January 1996 – are eligible for MEP subsidies. The MEP onshore subsidy in 2003 was 0.0495 euro/kWh; for offshore, it was 0.0685 euro/kWh. The subsidies will be paid from an MEP fund, which will hold 141 million euro in 2003, 164 million euro in 2004, 181 million euro in 2005, and 199 million euro in 2006 for renewable energy.

The MEP fund is financed through an MEP surcharge on all customers' bills. The surcharge will be determined every year – in 2003 it was 34.00 euro. The customer will be compensated from the surcharge through a lower income tax. Producers sell their electricity to TenneT, the national transmission system operator.

Year	Wind generated electricity	Primary energy savings	National electricity consumption
	GWh	PJ	GWh
1985	6	0.05	
1986	7	0.06	
1987	14	0.12	
1988	32	0.26	
1989	40	0.33	
1990	56	0.46	
1991	88	0.73	
1992	147	1.21	
1993	174	1.43	
1994	238	1.97	
1995	317	2.62	85,641
1996	437	3.61	88,665
1997	475	3.92	92,000
1998	640	5.28	95,421
1999	645	5.33	97,549
2000	829	6.85	100,604
2001	825	6.82	103,495
2002	910	7.51	106,815
2003	1610	13.32	110,241
* 2003 numbers have been estimated			

Table 14.2 Wind-generated electricity, avoided fossil fuel, and national electricity consumption

Additional legislation will be implemented, beginning 1 January 2004. In September 2003, the government announced in the state budget that demand stimulation through exemption of ecotax has worked, and 1.8 million households in the Netherlands buy green electricity. On the other hand, this has not created enough generating capacity in the Netherlands, and green electricity is being imported and taxpayer money is leaking abroad. The government expects that the MEP scheme will create a higher demand for generating capacity.

The government proposes to further decrease demand stimulation through the exemption of ecotax (REB 36i) to 0.015 euro/kWh by 1 July 2004 and to 0.00 euro/kWh by 1 January 2005. Table 14.3 gives an overview of the financial framework for RE stimulation. And Table 14.4 shows the gradual change in payback rates for wind energy shifting from ecotax (REB 36i) to MEP subsidies.

Unit Cost Reduction

Reliable statistical data for 2003 do not exist; however, data from the Dutch Wind Energy Association, published in 2002, provide a breakdown of investment cost and operation and maintenance (O&M) cost for typical small projects. The project costs are 1,119.00 euro/kW, with 944.00 euro/kW for turbines. O&M costs are 38.00 euro/kW, or 3.43% of the investment. (Table 14.5)

14.5 DEPLOYMENTAND CONSTRAINTS

Wind Turbines Deployed

Of the wind turbines installed in 2003, 52% are from Vestas. For the first time, Enercon has a relatively large share in the Dutch market, with 26%. A new turbine type for 2003 was the NEG-Micon NM 2.75-MW, 92-m machine. (Table 14.6)

Nine wind farms, with an installed capacity higher than 10 MW, were installed in 2003. The largest wind farm is 21 MW, with 12 Vestas 1.75-MW, 66-m diameter turbines at Ooltgensplaat. The second largest wind farm has 10 Enercon 1.8-MW, 70-m diameter turbines at the Meeuwentocht near Lelystad in the province of Flevoland. This province houses 381 MW, of which 126 MW were installed in 2002, and 106 MW were installed in 2003, which is almost half of the total installed wind capacity in the Netherlands (905 MW). Additional details are noted in Table 14.7, and more project information can be found at http://home.wxs.nl/~windsh/nwturtab03.html.

		Before January 1, 2003		From July 1, 2003		From January 1, 2004	
	Name	Instrument	Effect	Instrument	Effect	Instrument	Effect
Investment support	EIA	Deduction of 52% of investment on company income	18% cheaper investment, about 1.1 eurocent/kWh	Continued	Same	Continued	Same
	VAMIL	Free depreciation of investment	9% cheaper investment, about 0.6 eurocent/kWh	Discontinued	Decrease in investment support	Discontinued	Decrease in investment support
	Green Funds	Exemption of tax on interest on provided capital	1% to 2% point cheaper capital for wind investors, about 0.5 eurocent/kWh	Continued under slightly different conditions	Unknown, but probably less cheap capital	Continued under slightly different conditions	Unknown, but probably less cheap capital
Production support	REB (36o)	Feed back ecotax 2 eurocent/kWh on top of basic feed back rates; foreign imports possible	Fixed income for producers on top of basic feed back rates for avoided costs	Discontinued	Foreign imports less attractive	Discontinued	Foreign imports less attractive
	Green certificates	Certification of green electricity, also foreign	Free trade of green certificates	Continued	Same	Continued	Same
	MEP			Fixed for 10 years, wind on land 4.95 eurocent/kWh, wind off shore 6.85 eurocent/kWh, max 18,000 h (on top of basic feed back rate)	Risk profile investors improved, through fixed income per kWh produced	Fixed for 10 years, wind on land 4.95 eurocent/kWh, wind off shore 6.85 eurocent/kWh, max 18,000 h (on top of basic feed back rate)	Risk profile investors improved, through fixed income per kWh produced
Demand stimulation	REB (36i)	Exemption from ecotax (5.9 eurocent/kWh) for consumers of green electricity; compensation in income tax	Green has same price as grey; from the 5.9 eurocent/kWh an extra 3 eurocent/kWh is passed on to producers	Ecotax 6.39 eurocent/kWh; exemption 3.19 eurocent/kWh; compensation in income tax	Green has the same prices as grey; from the 3.19 eurocent/kWh an unknown amount is passed on to producers	Ecotax 6,39 eurocent/kWh; exemption 3.19 eurocent/kWh; compensation in income tax	Green has the same prices as grey; from the 3.19 eurocent/kWh an unknown amount is passed on to producers
	MEP			Surcharge of 34 euro in 2003 for all customers; compensation in income tax	MEP fund of 141 million euro in 2003 for payment of MEP-subsidies via grid operators	Surcharge of 36 euro in 2004 for all customers; compensation in income tax	MEP fund of 164 million euro in 2004 for payment of MEP-subsidies via grid operators

Eurocent/ kWh	Wind on land	Wind at sea
1-7-2003	*4.9* + 2.9 = 7.8	*6.8* + 2.9 = 9.7
1-1-2004	*4.8* + 3.0 = 7.8	*6.7* + 3.0 = 9.7
1-7-2004	*6.3* + 1.5 = 7.8	*8.2* + 1.5 = 9.7
1-1-2005	*7.7* + 0.0 = 7.7	*9.7* + 0.0 = 9.7

Table 14.4 MEP subsidies for wind energy (MEP + REB = total)

In 2003, 45 turbines were decommissioned. They had an average capacity of 160 kW and a total capacity of 7.3 MW. Most of them were Lagerwey 80-kW, 18-m diameter machines. Of these decommissioned turbines, 35 turbines (with a capacity of 5.7 MW) were replaced with 32 turbines with a total capacity of 26.5 MW. The net re-powering effect was 20.8 MW.

Operational Experience

There were no major incidents or accidents in 2003.

Main Constraints on Market Development

Spatial Planning and Support

The main challenge in the Netherlands for onshore wind remains securing enough sites for wind turbines (i.e., spatial planning). Under the Administrative Agreement National Development Wind Energy (Dutch acronym, BLOW), each province has a target to designate locations for wind turbines, specified in megawatts, before 2005. The agreement is aimed at realizing 1,500 MW of wind capacity on land by 2010.

Spatial planning support is also a challenge in the Netherlands. The Netherlands Agency for Energy and the Environment (Novem) has formed a so-called BLOW Expert Pool of certified independent consultants to assist provinces and local councils (that do not have sufficient expertise) with activities to establish regional and local spatial planning for wind. Up to half of the costs – to a maximum related to the amount of megawatts of the wind farms to be realized – are subsidized by Novem.

Under the BLOW agreement, each province has submitted its action plan to designate locations for wind turbines. On a lower level, several regions in various provinces are concluding wind agreements this year to designate locations with a total capacity of 140 MW. Table 14.8 outlines progress towards BLOW targets per province.

◄

Table 14.3 Financial framework for renewable energy stimulation

Unit costs wind farms 2003	
Break down investment costs	**Euro/ kW**
Turbines including foundation and transformer	**944**
Grid connection and farm cable	**51**
Roads, etc.	**21**
Plan development	**52**
Contingency (5%)	**51**
TOTAL investment	***1,119***
Break down O&M costs	
O&M contract	**15**
Insurance	**3**
Grid costs (fixed and system costs)	**4**
Lease	**9**
Management costs (0.2%)	**2**
Property tax (0.25%)	**3**
Contingency (10%)	**3**
TOTAL O&M costs	***38***
O&M cost as percentage of project investment	**3.43%**

Table 14.5 Unit costs for wind farms in 2003

Manufacturer	Turbines	Installed		Rotor area
		MW	%	m²
Vestas	100	120.8	52%	275,947
Enercon	33	60.0	26%	122,343
NEG-Micon	34	33.2	14%	80,283
General Electric	9	13.5	6%	34,636
Lagerwey	8	6.0	3%	16,343
Bonus	1	0.6	0%	1,521
Total	185	234.1	100%	531,073

Table 14.6 Distribution of new wind turbines by manufacturer

Offshore Concession Regime

On 4 July 2003, the Minister of Economic Affairs – as well as sub-secretaries of state from the Ministries of Transport, Public Works, and Water Management and the Ministry of Housing and the Environment – informed Parliament on their plans for wind energy offshore. They established the main points of a concession regime for wind farms at the North Sea, after a first consultation with offshore market parties.

The initial idea to use designated areas for offshore development has been abandoned. However, developers will be able to apply for planning consents for the entire Netherlands Exclusive Economic Zone (NEEZ), with the exception of areas such as shipping lanes and military practice zones. A planning consent grants the exclusive right to apply for a building permit on the basis of the law, *Management of Water State Activities* (Wbr), which will be adapted as the legal base for a concession regime.

Applicants must meet certain conditions and can apply for a planning consent for a maximum area of 50 km^2. The area for which a planning consent is granted is reserved exclusively for wind farms, and any other use of the area will be rejected. The government is preparing rules for planning consent, which should add as little time as possible for building permit granting procedures. These rules include a mandatory Environmental Impact Assessment and submission of a building permit application under the Wbr within a year. The government strives for the implementation of the concession regime in 2004.

Detailed information about the Dutch concession regime, as well as planning consents, are available online at http://www.offshorewind.nl.

Offshore Grid Integration

The Ministry of Economic Affairs is carrying out the project, Connect 6000, which maps technical and infrastructure conditions for the installation of offshore wind power. This project is a follow-up to the project, Survey of Integration of 6,000 MW Offshore Wind Power in Netherlands Electricity Grid in 2020. The objective of Connect 6000 is to develop a vision on the integration of 6,000 MW of offshore wind power in the Netherlands electricity grid and to clarify the responsibilities, tasks, and authority of the government, TenneT (the national transmission system operator), and market parties. Novem is consulting for the ministry on this subject and is conducting the

Wind farm > 5MW	Manufacturer	Turbines	Height	Diameter	Capacity	Swept area
			m	m	MW	m^2
Ooltgensplaat, WP Piet de Wit	Vestas	V 66 / 1.750	67	66	21.0	41,054
Lelystad, Meeuwentocht	Enercon	E 66 18.70	58	70	18.0	38,485
Rotterdam-Sufterdam-West	General Electric	GE 1.5 s	65	70	13.5	34,636
Wieringerwerf, Waterk.tocht	Vestas	V 66 / 1.650	78	66	13.2	27,370
Rotterdam, Hartelbrug-West	Enercon	E 66 - 20.70	85	70	12.0	23,091
Lelystad, Pijlstaartweg	Enercon	E 66 - 20.70	70	70	12.0	23,091
Zeewolde, Dodaars - Reigerweg	Vestas	V 52 / 850	37	52	11.9	29,732
Middenmeer, Groettocht	Vestas	V 66 / 1.650	78	66	11.6	23,948
Dronten, Ansjovistocht	Enercon	E 66 18.70	70	70	10.8	23,091
Middenmeer, Waardtocht	Vestas	4*V 66/1.750 en 1*V66/ 1.650	78	66	8.7	17,106
Dronten	Vestas	V 80 / 2.000	67	80	8.0	20,106
Swifterbant, Vuursteentocht	Vestas	V 80 / 2.000	67	80	8.0	20,106
Zeewolde, Grutto - Wulpweg	Vestas	V 52 / 850	70	52	7.7	19,113
Nieuwe Sluis, Ulketocht	Lagerwey	LW 51/750	55	51	6.0	16,343
Punthorst	Enercon	E 66 - 20.70	85	70	6.0	11,545
Various < 5MW	Danish/Dutch/ German	-	-	-	65.9	162,256
Total					234.1	531,073

Table 14.7 Size of wind plants installed in 2003

Province	Total 2003	BLOW Goal 2010
	MW	MW
Flevoland	381	220
Noord-Holland	149	205
Zuid-Holland	126	205
Fryslân	89	200
Groningen	62	165
Zeeland	57	205
Brabant	38	115
Overijssel	6	30
Drenthe	1	15
Limburg	1	30
Gelderland	1	60
Utrecht	0.2	50
Total	910	1,500

Table 14.8 Progress towards BLOW targets per province

necessary technical background studies with the help of ECN and KEMA.

A project team from the Ministry of Economic Affairs and Novem ordered a number of studies, which include the following issues:

1. Available areas and costs for installation of offshore wind farms
2. Consequences for the land-based electricity grid
3. Possibilities for an electricity grid at sea

Based on the studies, three possible scenarios were identified for the realization of 6,000 MW of offshore wind power in the Netherlands Exclusive Economic Zone (NEEZ):

1. A base scenario leading to 6,000 MW in 2020
2. A progressive scenario leading to 8,000 MW in 2020
3. A conservative scenario leading to 5,000 MW in 2020

The project team also looked at the international situation and the legal and ecological consequences.

The first study to identify available areas and costs for installation of offshore wind farms was carried out by ECN, which used its model, OWECOP. The study accounted for technical and economic aspects and the excluded areas for the NEEZ. Excluded areas included oil and natural gas exploration areas and shipping lanes. The point of departure was that connection to the grid on land would be at Maasvlakte and Beverwijk. Relative costs were determined, taking into account such issues as cable connection lengths, service harbor distances, and wind speeds. A strip of sea 25 km to 50 km from the coast appears to have the least expensive exploitable areas.

The study to determine the consequences for the land-based electricity grid was conducted by KEMA and is based on the former study carried out in 2002 (Survey of Integration of 6,000 MW Offshore Wind Power in Netherlands Electricity Grid in 2020). Connecting 6,000 MW of offshore wind power to the Netherlands electricity grid will make it necessary to reinforce the existing land-based electricity grid. The study examined which parts of the grid have to be reinforced in consecutive steps (of time and money) with increasing offshore wind power based on the three possible scenarios.

Total cost of reinforcements is estimated at 310 million euro. This can increase to 920 million euro if a part of these reinforcements have to be carried out underground (i.e., with cables). The preparations and implementation of these reinforcements may take of nine to fourteen years. (Table 14.9)

Figure 14.3 Wind farm Meeuwentocht in Flevoland

The study to determine the possibilities for an electricity grid at sea was also carried out by KEMA. It was meant to answer the question of whether or not it is desirable to design a part of the necessary electrical infrastructure "together" instead of using individual connections per wind farm. Four configurations were studied. They differ in use of alternating and direct current, number of cables, and costs. Although there are cost differences between individual connections and a grid at sea, it is too early to draw firm conclusions about the most economic configuration. Cable (laying) costs, especially, constitute a dominant cost factor that could not yet be accurately estimated. However, it seems that a grid at sea (i.e., bundling) is essential from the point of view of spatial planning and environment. (Table 14.10)

The three studies just discussed and the scenario study by Novem were integrated in the report, *Connect 6000 MW Scenarios Interim Report*, and published for consultation with interested and/or involved parties in November, 2003. After an update based on the findings of the consultation, the vision of EZ will be available in the first quarter of 2004. The full reports can be downloaded from the website http://www.offshorewind.nl.

14.6 ECONOMICS

Trends in Investment

Based on an average price of 1,119.00 euro/kW, the investment in 232 MW of new wind turbines totaled 260 million euro in 2003.

Trends in Unit Costs of Generation and Buy-Back Prices

Trends in unit costs of generation are unknown, mainly due to the commercially sensitive nature of unit costs. The total payback rate offered by energy companies for five- to ten-year contracts in 2001 was between 0.068 euro/kWh and 0.080 euro/

Reinforcement		Wind power limit without reinforcement	Costs HV-lines	Costs with 30% cable
Landfall	**Trajectory**	**MW**	**Million euro**	**Million euro**
Beverwijk	**Oostzaan-Diemen**	**500**	**48**	**114**
	Beverwijk-Oostzaan	**1,500**	**60**	**176**
	Diemen-Lelystad	**1,500**	**95**	**313**
	Lelystad-Ens	**3,000**	**29**	**79**
Maasvlakte	**Krimpen-Geertruidenberg**	**1,500**	**78**	**236**
Total			**310**	**918**

Table 14.9 Order of trajectories, reinforcement capacity, and investments for the land-based electricity grid

		150 kV	380 kV	VSC	HVDC	Individual
Maximum cable length	**km**	**>30**	**30**	**>140**	**>140**	**>30**
Maximum power	**MW**	**500**	**500**	**500**	**>1000**	**500**
Module size	**MW**	**500**	**500**	**500**	**1000**	**100**
Maximum number of cables for landfall	**Beverwijk**	**42**	**15 of 5x3**	**14**	**6**	**25**
	Maasvlakte	**30**	**21 of 7x3**	**10**	**4**	**35**
Costs	**Million euro**	**2.6**	**2.5**	**3.2**	**2.9**	**2.1**

Table 14.10 Preliminary cost estimates for a grid at sea in various configurations

kWh. No numbers are known for 2002 and 2003, mainly due to the commercially sensitive nature of the contracts. The payback rate under the MEP is reported in Table 14.4. MEP subsidies wind energy (MEP + REB = total).

14.7 INDUSTRY

Manufacturing

In May 2003, the activities of Lagerway for the 2-MW, 70-m turbine were sold to Zephyros, which is a new company run by former employees and management from Lagerwey. Zephyros is owned by the Triodos Bank and BVT, a German wind farm developer. Lagerwey went bankrupt at the end of September 2003, and assets of its 750-kW technology are being sold to the highest bidder.

Industry Development and Structure

NEG-Micon has built a prototype of the 2.75-MW, 92-m turbine at ECN's test site in the Wieringermeer. Here, it will be put to extensive testing before this turbine type will be used in the NSW. More information about ECN's test site can be found at http://www.ecn.nl/wind/products/mmt/index.en.html.

ECN also ordered five Nordex 2.5-MW, 80-m turbines to be placed on the production part of its test site. The investment costs are 11 million euro. These turbines will be among others used in the project, validation measurements of turbulence, wakes and of extreme fatigue loads at the ECN Wind Turbine Test Farm Wieringermeer, and the project, field experiment and development of acoustic-optic registration of bird collisions on wind turbines.

ECN and Delft Technical University (TU Delft) have built a new test facility for their new joint venture, Wind Materials and Construction Group, about 5 km north of the ECN test site. The facility is located at a small harbor, which enables water transport of large blades. Wind turbine blades up to a length of 70 m will be put to extreme fatigue load tests in this facility. More information is available at http://www.wmc.citg.tudelft.nl/index.html.

14.8 GOVERNMENT-SPONSORED R,D&D

In 2001, 2002, and 2003 Novem carried out the Renewable Energy Programme, in which all renewable options compete for subsidy in a tender process.

Priorities

The Netherlands R&D-strategy Wind Energy 1999-2003 (NRW) was still the background for the research programs of ECN and TU Delft in 2003. Priority subjects are as follows:

New developments – Offshore, innovative materials, and recycling
Testing and measuring – Condition-monitoring systems and wind turbine test facilities
Databases – Wind turbine and component failure
Design tools – Reliability, wind turbines, control, and aerodynamics

New R,D&D Developments

Several contracts were awarded under the Novem renewable energy program. In 2002, Novem carried out the Renewable Energy Programme, in which all renewable options compete for subsidy in a tender process. From the 22 million euro subsidy, about 4.2 million euro was allocated to the following wind energy projects, with total project costs of 10.6 million euro:

1. Database on Wind Characteristics, IEA Wind Annex XVII
2. Standards for Offshore Wind Turbines, contribution to IEC TC88
3. FYNDFARM, computer program for design and optimization of wind farms with regard to fatigue loads and sound emission from wakes
4. Extrapolation of extreme external loads
5. IEA Wind Annex XX: Analyse NASA-Ames Wind Tunnel Measurements
6. CONMOW: Condition Monitoring of Offshore Wind Farms
7. STABCOM: Aeroëlastic Stability and Control of Large Wind Turbines
8. Field experiment Offshore Access System
9. Detailed offshore wind resource map for the Netherlands North Sea
10. ERAO-3, IEA Wind Annex XXI verification of electric and control aspects of offshore wind farms
11. Fibre Optic Blade Monitoring
12. Design of high hybrid towers of concrete and steel for wind turbines
13. Field experiment and development of acoustic-optic registration of bird collisions on wind turbines at ECN test wind farm
14. SIROCCO, design procedures for silent rotors
15. BLADKNIK, improved predictions for buckling of rotor blades

Figure 14.4 NEG-Micon 2.75-MW turbine at the ECN test site

Photo courtesy: Jaap 't Hooft, Novem

16. Real-time Process Simulator for Wind Turbines, Phase 2
17. Validation measurements of turbulence, wakes and of extreme fatigue loads at the ECN wind turbine test farm Wieringermeer
18. ACCUWIND, tools and methods to improve the accuracy of cup and sonic anemometers

From the 2003 budget, only the projects of the first tender have been allocated. From a total of 8 million euro for renewables, 1.8 million euro was awarded to the following wind research projects, with total costs of 3.1 million euro:

1. Heat and flux turbine control, to enhance output of large wind farms
2. Heat and flux turbine fundamental theory, to enhance output of large wind farms
3. Controlling wind tunnel experiments, to enhance output of large wind farms
4. Technical development of the RailWind turbine concept
5. Fibre Optic Blade Monitoring, Phase III
6. Field experiment with innovative direct-drive wind turbine control
7. Field experiment and development of acoustic-optic registration of bird collisions on wind turbines at ECN test wind farm

Summaries in Dutch of the project proposals can be found at http://www.den.novem.nl/ under Gehonoreerde BSE-projecten, Windenergie.

Offshore Siting

NSW Demonstration, Monitoring, and Evaluation Program

The Near Shore Wind farm (NSW) is a 100-MW demonstration wind farm supported by the government of the Netherlands. It will be built by a consortium consisting of Shell Wind Energy and NUON Renewables near Egmond aan Zee. The wind farm will be built 8 km to 15 km from the coast in 15-m to 20-m deep water. It will use 36 NEG-Micon 2.75 MW, 92-m turbines, built on a monopile. Erection of the wind farm is expected in 2005. The monitoring and evaluation program (MEP-NSW) defined the required and recommended measurements to be carried out in the areas of (1) technology and economy and (2) nature and environment.

In September 2003, the consortium NoordzeeWind submitted the Environmental Impact Statement for the wind farm, which serves also as the application for the building permit under of the law *Management of Water State Activities* (Wbr). This was the subject of a public hearing on 30 September 2003. Taking into consideration any concerns voiced until 16 October, the minister issued a draft building permit in November, which was available for public perusal within four weeks. The minister will publish the final building permit in March 2004.

In November 2003, the NSW consortium, NoordzeeWind, built the meteorological mast necessary to carry out all the planned measurements for wind and wave data. The mast has a height of 118 m above average sea level and is equipped with solar panels for energy supply (Figure 14.5).

NSW-MEP Project Organization

On the order of the government, Novem takes care of the project organization, NSW-MEP. The project organization guards and promotes the learning objectives. It reports results to the Ministry of Economic Affairs.

For the collection of data on nature and environment, Novem is collaborating with the State Institute for Coast and Sea (RIKZ), which is part of the Directorate North Sea of the Department of Traffic and Waterstate. NSW-MEP environmental baseline measurements on behalf of the government for birds, fish, sea-mammals, and sea-bottom organisms began 1 April 2003. The research work for these studies has been laid down in a strategy of approach, as described in the following paragraphs.

Baseline studies of birds will determine which species occur in what numbers on the site of the wind farm. For this, a distinction must be made by seasons, for spring or autumn migration, day/night, various weather conditions, migratory path widths, birds' flight patterns and intensity and height. Additionally, the measurements must occur at various distances from the coast (8 km and 12 km). Furthermore, specific quantitative data must be collected with regard to foraging behavior of coastal summer birds and resting birds.

The baseline studies for fish will have to answer three main questions: (1) What species of fish are found on the site and how many? (2) What is the level and nature of noise underwater in the situation without a wind farm? and (3) What is the sensitivity of fish to noise in order to be able to determine the interaction with noise and vibrations caused by turbines? The study on fish has been subdivided into two parts: Studies of demersal fish (benthic fish) and studies of pelagic fish (other fish).

As a baseline survey for benthos (organisms in and on the seabed), the occurrence,

Figure 14.5 Met mast NoordzeeWind

Photo courtesy of NoordzeeWind

density, and population structure must be examined. The first result of the baseline studies for benthos became available in December 2003.

The baseline study for marine mammals required by the national government consists of determining the occurrence of porpoises on the site of the wind turbine farm.

The other results of the baseline measurements on behalf of the government for birds, fish, sea-mammals, and sea-bottom organisms are expected during 2004. The NSW operator, NoordzeeWind, is responsible for collecting and supplying all the other data of the NSW-MEP. Initial measurements are expected in 2005. All background information and available data can be found at the website http://www.mep-nsw.nl.

References

- Duurzame Energie in Nederland, Bijdrage aan de energievoorziening 1990-2002 (Vaststelling 2002); Renewable energy in the Netherlands; Contribution to the energy supply 1990-2002; Final version, September 2003, Novem and CBS
- CBS Central Bureau of Statistics, publication Electricity Balance 1995-2001, 23 January 2003
- NEWIN, Toetsing uitgangspunten MEP-berekeningen, 14 November 2002

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Chapter 15
Norway

15.1 INTRODUCTION

In 2003, 3 MW of new wind energy capacity were installed in Norway. Interest is high for wind power as a commercial source of electricity – however, financing and public acceptance remain substantial hurdles to wind turbine installation. The electricity price increase in the Nordic electricity market in fall 2002 and winter 2003 heightened interest in energy in general, as well as somewhat in wind energy. However, since estimated long-term future electricity prices are still quite low, this situation in itself is not a strong enough incentive to spur new investments in wind energy.

15.2 NATIONAL POLICY

Strategy

The key features of Norwegian energy policy are: improved energy efficiency; more flexibility in the energy supply; decreased dependence on direct electricity for heating; and an increased share of renewable energy sources, other than large hydropower, in the energy supply mix.

The Norwegian parliament adopted the following national objectives in the spring of 2000:

1. Limit energy use considerably more than if developments were allowed to continue unchecked
2. 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
3. Install wind power capacity of 3 TWh by the year 2010
4. Increase environmentally friendly land-based use of natural gas

Progress Towards National Targets

The ambition of the Norwegian government is to have an annual electricity production based on wind energy of 3 TWh/yr by the year 2010, which represents approximately 1,000 MW installed capacity, at the average availability at the most favorable sites.
The total installed capacity in Norway is 100 MW, which normally represents a production of 300 GWh/yr.

Two projects, totaling 500 GWh, have received national grants and are under construction. The government has given grants to three other projects, with a total production capacity of 800 GWh. If all projects are carried out, Norway will reach approximately 50% of its national target of 3 TWh wind power production.

The Norwegian Water Resources and Energy Directorate (NVE) has done research work with regard to a green certificate market for Norway, and the report has been sent to the Ministry of Petroleum and Energy. The ministry will consider the conclusions from the report and decide whether or not Norway will implement a green certificate market.

Additionally, the governmental enterprise, Enova, has finished a repot study on several transition schemes to a green certificate market for Norway.

15.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The total installed capacity for Norway is 100 MW, with approximately 300 GWh of wind energy production per year. Two wind farms were commissioned during September and October 2002, which increased the total installed capacity from 17 MW to 97 MW in 2002.

The first wind farm consists of 20 turbines, each rated 2 MW. It is located at the western coast of Norway, on the island Smøla, and has an estimated energy production of 118 GWh/yr.The second wind farm consists of 16 turbines, each rated 2.5 MW. It is located close to the North Cape, near the town Havøysund, and has an estimated energy production of 120 GWh/yr.

An overview of the Norwegian wind turbines and the energy production in 2003 is shown in Table 15.1.

15.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

Enova, a governmental enterprise established in 2002, is empowered to be in charge of the Norwegian investment program for wind power, and a technology implementation program including wind technology.

Enova offers a maximum of 10% investment grants for new wind farms based on a maximum investment cost of 6,000.00 Norway Krone (NOK)/kW installed (694,000.00 euro/MW). Wind farm owners also received a production subsidy of 0.0475 NOK/kWh (5.49 euro/MWh) in 2003. The Norwegian parliament decides this premium price annually. The production subsidy has been discontinued for 2004. (See http://www.enova.no for more information.)

15.5 ECONOMICS

Trends in Investment

The unit cost of the Norwegian wind turbines erected in 2002 was approximately 8,300.00 NOK/kW, including infrastructure and grid connection. No commercial wind farms were established in 2003 so the unit costs for 2003 were not calculated.

Estimations on production costs from sites with favorable wind conditions suggest a production cost of as low as 220.00 NOK/MWh to 260.00 NOK/MWh, including capital and operation and maintenance (O&M) costs. Therefore, compared with the spot market electricity price, wind energy, on average, cannot yet compete on current commercial terms. However, compared with the price of new hydropower projects, some wind energy projects are almost competitive.

During 2001, 2002, and 2003, several interesting commercial agreements were made, based on export of wind energy produced in Norway for the Netherlands. The market for Norwegian wind energy in the Netherlands is now closed.

15.7 INDUSTRY

Manufacturing

The Norwegian/Swedish Company, Scanwind Group AS (SWG), has developed two different wind turbine designs: a 3-MW, direct-driven generator and a 3-MW geared generator. The first direct-driven generator was erected at Hundhammerfjellet in mid-

Wind Turbine Projects	Year	No. Units	Total Power	Production 2003
			KW	GWh
Frøya	1986	1	55*	0.15*
Frøya	1989	1	400	0.7
Vallersund	1987	2	75	0.15
Kleppe	1988	1	55	0.05
Smøla	1989	1	300	0.56
Andøya	1991	1	400*	1.2*
Vesterålen	1991	1	400*	1.2*
Vikna I & II	91/93	5	2200*	5.5
Hundhammarfjellet	1998/2003	1	1,650+3,000**	3.9
Lindesnes	1998	5	3,750	8.7
Sandøy	1999	5	3,750	9.2
Kvalheim	2001	5	4,000	12.4
Smøla	2002	20	40,000	95.8
Havøygavlen	2002	16	40,000	80.3
TOTAL		65	100,035	219.8

***Estimated production. Data not received from utility company**
**** 3MW Scanwind turbine erected summer 2003**

Table 15.1 Overview production data from Norwegian wind farms

Norway (Figure 15.1). The first geared version will be erected in summer 2004. The testing period for the direct-driven generator showed very good results.

ScanWind is now in the decision phase for establishing production lines for blades, towers, generators, and invertors. ScanWind has established the first assembly line in Norway at Verdal in mid-Norway.

UMOE Ryving, a Norwegian-based investment company, is now in series production of high performance, 1,500-kW wind turbine blades. After the company delivered the first set in February 2003, positive operational experience and test results are now present from the first turbine in operation with Umoe blades.

In 2001, in order to assist the development of wind energy in Norway, SINTEF Energy Research, 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 is under construction and will be in operation in 2004 or 2005.

Author: Viggo Iversen, Enova SF, Norway

Figure 15.1 Erection phase for the direct-driven ScanWind 3000 DL turbine at Hund-hammerfjellet

Chapter 16
Portugal

16.1 INTRODUCTION

In the past decades, Portugal has had little development of wind power plant installations, mainly due to the low tariffs practised. However, at the end of 2001, the scenario changed with the publication of new legislation and tariffs. By 2003, that change became reflected in the implementation of new wind park projects and a strong increase in the development rate of capacity installed. In the following sections, a synthesis of the past as well as a summary of the current situation is presented with a main focus on the Portuguese current state of development and trends.

16.2 NATIONAL POLICY

Strategy

On 28 April 2003, the Government Journal published the *Resolution of the Council of Ministries* (*RCM 63/2003*), held on 13 March 2003, which approved the main orientations of energy policy defining the objectives and the measures to implement these objectives. This resolution suspended the *Resolution 154/2001*, which created the E4 program. According to *RCM 63/2003*, the Portuguese energy policy is based on three main vectors: I-security of supply; II-sustainable development; and III-promotion of national competitiveness.

Within the first vector, security of supply, the reduction of external dependency on energy gave rise to the establishment of new objectives to attain in 2010 for the electricity produced by renewable energy sources (RES). Within the second vector, sustainable development, the resolution proposes measures to assure the commitment of Portugal in the framework of the Kyoto protocol, namely a commitment to use renewable energies and promote rational use of energy. Within the third vector, promotion of national competitiveness, the main topic is market liberalization and the decrease of energy intensity in the product. It is important to note here the actions to be taken towards the Iberian market of electricity (the MIBEL).

This new resolution, *RCM 63/2003*, follows the legislation already available concerning renewable energy systems and co-generation that was first regulated in Portugal by the *Decree-Law 189/88*, published in the official government journal, *Diário da República*, in May 1988. Since than, the legislation was reviewed several times, the most recent in December 2001 by the *Decree-Law 312/01* and *Decree-Law 339-C/01*. The first law covers the technical and licensing procedures, and the second law covers the tariffs for renewable energy production.

The *Decree-Law 312/2001* concerns renewable energy systems and co-generation. The law "establishes the procedures regulating the awarding and management of the interconnection points with the Public-Service Electrical System (SEP) for the delivery of electricity received from new power plants, in the framework of the Independent Electrical System (SEI)."

In 2002, the *Decree-Law 68/2002* was published, which concerns the micro-power producers. Its mechanism is intended to speedup administrative and technical procedures associated with the interconnection of micro-generators to the low-voltage grid.

For 2002 tax incentives, the Ministry of Finance is directing favorable taxation towards private investors, who get tax credits for investing in renewable energies (personal income tax). The scope of this tax is, therefore, to stimulate investment in renewable energy technologies by making the investment more economically attractive. However, it is important to remind that the lower value-added tax (VAT) rates of 5% applied for renewables in the country are no longer in force due to the European fiscal harmonization of 2002 (12%).

Resources	2001 [MW]	2010 [MW]
Wind	101	3750
Small hydro	215	400
Biomass	10	150
Biogas 1 50		
Solid waste	66	130
Wave	0	50
Photovoltaic	1	150
Large hydro	4,209	5,000
Total	4,603	9,680

Table 16.1 Endogenous installed and planned capacity (evolution 2001 to 2010)

Progress Towards National Targets

Currently, Portugal's bulk of renewable energy production is supplied by hydropower; biomass/waste sources; and, more recently, a steadily growing capacity of wind power. In view of the country's high dependence on imported fuels, the government has established a number of policies to increase the level of renewable energy development.

Recently, *RCM 63/2003* established that the energy policy of Portugal should reduce its external dependency, which gave rise to the establishment of new objectives to attain in 2010 for the electricity produced by RES. These objectives are shown in Table 16.1.

Wind energy capacity has been stimulated by a series of national policies, reaching the level of 289 MW in 2003. The supporting policies include financial incentives and feed-in tariffs (*Decree-Law 312/2001* and *Decree-Law 339-C/2001*) that have been provided to promote an increase of endogenous renewable energy production. In addition, applications for 7,000 MW of new wind capacity were received at the beginning of 2002 after the most recent PRE law was issued.

16.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Table 16.2 presents the wind capacity and number of turbines installed in Portugal during 2003, and Table 16.3 presents the accumulated values.

Rates and Trends in Deployment

In 2003, an estimated total energy – based on the average capacity factor of different locations – of 720 GWh was produced. Figure 16.2 and Figure 16.3 show the evolution in capacity installation and wind energy production, respectively.

A rate of growth of approximately 50% was verified in 2003, which is slightly lower than 2002. However, a large number of wind park projects reached their final installation phase during 2003 even though they did not begin operation in that year. The rate of development for the past ten years is displayed in Figure 16.4.

Contribution to National Energy Demand

Although only estimates for gross and net energy consumption are available, it

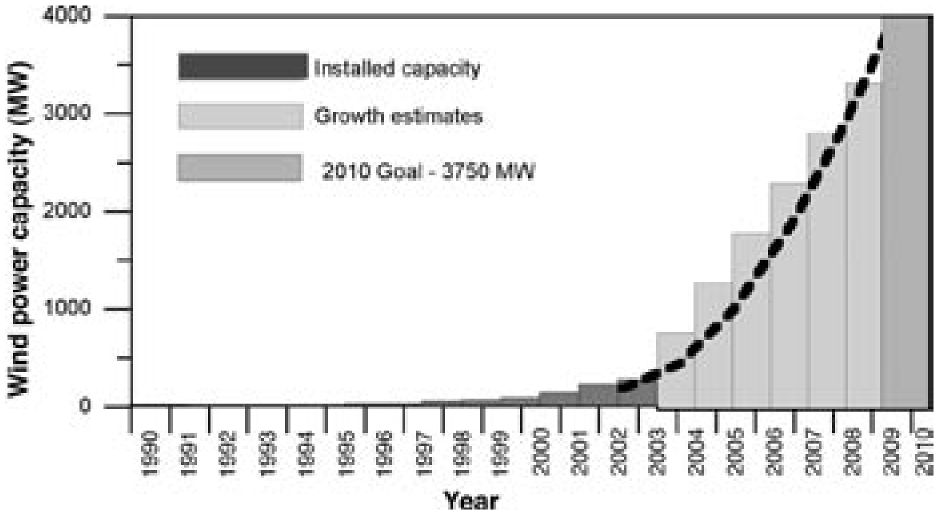


Figure 16.1 National targets for wind power capacity and growth estimates for 2010

is possible to calculate an approximate value for the wind energy contribution to Portuguese demand. Assuming an increase of 4.5% to the 2002 values, the estimated gross demand for 2003 would be 50,166 GWh –therefore, only 1.4% percent of this is wind.

MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The most significant government initiative introduced in the framework of the E4 Programme was the above mentioned 2003 Cabinet Resolution, which re-affirmed the national objective of promoting the installation of 3,750 MW of wind capacity by 2010.

There are also financial incentives under the POE/PRIME program (2000 to 2006), and some tax reductions for renewable energy that also apply to wind energy, as well as a partial support of this program budget on the costs of the transmission network reinforcement requested for the grid integration of further wind capacity in some areas of the country.

Unit Cost Reduction

During 2003, a stable reduction in the unit cost of wind turbines could be noticed – the actual mean cost of installed kilowatt-hours (excluding terrain cost and grid connection) ranged from 750.00 euro/kWh to 950.00 euro/kWh, depending on the country of origin of the turbines and individual capacity. This unit cost reduction has not been as significant as in other countries because the tendency in Portugal, mainly due to the high terrain cost, is to install turbines of more than 1.3 MW/2.0 MW, which have higher individual costs than smaller units.

Project Name	Local	Owner/ Promoter	Power per turbine [kW]	Manufacturer	Model	Installed capacity 2003 [MW]	Installed wind turbines 2003
MAÇÃO_III	Serra Amêndoa	ENERVENTO	900	NEG-MICON		4.5	5
Cabeço Raínha (ampl.)	S. Cabeço Raínha	ENERNOVA	2,000	Enercon	E66/ 2.0-70	6.0	3
VERGÃO	Serra Vergão	GENERG	1,300	Nordex	N60	13.0	10
Srª_CASTELO II	S. Montemuro	FINERGE	2,000	Enercon	E66	4.0	2
Srª_CASTELO III	S. Montemuro	FINERGE/ Catavento	600	Enercon	E40	0.6	1
AGUEIRA	S. Larouco	FINERGE	600	Enercon	E40	0.6	1
ALTO VACA II	Serra Cabreira	FINERGE	600	Enercon	E40	1.2	2
SERRA DO BARROSO	Serra do Barroso	ENERNOVA	2000	Vestas	V80	18.0	9
BOLORES	Loures	TECNEIRA	1,300	Izar Bonus	B62	5.2	4
MEROICINHA	Serra do Alvão - Pena Suar	GRUPO ENERSIS	3@2,000 1@3,000	Vestas	V80, V90	9.0	4
PICOS VERDES II	Vila do Bispo	Unit [E] Portugal	1,500	Fuhrlaender	MD70/ 77	10.5	7
MOINHOS DO OESTE	Oeste	Auditerg	2,000	Enercon	E66/ 70	4.0	2
TRANDEIRAS	Vila Pouca de Aguiar	ENERGIEKONTOR	1,300	Izar Bonus	B62	18.2	14
TOTAL						94.8	64

Table 16.2 Installed number of wind turbines and capacity by wind park and region

	Total operating capacity (Dec. 2003) [MW]	Total operating wind turbines (Dec. 2003)
Continent	273.55	287
Azores	5.25	22
Madeira	9.75	43
TOTAL	288.55	352

Table 16.3 Operating capacity and wind turbines in Portugal in 2003

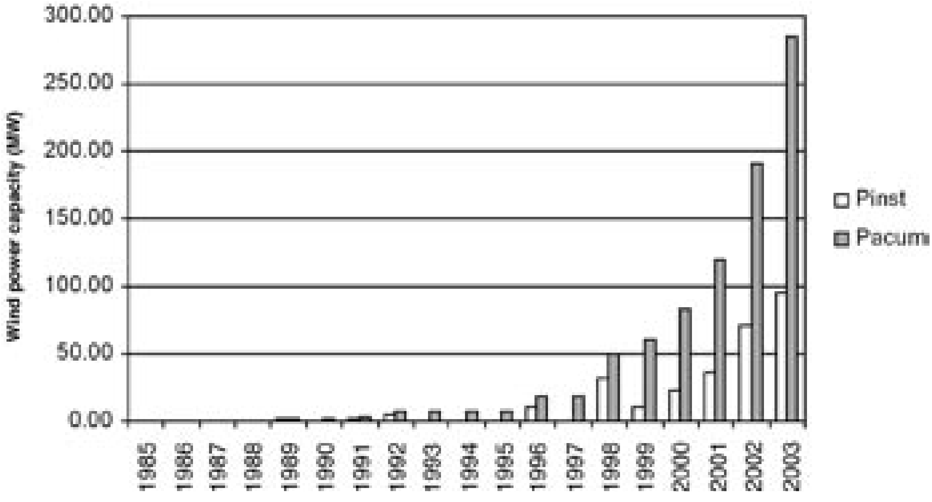


Figure 16.2 Installed and accumulated wind power capacity, 1985 through 2003

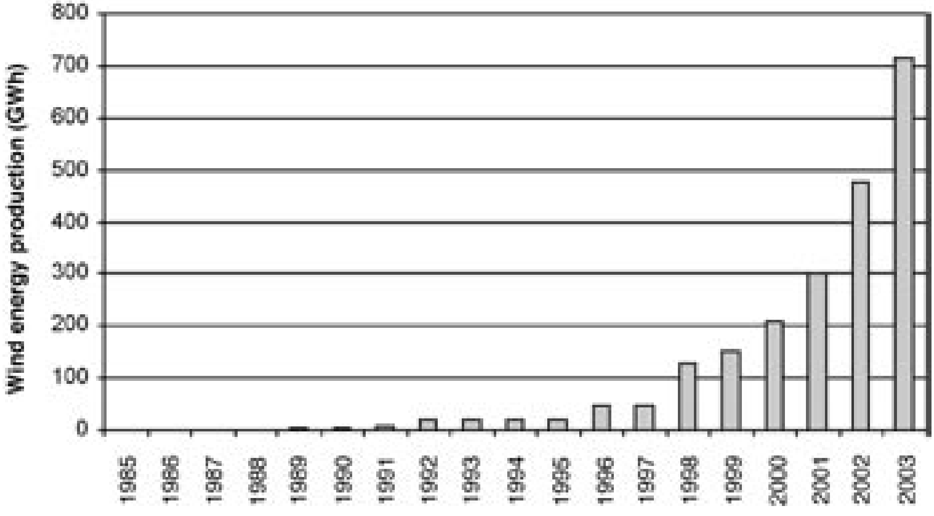


Figure 16.3 Wind energy production, 1985 through 2003 (calculated values)

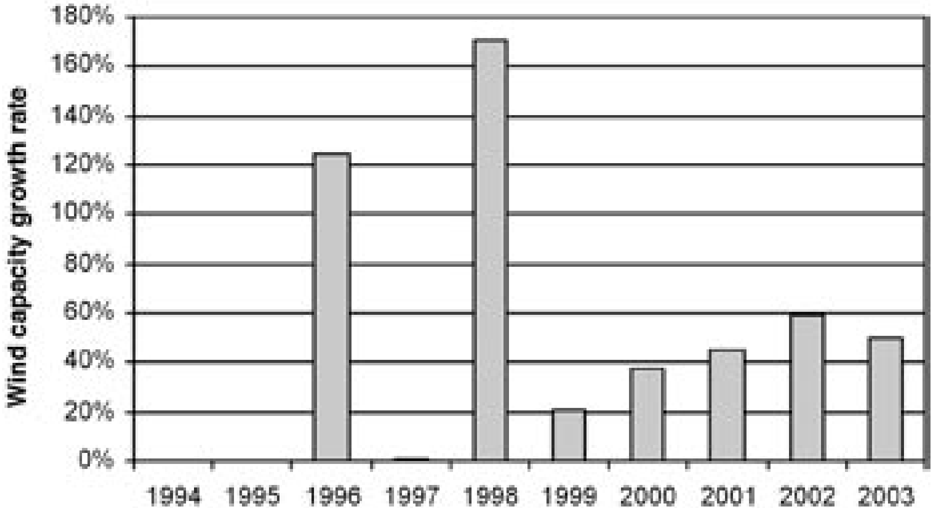


Figure 16.4 Wind capacity growth rate, 1993 through 2003

16.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

In 2003, 64 wind turbines were installed in Portugal with individual capacities ranging from 0.6 MW to 3 MW, all from European manufacturers. The share of installed power by manufacturer is displayed in Figure 16.5.

Operational Experience

During 2003, no major failures of wind turbines were been reported, with the exception of the collapse of one Mitsubishi 500-kW wind turbine in the wind park of Vila do Bispo, Algarve. This was due to a succession of low-probability occurrences, including a loss of grid connection and failure of the two existing over-speed protection systems. The main reason for the wind turbine over speed was attributed to a misinstalled blade that during periodic maintenance was set to a wrong pitch angle.

Main Constraints on Market Development

The market in Portugal had a major burst during 2003, after the legislation published at the end of 2001 and the new projects developed during 2002, which were ready for installation in 2003. The major constraint in Portugal continues to be the excessively bureaucratic and long authorization system in order to obtain all the different permits required to install and operate a wind park. It takes four to five years from initial application to the installation phase. And there is the extreme exigency of the environmental institutions, from which a permit may take up two years to be issued.

16.6 ECONOMICS

Trends in Investment

The trends in investment in the wind sector in Portugal are pronounced towards multi-megawatt wind machines due to the high cost of land. Although the cost structure of

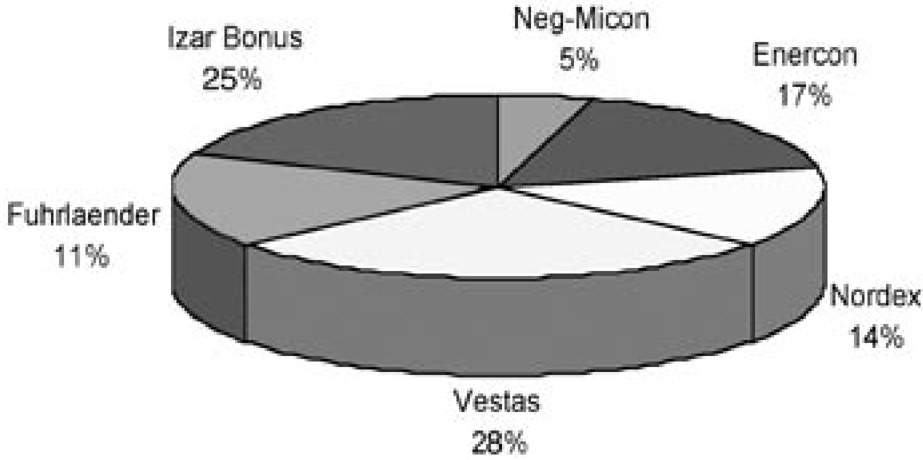


Figure 16.5 Share of installed power by manufacturer

wind park projects is considered a classified subject by all private investors and financial institutions, the total costs in 2003 are in the range of 900.00 euro to 1,200.00 euro. Annual costs for operation and maintenance (O&M) vary between 2% and 4% of the investment cost.

Trends in Unit Costs of Generation and Buy-Back Prices

Although production and trade costs are not yet available for other forms of energy, the tariffs for renewable energy, including wind power-based production, are fixed by the government's decree within *Law 339-C/ 2001* and are presented in Figure 16.6.

16.7 INDUSTRY

Manufacturing

Wind turbines are not manufactured in Portugal, but there is some incorporation of technology in towers and electrical equipment, such as power transformers and wind park cabling.

Industry Development and Structure

During 2003, the intention to install wind turbine industrial and assembling units in Portugal was announced by three different manufacturers in order to comply with the requirements of the national strategy and the consequent development of the Portuguese wind energy market. These announcements included an investment in two assembling factories in the north and center interior, and an investment in a new production factory in the northern littoral.

16.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Portugal does not currently have a governmental program for sponsoring R,D&D activities related to wind energy. However, the National Institute for Engineering and Industrial Technology (INETI) is a part of the Ministry of Economy, and its activities are partly financed by the government.

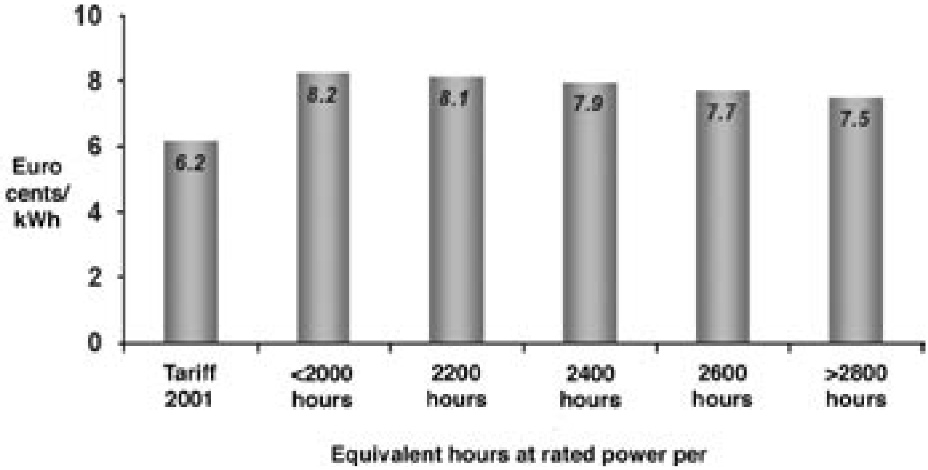
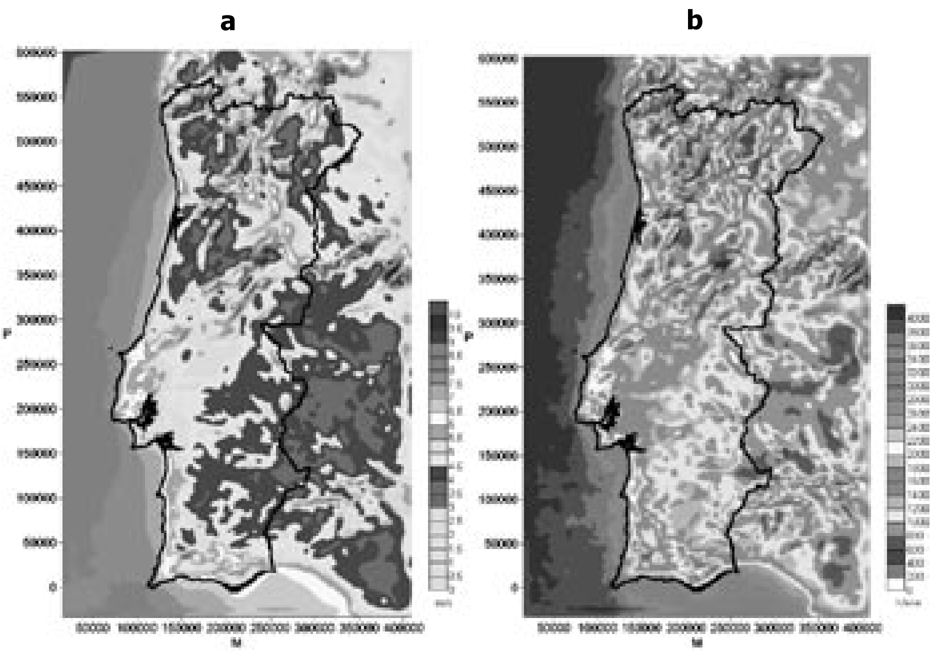


Figure 16.6 Tariffs applied in Portugal versus equivalent hours at rated power per year



Figre 16.7 Wind atlas: a) mean wind speed at 80 meters above ground and b) yearly equivalent full-capacity hours

Figure 16.8 Anemometric stations available in the EOLOS 2.0 database

During 2003, the Portuguese wind atlas, as displayed in Figure 16.7, was developed together with a national database for wind characteristics (EOLOS 2.0) with information of about 50 anemometric stations (Figure 16.8).

The main R,D&D priority for INETI is currently the forecast of wind power production, which INETI intends to carry out with the Portuguese network operation and dispatch company Rede Eléctrica Nacional (REN).

New R,D&D Developments

New trends in what concerns wind energy are oriented to the development of wind/hydro common regulation (e.g., 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.

Offshore Siting

Although INETI participated in the identification of possible sites for offshore wind park installation, the possibilities are globally low due to the high depth and fast slope of the continental platform, which leads to technical problems or very high costs. So far, there is no consistent plan for offshore wind farms.

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Chapter 17
Spain

17.1 INTRODUCTION

The production of electricity by wind energy has a strong importance in the energetic national scenario. It covers an important part of the electricity demand without bad side effects to the environment. Wind energy helps reduce the strong dependency on external sources of energy, supports the fulfillment of the Kyoto compromises, and increases the industrial and technological capability of the country.

Wind energy in Spain continues the growth started in the mid-1990s, taking a leading worldwide position along with Germany and the United States. At the end of 2003, the power in operation in Spain was over 6,200 MW. The electricity generated by wind energy represents nearly 5% of the total production, and plans for the future show the possibility of reaching 13,000 MW grid connected by the end of 2010. The wind industry in Spain is a solid sector with great potential and strong investments in R&D activities and job creation.

One explanation for this growth is the existence of a stable legal framework for electricity producers using renewable energy sources (RES). The regulations contained in the *Special Regime of the Electrical Sector Act* imply that electricity producers using wind have guaranteed access to the grid. The price per kilowatt-hour generated has a bonus over the sale price of electricity, and a new regulation is in discussion between the administration and the wind sector in order to ensure the economic regime of wind farms during the life period of the installations. New manufacturers, investors, producers, and researchers have been incorporated into the wind energy business in the last year, and a process of merge and association between companies has occurred.

17.2 NATIONAL POLICY

Spain is a country with a strong dependency on external sources of energy – there are no oilfields or gas fields, and the few coal mines are of low quality coal. Table 17.1 shows the energy balance in both the mainland and island electric systems during the year 2003. During this year, the demand for electricity was 5.9% higher than the previous year, with a total value of 236,538 GWh.

During 2003, the contribution of hydro to total production was 20%; nuclear groups represented 31%; coal represented 37%; and the electricity produced inside the Special Regime, which includes cogeneration, small hydro, and renewable energy, reached 39,563 GWh, 10.6% more than the previous year.

A total of approximately 1,400 MW of new power capacity has been installed in Spain, in gas power plants and RES, mainly wind farms.

Strategy

The strategy of the Spanish government is summarized in the *Program for Promotion of Renewable Energies*, approved by Parliament.

The overall target is to meet 12% of total primary consumption from RES by 2010. For wind power, the aim is to have ready-installed capacity of 13,000 MW by the end of the year 2011 (according to *Planning of*

	Mainland			Islands			Total country		
Source	Electricity production (GWh)	Variation 2002/ 2003 (%)	Power installed Dec 31 (MW)	Electricity production (GWh)	Variation 2002/ 2003 (%)	Power installed Dec 31 (MW)	Electricity production (GWh)	Variation 2002/ 2003 (%)	Power installed Dec 31 (MW)
Hydro	38,734	72.00	16,657	1	39.00	1	38,735	72.00	16,658
Nuclear	61,848	-1.90	7,816	-	-	-	61,848	-1.90	7,816
Coal	72,562	-7.90	11,565	3,544	0.10	510	76,105	-7.50	12,075
Fuel / Gas	23,146	6.30	11,324	9,669	13.70	2,995	32,815	8.40	14,319
Total norm regime	196,290	5.50	47,362	13,214	9.70	3,506	209,504	5.70	50,868
Special regime	38,852	10.90	12,504	712	-2.90	238	39,563	10.60	12,504
Electricity demand	223,480	5.80	-	13,088	9.30	-	236,568	6.00	-

Source: Red Electrica de España

Table 17.1 Energy balance and power capacity in 2003

the Utility and Gas Sectors Expansion of Transport of Grids 2002-2011, approved by the Council of Ministers in September 2002).

The structure of the energy sector for the year 2011 is described in Table 17.2 and illustrates a strong effort to modify the primary energy consumption towards a more clean and efficient system: increasing the contribution of natural gas, saving energy, and using renewable energy sources.

The objectives included the Spanish incorporation of the European recommendations made in the *White Paper on Renewable Energies*. The main measures were as follows:

1. Adequate remuneration for each kilowatt-hour generated
2. Development of infrastructure to transport power away from point of supply
3. Standardization, official type approval, and certification of wind turbines; and consolidation of the technology

	Year 2002	Scenario 2011
Electricity generation	**(Percent)**	
Natural gas	**9.7**	**34.2**
Oil	**9.9**	**4.8**
Coal	**35.9**	**12.0**
Nuclear	**27.6**	**20.1**
RENEWABLES	**20.1**	**28.9**
Energy consumption		
Natural gas	**12.2**	**22.6**
Oil	**51.7**	**47.6**
Coal	**17.3**	**8.2**
Nuclear	**13.0**	**9.0**
RENEWABLES	**5.6**	**12.0**

Table 17.2 Targets for the year 2011

Figure 17.1 Ecotécnia 62 at the La Bandera wind farm

4. Support for R,D&D of applications before the commercialization stage

Progress Towards National Targets

The situation for wind energy is optimistic in regard to the fulfillment of the Spanish targets – according to present data, the target will be reached earlier than planned. The power installed at wind farms in operation at the end of 2003 was close to the target for the year 2006, despite the fact that in 2003 the rate of installations had a slight reduction due to grid-connection problems.

The majority of the autonomies have regional wind energy programs that give a total of more than 10,000 MW to be installed in the next years (exceeding the PPRE target).

17.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 2003, another 1,320 MW were installed, and the total power as of 31 December 2003 was 6,202 MW. The average power unit installed during 2003 presents a moderate increase, reaching 840 kW (approximately 800 kW during the previous year). The models used in the wind farms are wind turbines ranging from 750-kW to 1,500-kW rated power.

Rates and Trends in Deployment

Annual power installed continues growing. Figure 17.3 shows the annual power installed in Spain in the last years. The figures for 2003 show a small reduction in the tendency of continuously increasing rates from the previous year. The reasons for this could be that more difficulties than expected in the grid connection of wind farms have occurred due to the lack of electrical infrastructures, and several projects of wind farms have been delayed. Nevertheless, the wind energy sector – which includes manufactures, suppliers, and investors – is solid and the expectation for the future is optimistic.

The sector requires new regulations of the electricity price for covering long-term price guarantee. The draft of the new regulations is under discussion with the sector.

The distribution of the installations is shown in Figure 17.4. The Association of Promoters of Wind Farms (APPA) supplies the data.

At the present time, almost all the Spanish autonomies are involved in the incorporation of wind energy in their energetic structure. Aragon, Castilla-León, Castilla La Mancha, and Galicia are the autonomous communities with the most activity during 2003.A new strategic plan

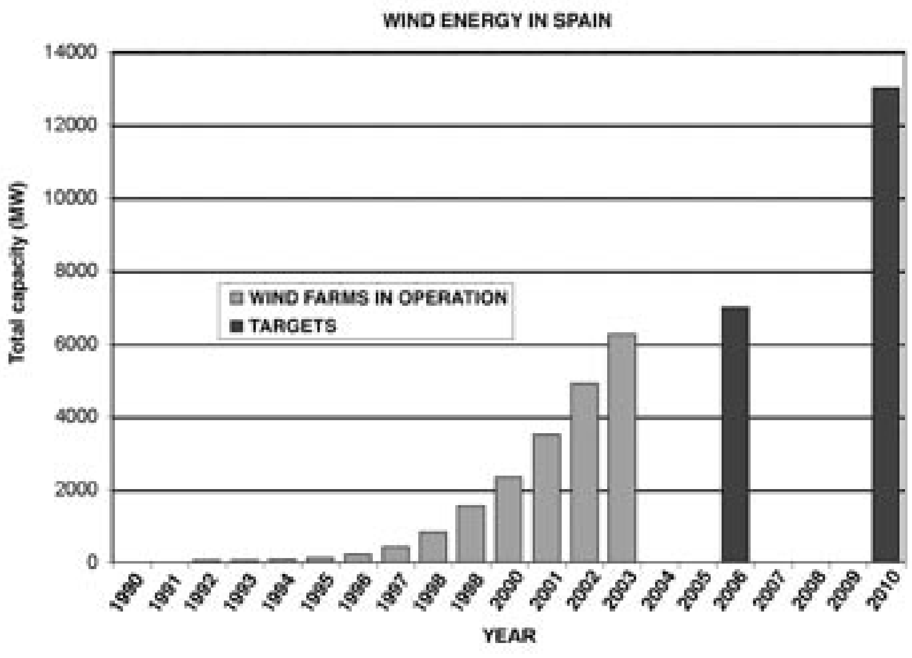

Figure 17.2 Wind installations in Spain and targets for 2011

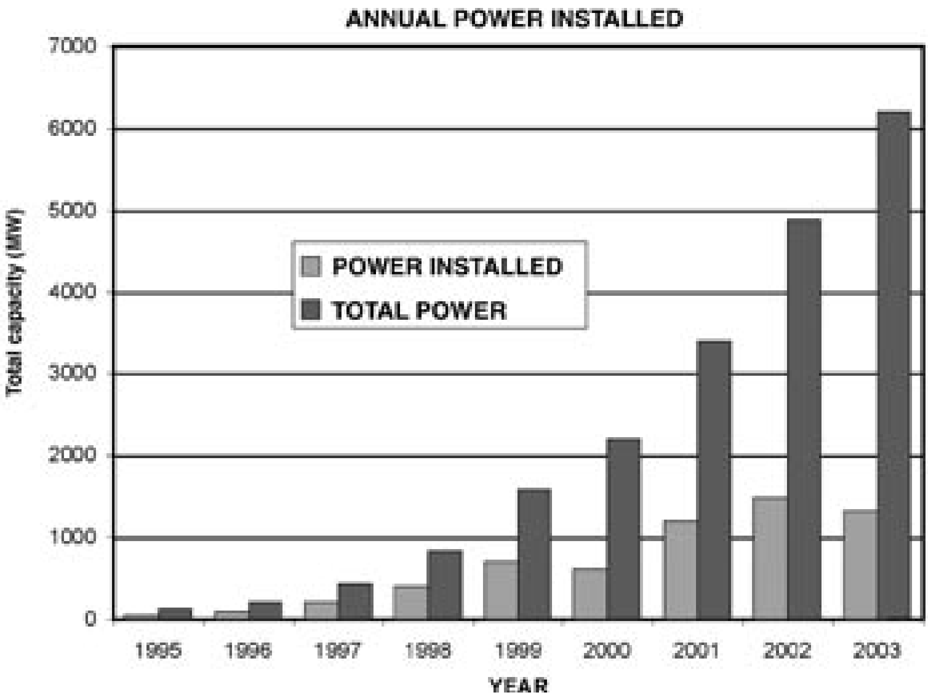

Figure 17.3 Annual installed power

with a total capacity of 2,000 MW has been approved in the Comunidad Valenciana, and preliminary industrial activities in the region have been started.

The profile of the investors in Spain is a big company with strong capability of promotion and development. Several regional governments are interested in the promotion of small investors and municipalities, and they are preparing new regulations in this sense. Galicia, Navarra, and other regions have a special procedure to permit wind farms less than 5 MW when a part of the electrical production is used by the owner of the wind turbines.

Contribution to National Energy Demand

The total production of wind power plants for 2003 was 11,370 GWh, according to the National Energy Commission. The total demand for electricity in Spain during 2003 was 236,538 GWh (6% higher than the previous year). The evolution of wind energy production was 2,696 GWh in 1999; 4,700 GWh in 2000; 6,932 GWh in 2001; 9,603 GWh in 2002; and 11,370 GWh in 2003.

In 2003, wind electricity reached 4.8% of the total electricity demand. Figure 17.5 shows the evolution of wind electricity, along with the demand for electricity. The electricity produced by wind farms during 2003 was equivalent to the increase in demand.

Wind energy is already integrated into the electrical system, and there is a regulation of wind farm production at special occasions. For example, during holidays such as on December 25 and January 1 when there is low consumption and strong winds, the production of wind farms has

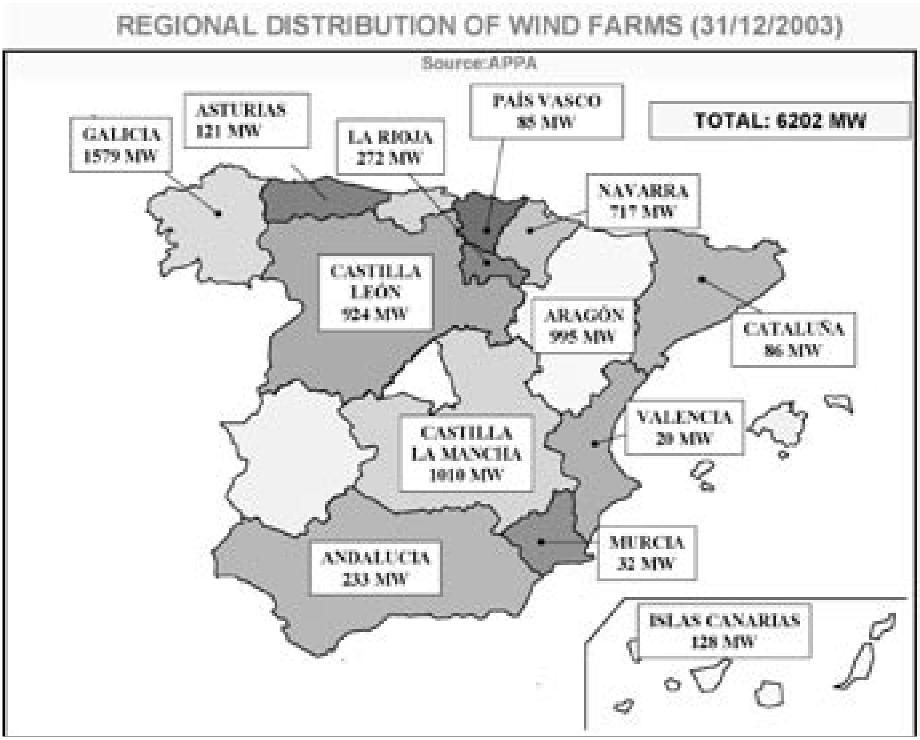

Figure 17.4 Regional distribution of wind installations

been voluntarily reduced, following the recommendations of the organization that manages the grid in order to maintain stability of the system.

17.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The main action for market stimulation is the price paid for electricity generated by RES, and it is regulated through two royal decrees (the latest approved in December 1998), which obligate utilities to pay a guaranteed price to RES generators for a five-year period. This price, and the related bonus, is revised and fixed every year according to the variation of the electricity market price.

Another positive point to stimulate the promotion of wind farms is the regulation of administrative procedures for the authorization of wind power installations.

Unit Cost Reduction

Does not apply.

17.5 DEPLOYMENT AND CONSTRAINTS

The rapid increase of installed power is welcomed by society, which appreciates not only the contribution to environmental conservation but also the industrial development and associated job creation. Job creation is the most important aspect of wind energy for the Spanish population. The development of new installations is favored at the local level (landowners and municipalities) because of the benefits obtained.

The conditions for developing wind projects in Spain are regulated under the *Law of the Special Regime for Electricity Production (Dec/98)*. The grid operator (REDESA, a national public company) and the utilities have the obligation to allow the connection of wind turbines to the grid. Developers have to fulfill the technical requirements defined in the electrical law. The cost associated to the connection is the responsibility of the plant developer. There are no widespread complaints about the process to obtain permission for connection to the grid.

Wind Turbines Deployed

The wind turbines installed in 2001 in Spanish wind farms had capacities ranging from 750 kW to 1,500 MW. The average size of the wind turbine installed during 2003 was 844 kW. During 2003, a total of 1,320 MW was installed in Spain.

Operational Experience

The year 2003 was a little less windy than the previous one, and the operation parameter of the wind farms was lower than in previous years. An estimation of the capacity factor in the country calculated by the monthly values supported by the Comision Nacional de la Energía (CNE) are 0.21 for 2003 and 0.22 for 2002. This variation is according to the perception of the wind farm operator during the actual year.

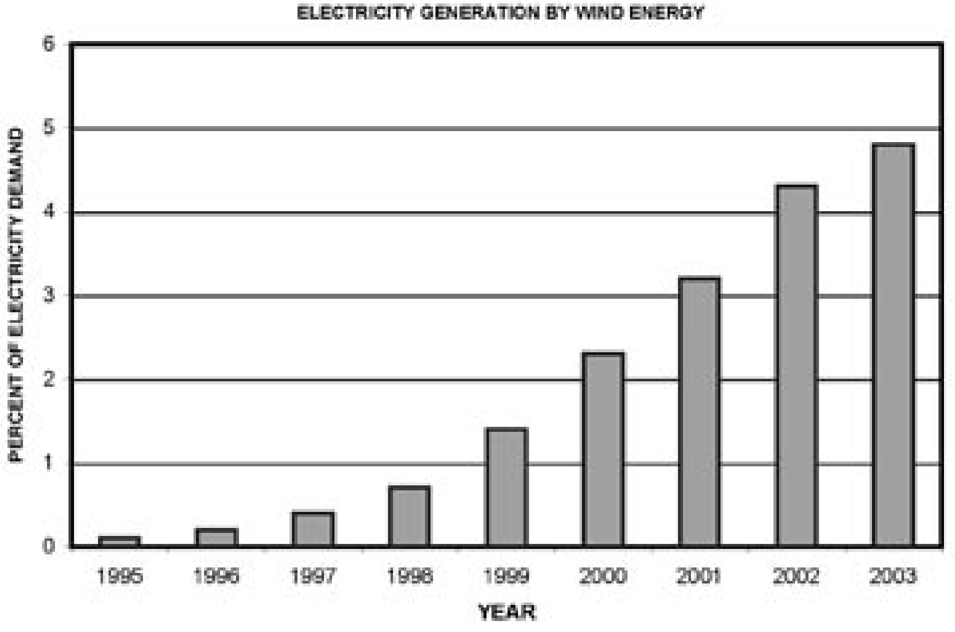

Figure 17.5 Electricity generation by wind energy

Figure 17.6 Caparroso wind farm

The regional distribution of the capacity factor shows variation from the higher values of Andalucia (0.28 capacity factor over 230 MW installed) or Canary Islands (0.31 of capacity factor over 130 MW installed) to the moderate values of Castilla La Mancha in the central part of Spain (capacity factor of 0.17 over 1,010 MW installed).

Information about the instantaneous production of Spanish wind farms (and historical data of previous periods) is available on the Internet at http://www.ree.es.

Main Constraints on Market Development

In 2003, some opposition emerged against the installation of new wind farms in areas with strong development. This opposition was launched by local ecologist groups that complain about the landscape impact and the possible impact on bird life. That opposition causes delays in the permission of wind farms.

The main constraint on market development is the existing limitation on the capacity of the grid for energy evacuation. Generally, wind farms are located in areas with low-density population, and the grids are weak and require reinforcement and improvement. Concerted actions between utilities and developers are ongoing in order to solve the problem.

The development of wind power installations is strongly affected by the rigidity of the administrative procedure and the uncertainty to obtain the required permission and authorizations for civil works grid connection and start-up of the wind farm. These limitations imply a period of four years for the completion of all steps – from the first application to wind farm operation – and mean an important increase of wind farm promotion cost. A great number of megawatts planned for 2003 were delayed for these reasons.

17.6 ECONOMICS

Trends in Investment

No information available.

Trends in Unit Costs of Generation and Buy-Back Prices

The *Royal Law 2818/1998-23 December 1998*, about the Electrical Special Regime for renewable energy plants connected to the grid, fixed the conditions of the plants to be included in this special regime. This law was a new step in the strategy for promoting the use of renewable energies, with the specific target that "the contribution of the renewable energies to the Spanish energetic demand, will be at least 12% for the year 2010." All installations using renewable energy as a primary source, with an installed power equal to or less than 50 MW, could be included in that regime.

The regime gives two choices to producers: one is a fixed priced for kilowatt-hours generated, and a second option is a variable price, calculated from the average price of the market-pool, plus a bonus per kilowatt-hour produced. The fixed price and the bonus will be up-dated every year by the Spanish Ministry of Energy and Industry according to the annual variation of the market price.

The updated values for are presented in Table 17.3. The evolution of the price of electricity generated by wind is shown in Figure 17.7.

17.7 INDUSTRY

Important activity in the wind energy field has intensely activated the development of the Spanish wind industry, covering not only the manufacture of complete wind turbines but also the manufacture of components for the wind industry, such as blades, generators, gear boxes, towers, and wind sensors. The service sector (e.g., installation, maintenance, engineering) also continues the growth that occurred during the last years.

The estimation of job creation associated with wind energy is, according to promoter associations, approximately 7,000 directs jobs in 2003 (and near 20,000 indirect jobs). The estimation for the total objective in the year 2011 is approximately 51,000 jobs related to wind energy activity when the capacity of 13,000 MW will be reached.

Manufacturing

The companies leading the Spanish industry are Gamesa Eólica, Ecotécnia, Izar-Bonus, NEG Micon, and GE Wind Energy. Gamesa Eólica is the leading company in the Spanish market, and new manufacturers are emerging, such as MTorres and EHN.

MTorres is a company with activity in the aeronautical field with a prototype of a 1.5-MW, upwind, direct-drive multipole generator, pitch-regulated wind turbine. Five units are in operation in Spain. The next step in the development is to incorporate permanent magnet technology.

EHN is a large wind promoter that has designed and put into operation its own model of a megawatt-class wind machine, which is a pitch-control, variable-speed turbine. The objective of the design is to be able to cover at least 30% of its own installations. A new company, called Ingetur, began manufacturing the models and is also designing new ones.

DeWind, Nordex, and Enercon are also initiating their activities in Spain. Enercon has an ambitious plan in the southeast of the country.

Buy-back electricity prices for RES 2002-2004						
	Year 2002		Year 2003		Year 2004	
Renewable source	Bonus added to the base price	Fixed price	Bonus added to the base price	Fixed price	Bonus added to the base price	Fixed price
	Euro/KWh	Euro/KWh	Euro/KWh	Euro/KWh	Euro/KWh	Euro/KWh
Small hydro	0.030051	0.063827	0.029450	0.064849	0.029450	0.064849
Wind plants	0.028969	0.062806	0.026625	0.062145	0.026625	0.062145
Primary biomass	0.027887	0.061724	0.033236	0.068515	0.033250	0.068575
Secondary biomass	0.025781	0.059620	0.025122	0.060522	0.025136	0.060582

Primary biomass : Agricultural crops
Secondary biomass : Agricultural and forest residues

Table 17.3 Buy-back electricity prices for RES in 2003

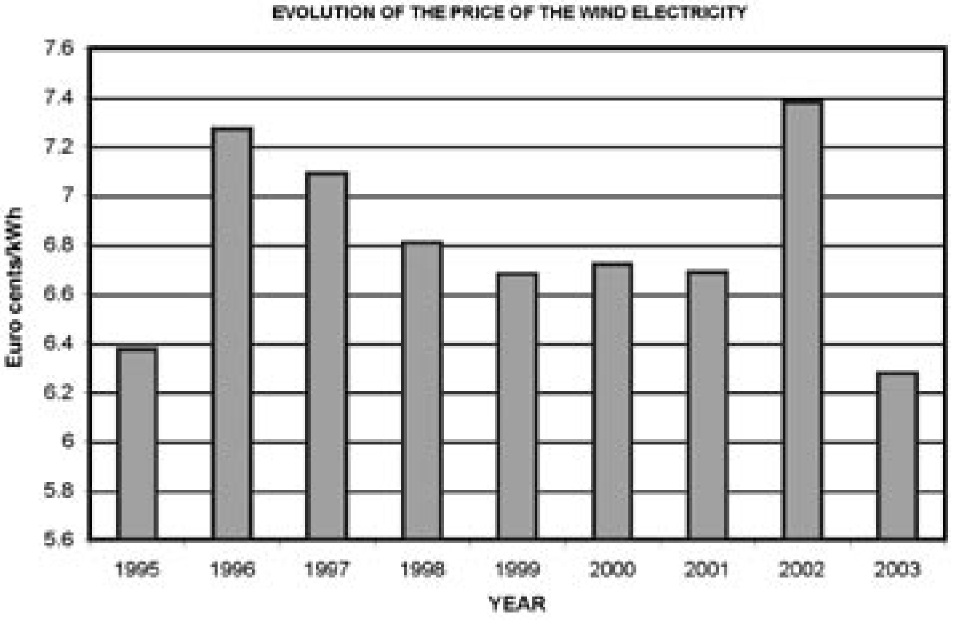

Figure 17.7 Evolution of the electricity price for wind energy

Gamesa Eólica is the leading company in the Spanish market. The company manufactures wind turbines between 660 kW and 2 MW, as well as a majority of components (e.g., blades, nacelles, gearboxes, towers). Gamesa Eólica has a total of 2,000 employees and more than 15 subsidiary factories.

Gamesa Energia is also one of the major wind farm developers in Spain. During 2003, the company sold 1,380 MW – most of this for the domestic market and the rest for projects in other countries like China, Germany, Italy, Japan, Portugal, and the United States. The wind turbines are pitch-controlled and variable-speed using the Ingecom system developed by Gamesa Energia. During 2003, Gamesa purchased the company Made, one of the pioneering wind turbine companies in Spain. Since 1982, Made has developed ten different models of wind turbines, ranging from the first design, a 24-kW machine, to the recent 2-MW turbine. The technology involved in the classical Made design is stall-regulated with an asynchronous generator. The most recent model, Made AE/52 (800-kW rated power), changed to a pitch-controlled wind turbine with a synchronous generator and variable-speed design. With this incorporation the Gamesa group increased the capability of design and production and covered a wide range of technologically options.

Ecotécnia started activities in wind technology development in 1981, having more than 20 years of experience in that field. The company has three factories, with a total of 350 workers. During 1999, Ecotécnia was incorporated into the MCC Group, one of the largest, worldwide co-operatives, with activities in the industrial, distribution, and financial sectors. The company has recently opened a new office in France. Ecotécnia has in production models with diameters of 48 m, 62 m, and 74 m, with rated powers of 750 kW; 1,300 kW; and 1,670 kW, respectively. A prototype of a 3-MW wind turbine with a 100-m rotor diameter is under development. During 2003, Ecotécnia supplied 29 wind turbines of 1,670 kW, 74-m rotor diameter, 64 units of the model 74 m, and 53 units of the Ecotécnia 48. Installations were nearly finished in 2003.

Izar is manufacturing 600-kW and 1.3-MW models of Bonus technology in its factory located in Ferrol (A Coruña). Izar is also developing two new models of 2 MW and 2.3 MW. The company's current annual capacity production is more than 200 MW.

GE Wind Energy is producing a 900-kW wind turbine (with a 55-m diameter) and a 1,500-kW model (with 70.5-m and 77-m rotor diameters) in the factory located in Noblejas (Toledo). GE is also offering new models based on the 2.X criteria with rated power from 2.3 MW to 2.7 MW. These new models are specially designed for onshore applications in a wide variety of landscape situations. GE continues the operation of its prototype of 3.6-MW turbine in Barrax (Albacete).

NEG Micon has three factories in Spain. The company has 160 workers and is manufacturing models from 44-m rotor diameter and 750 kW of rated power to the NM92 model of 2.7 MW covering a wide range of site and wind conditions. In Spain, NEG Micon has the following models in operation: NM44, NM48, NM52, NM64, NM72, and NM82, all manufactured in Spanish factories.

During 2003, NEG Micon supplied 195 wind turbines (154.1 MW) to the Spanish market, plus another five wind turbines to Portugal and nine more for a project located in France. Spanish factories can produce approximately 400 wind turbines per year.

In the sector of small wind turbines, Bornay is the company leader with active development in Spain and in the international market (e.g., Chile, Germany, Japan, Tanzania). Bornay is manufacturing models from 60 W to 6 kW and is developing new models of 7.5 kW, 15 kW, 30 kW, and 50 kW.

Solener is also manufacturing small wind turbines from 300 W to 15 kW and developing new prototypes from 25 kW to 40 kW rated power. Other companies like Atersa and Ecotécnia are supplying small wind turbines using foreign technologies from Vergnet and Bergey. The market for small wind turbines in isolated applications showed an active development during 2003 in Spain.

Industry Development and Structure

Two Spanish companies Gamesa Eólica and ECOTECNIA were among the world's ten largest manufacturers in 2003. Approximately 400 companies are involved in the wind sector, covering different areas of activity. Manufacturing includes wind turbines, towers, blades, gear-boxes, control systems, and electric and electronic equipment. Other active areas include erection and maintenance of wind turbines, engineering, civil works, wind assessment, and audits.

Domestic manufacturing capability is estimated at more than 1,900 MW/yr. The current state of technology generally implies the following options for providing wind energy:

1. Wind turbine manufacturers using Spanish technology, like Gamesa Eólica and Ecotécnia, which together represented 77% of the total installations during 2002
2. Spanish manufacturers with technology transfer agreements like Izar-Bonus, which represented 4% of the total installations in 2002

Figure 17.8 Traditional windmill in the south of Spain

3. Foreign technology with factories in Spain like NEG Micon, GE Wind, and Enercon, which together represented 19% of the total installations during 2002
4. New manufacturers using foreign technology, such as Nordex and DeWind

Currently, Spanish manufacturers are participating in future international projects and also increasing marketing activities in other countries. The wind industries are spread in the Spanish territory (i.e., almost all the autonomous communities are involved in the development of wind energy), and new factories of components for the industry were inaugurated during 2003.

7.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The *National Plan for Scientific Research, Development and Technological Innovation (2000-2003)* continues activity. The target areas defined in the plan for wind energy projects are the following:

1. Environmental Impact Reduction of Wind Systems
2. Technology Cost Reduction
3. Technology Development for Large Wind Turbines (1 MW to 2.5 MW)
4. Small Wind Turbines for Isolated Applications
5. Remote Control Systems for Grid Connection
6. Wind Power Penetration in Weak Grids

During 2003, 16 wind energy projects were submitted to the program, covering all the target areas. The projects approved (a total of 13) present a budget of 15.33 million euro – an important part of the budget was covering soft conditions loans, and the equivalent subsidy was approximately 2.8 million euro. The projects were presented mainly by industrial companies in co-operation with engineering companies and research centers and universities.

New R,D&D Developments

The centers and universities involved in R&D projects increased their activities during 2003. The wind power industry in Spain has a strong innovative character and its contribution to R&D growth in areas is considered strategic. According to the Manufactures and Promoters Association, Plataforma Eólica Empresarial, the R&D

Figure 17.9 Manufacturing of a hub by Gamesa

Figure 17.10 Hybrid system for an isolated application

investment by Spanish manufacturers amounts to 11% of the companies gross value added, which is well above the average 1% of Spanish companies as a whole, and higher than other industries such as the electronic equipment industry (5.4%).

The following main projects are supported by the national program and carried out by companies:

1. Developing a new wind turbine with a 100-m rotor diameter for easy transport and installation
2. Integrating wind farms in the electrical grid
3. Developing a new hybrid system, wind-photovoltaics-diesel, of 100 kW
4. Creating a test plant for isolated systems
5. Modeling hydrogen production with wind energy
6. Creating innovative concepts in commercial wind turbines
7. Developing wind turbines for special site requirements
8. Developing new control strategies and preventive maintenance
9. Creating electrical protections in the distributed generation using renewables
10. Developing a hybrid, three-phase system for electricity generation
11. Developing a direct-drive wind turbine prototype

The main public R&D organization in the field of wind energy in Spain is CIEMAT, a center for research in the technologies and environmental aspects of energy production. Inside CIEMAT, the Department of Renewable Energy is stressing activities in the field of autonomous wind systems, with a broad field of activity from development of components (e.g., small wind turbines, flywheel storage, control management units) to the testing of wind turbine components and systems in the test plant located in the CEDER center in the Soria province. Figure 17.11 shows one view of the test plant.

Offshore Siting

They are two main initiatives in offshore activities in Spain – one of them is a study carried out by Greenpeace Spain called, *Viento En Popa*, or "the need for an offshore wind generation plan in Spain," June 2003. The main conclusions of the study are an estimation of wind potential of 25,000 MW at the Iberian Peninsula (less than 30 km from the coast, 30 m deep); and the necessity of new regulations covering the public interest of the project, long-term price guarantees, and a plan for the organization of offshore activities.

Figure 17.11 CIEMAT test plant for small wind turbines

Another project in offshore activity is called *Mar De Trafalgar*. The first phase of the project is a study of a 1,000-MW wind farm in the south of the country, using wind turbines from 2.5 MW to 5 MW. A preliminary project was presented to the authorities in September 2003.

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Chapter 18
Sweden

18.1 INTRODUCTION

The year 2003 was a year of changes in the economics of wind power in Sweden. The investment subsidy program, which has been running since 1991 with varying levels expired at the end of the year. So did small-scale support. These subsidies were replaced by market-based support, a system using electricity certificates. The national target for planned deployment (as opposed to actual production) of wind power was set to 10 TWh in 2015. In order to meet this target, planning of new plants will mainly be focused on offshore sites.

18.2 NATIONAL POLICY

During the 1990s, the Swedish electricity market has been reformed in several steps. Since 1 January 1996, Sweden has had a deregulated electricity market. The objectives of the reform were to increase the freedom of choice for electricity consumers and create conditions for greater pressure on prices and costs in the electricity supply.

Sweden's energy policy, as decided by the Swedish Parliament in 1997, is to provide secure short-term supplies of electricity or other energy on competitive terms. The country's energy policy is intended to create conditions for efficient use and cost-efficient supply of energy – with minimum adverse effect on health, the environment, and climate – while at the same time assisting the move towards an ecologically sustainable society.

Considerable challenges face Sweden in the future. The decision to phase-out nuclear power, the commitment to reduce greenhouse gas emissions in line with the Kyoto Protocol, and the limitations on further expansion of hydropower resources make the development and market introduction of alternative energy sources, as well as successful energy efficiency measures, of crucial importance. Wind energy is one of the key elements in the transformation of the power system.

During 2002, the parliament decided to establish a planning target for wind power. The target is set at an electricity production from wind power of 10 TWh in 2015, provided that the economic conditions for wind power investments will be sufficient. The planning target should be seen as a mark of a level of ambition regarding the creation of opportunities for a future wind power development.

Strategy

An extensive energy policy program started in 1998 in order to facilitate the restructuring and development of the energy system. The main driver of this work is in the form of a substantial long-term concentration on R,D&D of new energy technology. More than 1 billion euro has been allocated to the program, which consists of two parts.

The first part lasts seven years and is an R,D&D program aimed at promoting renewable energy sources, new conversion, and end-use energy technologies. These long-term efforts will focus on new technology development of biofuel-fired combined heat and power; biofuel supply and ash recycling; new processes for ethanol from forestry raw materials; alternative motor fuels; wind power; and solar and energy efficiency in buildings, industry, and the transport sector. This part ends in 2004.

The second part of the energy program is to replace the electricity production loss of about 4 TWh from Barseback nuclear power plant. A five-year, short-term subsidiary program was finalized in 2002. This program promotes energy efficiency and electricity production from renewable energy sources, such as biofuels, wind, and small hydropower plants.

The total cost for the two-part effort is 1.07 billion euro, of which 0.6 billion euro are allocated to the long-term R,D&D program. The responsible authority for transforming the Swedish energy supply system into an ecologically sustainable system is the Swedish Energy Agency, which was formed on 1 January 1998.

In regard to wind energy, the government is supporting the development and installation of wind turbines in two efforts managed by the Swedish Energy Agency. They are as follows:

1. An R&D program with a three-year budget of approximately 90 million Swedish Krone (SEK) for 2002 to 2004
2. A project to support technical developments, in co-operation with market introduction, for large-scale plants offshore and plants in artic areas (began in 2003 with a budget of 350 million SEK and will run for five years)

The utilities are engaged in studies, demonstration, and evaluation projects. From 1994, the R&D activities of utilities are co-coordinated in a jointly owned company, Elforsk AB, which initiates projects and finds sponsors in the field of power generation. In addition to the activities of Elforsk AB, the largest utility, Vattenfall AB, has a wind energy development program of its own.

Progress Towards National Targets

The target of a five-year investment subsidy program (1998 to 2002) was to reach an annual wind electricity production of 0.5 TWh, which was managed in 2002. For different reasons, the program was extended in time and resources and came to an end in 2003.

18.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The expansion of the annual power generation from wind turbines (in GWh) and the installed capacity (in MW) at 31 December each year in Sweden is shown in Figure 18.1 and Figure 18.2.

Rates and Trends in Deployment

At the end of 2003, the total installed wind power capacity in Sweden was 399 MW, an increase of 54 MW from the previous year (a 16% increase). During 2003, the number of wind turbines increased by 9% to 55, creating a total of 675 turbines. Wind power generation during 2003 was 690 GWh (preliminary), an increase of 13% since 2002 (609 GWh). The year 2003 was a low-wind year in Sweden, 92% of a normal wind year. The generation recalculated to a normal year is 750 GWh.

Contribution to National Energy Demand

Wind power contributes to the national energy demand with 0.4% of the total electricity production. See Table 18.1 for the total installed electricity capacity and generation in Sweden.

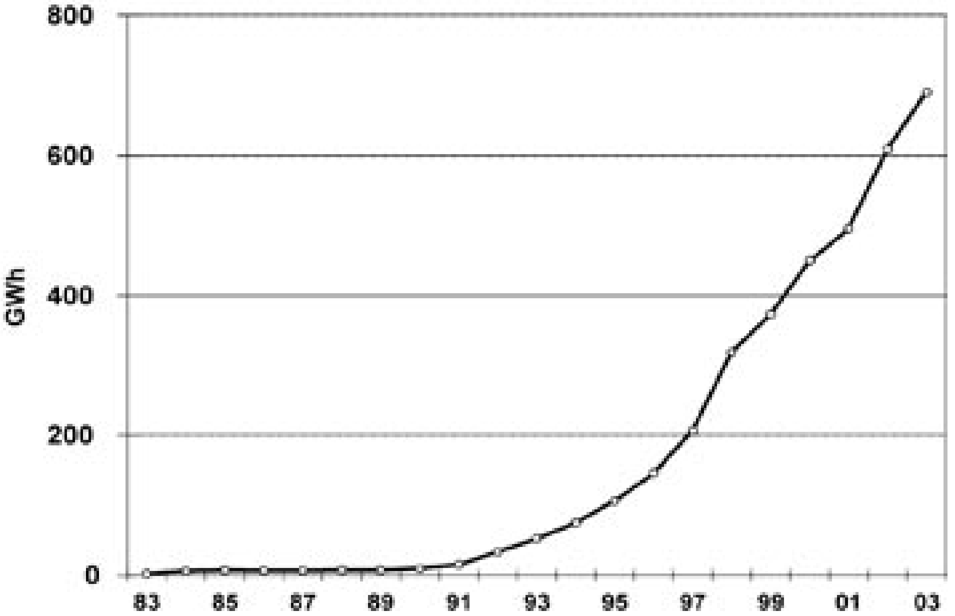

Figure 18.1 Wind power generation (GWh)

18.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

In 2003, the Swedish Energy Agency launched a project to support technical developments, in co-operation with market introduction, for large-scale plants offshore and plants in artic areas. The budget is 350 million SEK, and the project will run for five years.

The investment subsidy program for wind power (1998 to 2002) had the purpose of stimulating the market for wind power. During the lifetime of the program, the level of subsidies changed from 15% to 10% of the investment cost. The resources in the program were all allocated in 2003, and the program ended. The granted subsidies for 2003 were 83 million SEK. These projects had a capacity of 89 MW. Another support – "small-scale electricity support–" for generators of 1,500 kW ended in 2003 as well.

These two support systems were replaced by a new, market-based system with tradable electricity certificates (*Elcertifikat*) on 1 May 2003. The certificate system will move the cost for supporting renewables from the public treasury to electricity consumers.

The Swedish National Energy Agency is responsible for the administration of the certificate system and will evaluate the system during 2004. The Swedish National Grid company, Svenska Kraftnät, issues electricity certificates to the operators of approved power plants for wind, solar, small hydro (maximum of 1,500 kW), biomass, and new hydro. Existing, large hydropower (about 65 TWh/yr) is excluded from the electricity certificate system. Different renewables compete with each other on the market, and one certificate will be issued for each megawatt-hour of electricity

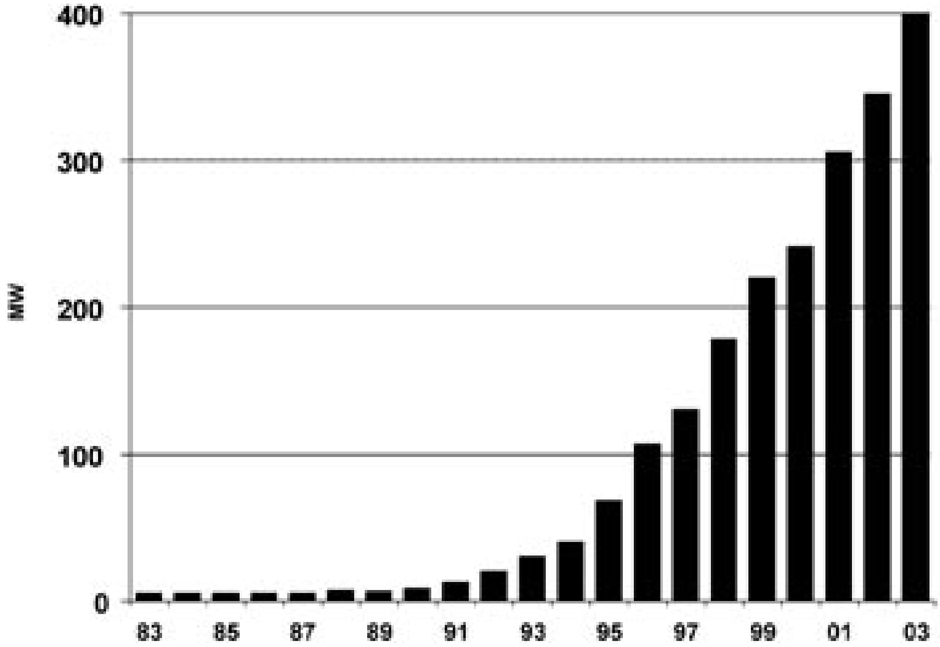

Figure 18.2 Wind power capacity (MW)

generated. From now on, the operator will have two products on the market: electricity and electricity certificates. They can be sold independent of each other.

The system includes a compulsory quota on electricity consumers. The first year it will be 7.4%, which means that, by law, electricity consumers must buy certificates that correspond to 7.4% of their electricity consumption during that year. The electricity-intensive industry will be excluded from the quota demand. In addition, a guarantee price of the electricity certificates is set during the years 2003 to 2007. The price in 2003 was 0.06 SEK/kWh. The quota will be increased by the parliament every year, and the quota for 2010 is planned to be about 17%. The sanction to be paid to the state for consumers and electricity suppliers that do not fulfill their quota demand is decided by the parliament to be 150% of the average certificate price during that year, but a maximum of 0.175 SEK/kWh for 2003 and a maximum of 0.240 SEK/kWh for 2004.

Unit Cost Reduction

Fundamental research at several universities, in co-operation with developers of wind projects and manufacturers, are continuously being carried out in order to reduce production cost.

18.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The average capacity of turbines installed in 2003 was about 980 kW. With a reduced cost of production, in combination with the new electricity certificate system, a reasonable condition for further development is expected.

Operational Experience

According to Swedish wind turbine monthly and annual statistics, the average availability during 2002 was 97.9%. The same data for 2001 was 98.2%. From 1996 to 2000, the average availability was 98.4%.

Main Constraints on Market Development

The process from planning a new power plant to actual production is very time consuming, especially for offshore projects, where fundamental work and money must be spent on environmental studies.

Public attitudes to wind power, especially its impact on the landscape, is a significant factor that influences practically every wind project. Other environmental aspects – such as noise emission and impact on wildlife, both onshore and offshore – are on the agenda in the process of obtaining planning and production permits. Extensive research has been carried out, and still is, in this area of interest. The aim is to come to an agreement on how windmills can be properly integrated in the environment.

Restrictions from the military have also stopped many wind projects. The military sees risks for disturbances of military microwave links, radar, intelligence activities, and aircraft at low altitudes. A research project is aiming to create a reliable model of the disturbance wind turbines cause on the military microwave links, radar, and intelligence activities. Thus far, the results show that the disturbance due to wind turbines on radar has been quite overestimated. New rules will facilitate deployment near such military activities.

Due to heavy investments involved in large-scale offshore projects, a market constraint may be the ability to get the actual funding for the project. Most large-scale projects will require so-called project financing as a financial solution, which requires a long-term forecast regarding revenue flow (i.e., the electricity price and the electricity certificate). This implies that the market-based system with certificates must be a trustworthy and long-term system.

8.6 ECONOMICS

Trends in Investment

During the years 1998 to 2001, approximately 400 million SEK/yr was invested in erecting wind turbines. The

	2002 MW	2002 TWh	2003 MW	2003 TWh
Hydropower	**16,097**	**66.0**	**16,097**	**53.0**
Nuclear power	**9,424**	**65.6**	**9,424**	**65.0**
Thermal power production (CHP, cold condensing, GT)	**6,374**	**11.2**	**6,374**	**13.0**
Wind power	**345**	**0.6**	**399**	**0.6**
Net import		**5.4**		**14.0**
Total	**32,234**	**148.8**	**32,294**	**145.6**

Table 18.1 Total installed electricity capacity and generation in Sweden, 31 December 2002 and 2003 (preliminary)

investment subsidy of 15% had a budget of 60 million SEK/yr. The decided extra 40 million SEK/yr for 2001 and 2002 has increased the investments for 2001 and 2002 to 660 million SEK.

The new, market-based system with electricity certificates for renewable electricity generation, which replaced the investment subsidy, has not yet been evaluated. Since it has been running less than a year, it is too early to draw a conclusion concerning its impact on the market development for wind power.

Trends in Unit Costs of Generation and Buy-Back Prices

The deregulation of the Swedish and Nordic electricity markets in 1996 initially led to low electricity prices, but the trend changed in 2001 and prices increased due to spot-market development. Consumers paid a significantly higher price in 2003 compared to a few years ago, especially those without a fixed-price contract. The increase of the electricity price is mainly due to a lower level of hydropower generation as a result of less water flow to reservoirs (Table 18.2). The prices charged to various customer categories are determined by tariff systems, which are made up of a mixture of variable and fixed charges.

The average NordPool price in Sweden during 2003 was 0.333 SEK/kWh (http://www.nordpool.no, under Elspot and then Monthly Prices). The deregulated market gives the possibility for the turbine owner to sell electricity to any customer. Since 1 November 1999, the wind energy producers must compete on the same market as conventional electricity producers.

The base price for electricity generation in Sweden for most producers is decided by the market price on the market place, NordPool. Since deregulation in 1996, monthly average spot prices have varied between 0.066 SEK/kWh and 0.668 SEK/kWh. Annual average price in 2001 was 0.211 SEK/kWh, and in 2002 it was 0.252 SEK/kWh.

Typical customer	Network services öre[1]/kWh			Electrical energy, öre/kWh		
	2002	2003	Change %	2002	2003	Change %
Apartment	42.8	43.4	1.40	35.6	51.9	0.46
Single-family house without electric heating	37.6	38.2	1.60	31.6	47.1	0.49
Single-family house with electric heating	20.9	21.1	0.96	29.6	44.7	0.51
Agriculture or forestry	22.2	22.8	2.70	29.3	44.5	0.52
Small industrial plant	15.4	15.4	0.00	28.8	44.3	0.54
Medium-sized industrial plant				28.5	44.8	0.57
Electric-intensive industrial plant				28.3	48	0.70

(Footnotes)
[1] 100 öre = SEK 1

Table 18.2 Price of network service and electricity, excluding taxes, on 1 January 2003 in sales of electricity to various typical customers
(Source: Elmarknaden, ET 10:2003, Swedish Energy Agency)

On top of that market price, the wind turbine owner receives by law a reduction of the energy tax, a so-called “environmental bonus,” which during 2003 has been 0.181 SEK/kWh. It is a compensation for the environmental advantages of wind power. The level of this bonus will gradually decrease and be replaced by the electricity certificate system, and after 2009 this bonus is expected to be zero. During this time, the bonus for wind turbines offshore will be slightly higher than for onshore. Additionally, there was a temporary support of 0.090 SEK/kWh for small-scale electricity producers (to a maximum generator size of 1,500 kW) until 30 April 2003. The wind turbine owner also gets an income from the net owner, related to the value of the decreased electricity net losses, which on average results in about 0.010 SEK/kWh to 0.015 SEK/kWh.

After the introduction of electricity certificates on 1 May 2003, wind turbine owners have, on average, received a market tender price and other support. Approximate prices are as follows:

market tender, 0.330 SEK/kWh;
environmental bonus, 0.181 SEK/kWh;
electricity certificates, 0.200 SEK/kWh;
local grid value, 0.010 SEK/kWh;
total average of 0.721 SEK/kWh.

18.7 INDUSTRY

Several manufacturers have service and sales activities in Sweden, such as Vestas, Enercon, Scan Wind, and Nordex. Two manufacturers have developed large wind turbines in Sweden: Kvaerner Turbin AB and Nordic Windpower AB.

Manufacturing

Does not apply.

Industry Development and Structure

The 3-MW prototype wind turbine, Näsudden II, on the island Gotland has generated 46.056 GWh by 2 February 2004. It began operation on 1 June 1993, and the generator has been connected to the network for 44,909 hours. This is a new world record for electricity generation by a single wind turbine. The former similar record was 36.634 GWh for the 3-MW wind turbine at Maglarp in southern Sweden (in operation 1982 to 1993).

18.8 GOVERNMENT-SPONSORED R,D&D

The overall goal for the Swedish wind energy research program is to develop the knowledge within the wind energy area to make it possible to manufacture and develop wind turbines and utilize wind energy efficiently in the Swedish energy system.

In the beginning of 2002, an R&D program in the wind energy area started with a three-year budget of approximately 90 million SEK for 2002 to 2004. The research activities are divided into four, goal-oriented categories: (1) more confident assessment of power production, (2) cost-effective wind energy converters, (3) effective integration of wind power into the power system, and (4) better impact assessments and appropriate planning and regulation. *The IEA Strategy on R&D*, published in 2001, influenced this subdivision.

The Swedish Defence Research Agency (FOI) manages the program on behalf of the Swedish Energy Agency. The program contains basic and applied research as well as development projects. Basic research is fully financed by the Swedish Energy Agency, while the latter requires funding from industry. More information can be found at http://www.vindenergi.org.

Priorities

Research was previously very technology oriented, but in a stage when more wind turbines fit into the landscape, “softer” issues (e.g., planning, environmental, acceptance) have been given higher priority. At the same time, it is important to continue research in the conventional technology areas in order to increase availability and reduce costs.

New R,D&D Developments

A bird study has been finalized at the offshore wind power plants, Utgrunden and Yttre Stengrund (in Kalmarsund). Radar has been used to follow bird movement in intense bird migration areas in order to evaluate possible effects on seabirds. The study shows that there is only a very small risk of collision between the seabirds and the windmills. The birds avoid the windmills with a margin of 200 m or more. Almost no birds have been recorded injured or dead at the wind power site.

L. Bergdahl, PhD, at Chalmers University, Sweden, has conducted a valuable contribution to the international standardization work regarding ice loads on offshore wind power plants. The project was funded by the Swedish Energy Agency through the three-year R&D program previously mentioned.

Offshore Siting

The following wind projects have been commissioned offshore in Sweden:

1990 Nogersund one 220-kW turbine
1998 Bockstigen-Valar five 500-kW turbines
2000 Utgrunden seven 1,400-kW turbines
2001 Yttre Stengrund five 2,000-kW turbines

In the sound, Öresund, between Sweden and Denmark, Eurowind has received governmental permission for an offshore project with 48, 1.5-MW wind turbines. West of the city, Karlskrona, in southeast Sweden, the utility Vattenfall conducted a feasibility study for an offshore project with large (3-MW to 4-MW) wind turbines. In the city’s preliminary oversight planning, the offshore site is planned for about 100, large MW wind turbines.

During the year, several other Swedish offshore wind farm projects were further developed, which are in different planning and study phases. The projects are planned to be located along the entire coastline, but with a concentration in the most southern part of Sweden. Discussions with local and regional authorities are being carried out, and the outcome of this is dependent on among others the economic prerequisites for wind power as well as permission from the government (for plants greater than 10 MW).

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Chapter 19
Switzerland

19.1 INTRODUCTION

Wind energy is an important part of the national program, SwissEnergy. Switzerland participates in the IEA Implementing Agreement on Wind Energy Research and Development, Task XIX – Wind Energy in Cold Climates.

19.2 NATIONAL POLICY

The objectives that have been set for the new SwissEnergy ten-year program are derived from the Federal Constitution and the *Energy and Carbon Dioxide Laws* and reflect Switzerland's commitments under the international convention on climate warming. Specifically, the objectives are as follows:

1. The consumption of fossil fuels in Switzerland and the concomitant carbon dioxide emissions must be reduced by 10% from 2000 to 2010.
2. The growth of electricity demand must not exceed 5%.
3. The contribution of hydropower to net demand must not be reduced, despite deregulation of the Swiss electricity market.
4. The contribution made by other forms of renewable energy to total electricity production must increase to 0.5 TWh, or 1%, and to heating energy by 3 TWh, or 3%.

Other important SwissEnergy objectives that are less easy to quantify include the following:

1. Development of greater awareness of the energy dimension among the general public as a prerequisite for the optimum implementation of voluntary measures
2. Closer co-operation among all partners
3. A spirit of innovation in all fields and an overall strengthening of the Swiss economy

All activities and projects within the wind program focus on installing wind power generators at the evaluated sites in the short and medium term. The operational experience gained will contribute significantly to fulfill the goals set by SwissEnergy in the field of renewable energy.

Strategy

The Federal Department of the Environment, Transport, Energy and Communications (DETEC) – with its offices Swiss Agency for the Environment, Forests and Landscape (SAEFL), Swiss Federal Office of Energy (SFOE), and Federal Office for Spatial Development (OSD) – have published a media report with a clearly positive statement concerning wind power generation in Switzerland. In accordance with the strategies developed by SwissEnergy, it aims at an annual production of 50 GWh to 100 GWh from wind power by 2010. This equals 10% of the goal for all renewable energies set by the federal program SwissEnergy.

Based on these targets, a concept called Konzept Windenergie Schweiz (BFE), conducted on behalf of the SFOE in the year 2003, identifies sites suitable for wind power plants that offer a potential to cover 3% to 5% of the electricity demand. At very windy locations outside landscape zones, about 300 wind power plants could produce electricity of about 500 GWh. This study is now actualized considering the newest wind turbines.

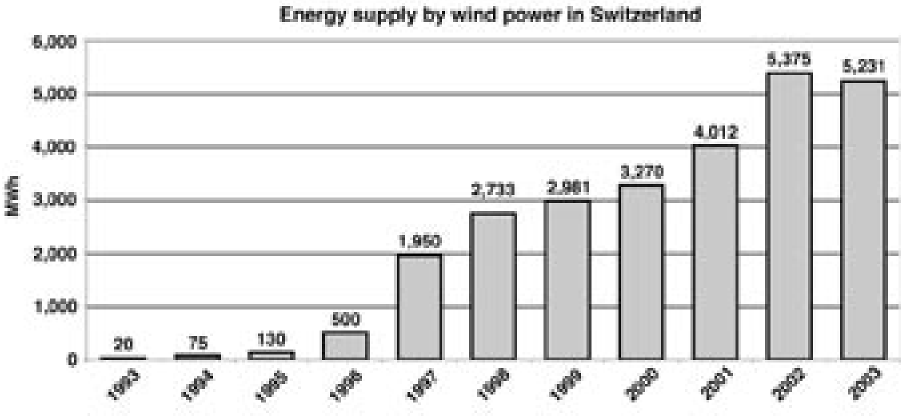

Figure 19.1 Development of Swiss wind energy supply

Specific focal points in research for wind power generation in hilly and mountainous terrain will provide more know-how to enhance Swiss companies' opportunities in the globally booming wind energy market.

In 2003, the budget for wind-energy-related R&D projects was 260,000.00 euro, which means a reduction of 28% compared to 2002. An amount of 400,000.00 euro is spent on promoting activities.

Progress Towards National Targets

The "wind year" 2003 was dull in Switzerland. Due to difficult planning procedures and growing opposition from landscape protectors, only one small wind turbine was newly installed. Besides that, the wind blew about 20% less than an average year. The 5,231 GWh produced by wind power plants in 2003 amounted to about 10% of the goals for 2010.

19.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The 21 plants installed so far, with a total capacity of 5.36 MWp, produced 5,231 GWh in 2003. The capacity of wind power plants in Switzerland has not increased in the last year.

Rates and Trends in Deployment

At the moment projects are planned with a total production of more than 35 MW. By the beginning of 2004, projects with a capacity of 4.35 MW will have building permits. So, it is likely that the amount of wind power produced in Switzerland will nearly double during 2004.

Contribution to National Energy Demand

Electricity produced by wind energy meets 0.01% of the total use of electricity in Switzerland.

19.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The federal government's wind energy program offers support to planners and operators of wind energy projects in various ways, including wind energy manuals, location maps, regional planning aid,

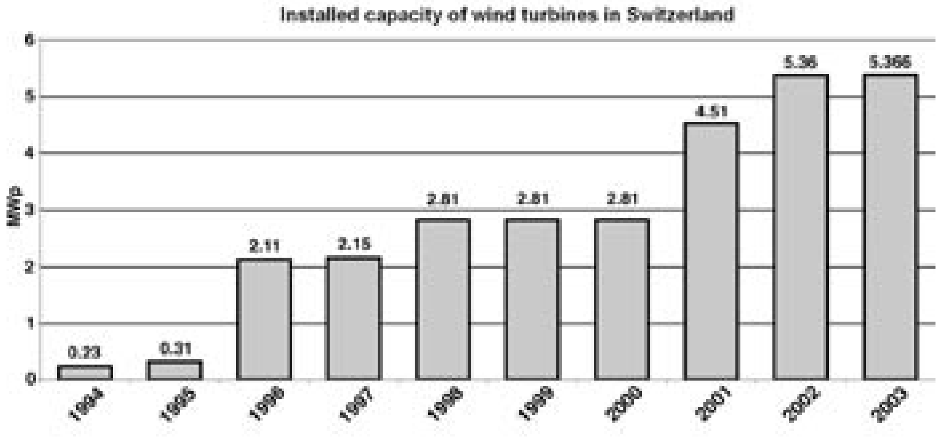

Figure 19.2 Development of installed wind power in Switzerland

promotion subsidies, and wind energy association memberships.

Suisse Eole is the organization for supporting wind energy in Switzerland. It supports the wind energy branch in fulfilling the goals of the federal office of energy. Suisse Eole is a recognized partner of the program SwissEnergy. More information on Suisse Eole can be found on its website, http://www.suisse-eole.ch/default-d.htm.

Unit Cost Reduction

Does not apply.

19.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Since 2000, wind energy plants installed in Switzerland have had capacities of 6 kW (nine plants), 800 kW (one plant), and 850 kW (two plants). Bigger plants (1.75 MW) will be installed in 2004. The installation of these large turbines will be a challenge, due to difficult exploitation in hilly and mountainous terrain and other issues.

Operational Experience

Several operations have made available consolidated data on the performance of wind power plants in hilly and mountainous areas under rough climatic conditions. These operations are the 30-kW wind power plant on Simplon pass (in existence since 1990 at 2,000 m above sea level); the 150-kW wind power plant on Grenchenberg (in existence since 1994 at 1,300 m above sea level); the 80-kW plant on Gäbris (in existence since 1995 at 1,100 m above sea level); the 2,960-kW wind park on Mount Crosin (in existence since 1996 at 1,200 m above sea level); the 30-kW plant on Titlis (in existence since 1997 at 3,000 m above sea level); and the 850-kW plant on Mount Gütsch near Andermatt (at 2,300 m above sea level). Unfortunately, the turbine on Mt. Gütsch suffered serious blade damage in December 2003.

Main Constraints on Market Development

Because of fundamental opposition of the Swiss Foundation for Landscape Protection, a national concept has been worked out, which realizes the goals set by DETEC. On the basis of agreed criteria, possible sites for small wind parks have been defined, described,

Figure 19.3 Repairing blades of the 800-kW wind turbine on Mount Gütsch, 2,300 m above sea level in Andermatt, Switzerland

and plotted on maps. This will reduce the uncertainties in the planning procedure by the cantons.

There is a good chance that due to the growing market with green electricity, the demand for wind power will rise in the near future.

9.6 ECONOMICS

Trends in Investment

Wind energy plants are not generally subsidized in Switzerland. For pilot and demonstration projects, the SFOE can support up to 60% of costs that cannot be recouped. This is also valid for studies and concepts for site assessments. Unfortunately, these finances are under strong political pressure and therefore have a very uncertain future.

Trends in Unit Costs of Generation and Buy-Back Prices

The specific costs of larger wind power plants amounts to about 2,000.00 Swiss Francs (CHF)/kW (1,380.00 euro). Thus, the prime costs at windy locations are lower than 0.20 CHF/kWh (0.135 euro). Wind energy offers good opportunities for local energy production in remote areas and its importance will increase in a liberalized electricity market.

The production costs of the newest, 2001-installed, 850-kW wind energy plants amount to about 0.12 CHF/kWh (0.085 euro). The SwissEnergy law obligates energy suppliers to re-buy the energy produced by independent producers to 0.15 CHF/kWh (0.105 euro). Current electricity producing price in Switzerland is 0.08 CHF/kWh

(0.055 euro). Because the supplementary costs cannot currently be passed on, the claiming of these means turns out to be very difficult. A new, progressive regulation – in which the high-voltage grid operators pay these costs– is about to be applied.

19.7 INDUSTRY

Manufacturing

Both offshore installations and power plants in mountainous areas must achieve high reliability, considering the limited access and the rough climatic conditions. This opens market opportunities for the expensive, but highly qualified, electrical and measuring industry in Switzerland.

The Swiss electrical industry's know-how in the matter of medium voltage gains in significance with the increasing power (greater than 1 MW). Firms like Bartholdi AG (a generator manufacturer), ids AG, and Technocon (an inverter manufacturer) have already faced this challenge. Aventa AG produces small power plants up to 6 kW, nine of which are installed in low wind areas.

Industry Development and Structure

Wind power generation holds enormous potential of great economic importance beyond the small Swiss market. Its development is linked to crucial fields of competence of the Swiss electrical and mechanical industry. A substantial home market is an invaluable asset for Swiss companies on the international market.

9.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The following research strategies have helped reach Switzerland's wind energy goals.

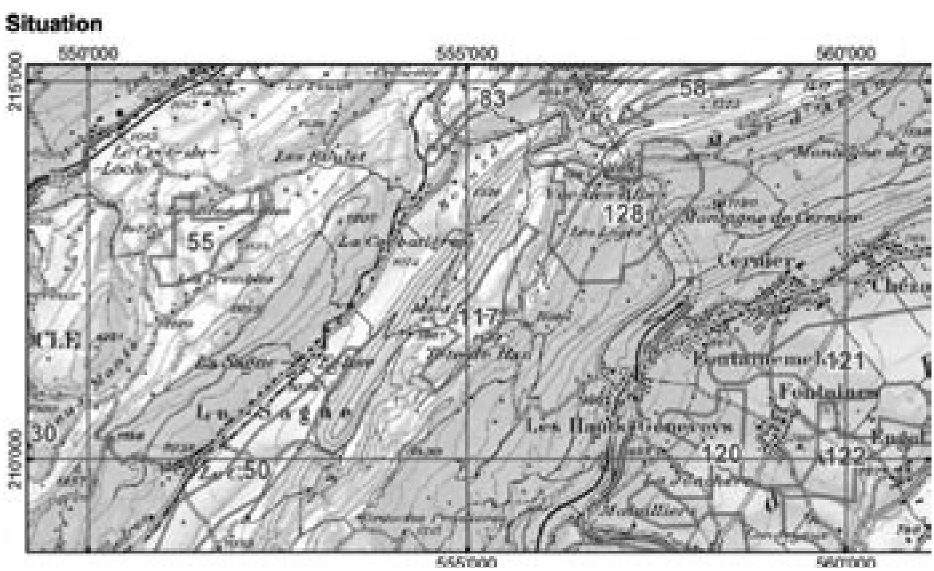

Figure 19.4 Possible sites for wind parks evaluated within the wind energy concept of Switzerland, example region Vue des Alpes

Promoting acceptance for wind power generation

1. Well-founded data analysis concerning the influence of wind power plants on fauna, flora, and tourism
2. Compilation of founded guidelines for projects with small impact on the environment, in co-operation with environmental organizations and the wind energy industry
3. Evaluation of wind power's contribution to sustainable energy supply and integration into global strategies
4. Elaboration of a nationally coordinated concept for wind power generation, including a definition of spatial development

Local electricity production in remote areas

1. Wind energy as a supplement to electrical power generation in grids, strategies for ecological power supply as an additional income of energy suppliers in remote areas, and marketing strategies
2. Appropriate participation models for the local population, also in regard to matters of acceptance
3. Wind energy as a supplement to electricity production in insular situations (e.g, alp co-operatives for southern countries)

Developing a centre of competence "Wind Power Generation in Mountainous Areas"

1. Enhancing expertise on project development in complex terrain, support for site assessments with specific requirements, and planning aids
2. Developing adapted modeling software for site assessments, validation, and optimization
3. Operating test plants in mountainous areas; interpretation of operational experience; and integration into new plant concepts for networks, small insular grids, and stand-alone plants
4. Analyzing date from the 800-kW wind turbine on Mount Gütsch
5. Participation in a project within the EU INTERREG III B Alpine Space Programme, titeld: ALPINE WINDHARVEST - Development of Information Base Regarding Potentials and the Necessary Technical, Legal and Socio-Economic Conditions for Expanding Wind Energy in the Alpine Space; Partners from Austria, Slovenia, Italy, France and Switzerland

Developing specific plant components and concepts

1. For rough climatic conditions (ice, cold, turbulence)
2. With high reliability (difficult access, also for off-shore)
3. For erection in areas with limited access

New R,D&D Developments

In 2003, the following projects have been accomplished within the above strategies:

1. Elaboration of a nationally coordinated concept for wind power generation, including a definition of spatial development
2. Inquiry for wind energy application in huts of the Swiss alpine club
3. Market study of Aventa turbines for use in low winds
4. Participation in a project within the EU INTERREG III B Alpine Space Programme, titled, Alpine Windharvest – Development of Information Base Regarding Potentials and the Necessary Technical, Legal and Socio-Economic Conditions for Expanding Wind Energy in the Alpine Space (partners from Austria, Slovenia, Italy, France, and Switzerland)

Wind Database on the Web

Detailed information on the following items is available from the Suisse-Eole website under the title, Windmaps of Switzerland:

1. Wind measurement points run by MeteoSwiss
2. Average wind speeds at the mentioned measurement points, years 1983 to 1997
3. Monthly averages of wind speed from 1998
4. Results of temporary measurements at supported wind energy projects
5. Location description of wind power plants and wind forecast for the next few days (useful for visits)
6. Publication of the potential maps (wind speed and landscape protection aspects)
7. V3-toolbox: calculation of the WEIBULL-parameter A, k from a measured frequency distribution, program in Microsoft Excel 97
8. Detailed description of the relevant geographical aspects, including zones of protected landscape

Site Assessment

The government's wind energy program substantially supports site assessment (i.e., wind measurements, expert opinion on climate and environmental matters, and feasibility studies) with financial aid. The results of these investigations have been published in reports via ENET, at http://www.energieforschung.ch.

Offshore Siting

Does not apply.

References

- http://www.suisse-eole.ch/default-d.htm
- http://www.sbg.ac.at/pol/windharvest/
- http://www.suisse-eole.ch/images/1300/petites-eoliennes-d.pdf
- http://www.suisse-eole.ch/techpro-outils-d.htm
- http://www.energieforschung.ch

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Chapter 20
United Kingdom

20.1 INTRODUCTION

In the United Kingdom in 2003, a total of 95.42 MW of new capacity was installed, bringing the total installed capacity to 647.6 MW, an increase of about 20%. Although encouraging, this figure falls short of that anticipated for 2003 and highlights the long way to go to meet the target of 10% from renewables by 2010.

In order to assist U.K. industry – and recognizing the reluctance of the financial community to take risks on wind projects with financing periods of 10 to 15 years – the government announced in December 2003 that it was increasing the level of the Renewables Obligation (RO) to 15% by 2015. The increased certainty provided by the higher target will be vital in securing the necessary financing for building large-scale wind projects, particularly those proposed offshore.

During early 2003, the U.K. government published its *Energy White Paper* that set out four goals for the U.K. energy policy. These are discussed in detail in the following section.

The Capital Grants Scheme for offshore wind has now awarded a total of some 117 million United Kingdom Pounds (UKP) spread over 12 offshore wind farms, with consents to build up to 1,163 MW of new capacity.

Finally, in late 2003, the Crown Estate announced the successful bids for 15 new sites in Round 2 of the United Kingdom's leasing for offshore wind farms. The wind farms, which are expected to be producing electricity by the end of the decade, are expected to provide between 5.4 GW and 7.2 GW of generating capacity, enough electricity for more than one in six U.K. households.

20.2 NATIONAL POLICY

The U.K. government is committed to putting the environment at the heart of its decision making. As a result, renewable energy is high on its political agenda. In the United Kingdom, the RO became law on 1 April 2002. This important government measure will provide an assured market for renewable energy for at least the next 25 years. Through the obligation, together with the Climate Change Levy (CCL), it is currently estimated that by 2010 the value of support to the U.K. renewables industry will be 1 billion UKP per year.

On 24 February 2003, the government released its *Energy White Paper: Our Energy Future – Creating a Low Carbon Economy*. In drafting the white paper, more than 6,500 individuals and groups took part in the consultation, representing the most significant consultation on energy policy ever carried out in the United Kingdom. The white paper set out four goals for the nation's energy policy, as follows:

1. To work towards cutting carbon dioxide emissions by some 60% by 2050 (as recommended by the Royal Commission on Environmental Pollution), with real progress by 2020
2. To maintain the reliability of energy supplies

3. To promote competitive markets in the United Kingdom and beyond, helping to raise the rate of sustainable economic growth and to improve productivity
4. To ensure that every home is adequately and affordably heated

A range of measures were announced including the following:

1. An ambition to double the share of electricity from renewables by 2020 from the existing 2010 target of 10%
2. 60 million UKP in new money for renewables projects, bringing total spending on renewable energy up to 348 million UKP over four years
3. Reforming planning rules to unblock obstacles to renewable energy
4. A new carbon trading system to come into effect from around 2005 that will give energy suppliers and consumers incentives to switch to cleaner energy
5. creating a new Energy Research Centre to help develop the latest cutting- edge energy technologies.

Strategy

To help deliver the stated energy policy, the United Kingdom has put in place a range of measures. They are as follows:

1. Introduced a Renewables Obligation for England and Wales in April 2002 that will provide incentives to generators to supply progressively higher levels of renewable energy over time – the cost is met through higher prices to consumers
2. Exempted renewable electricity from the CCL
3. Created a renewables support program worth 250 million UKP from 2002 to 2005
4. Drew up a strategic framework for a major expansion of offshore wind
5. Created a new organization within government, Renewables UK, to help the nation's renewables industry grow and compete internationally

In addition, from 2005 onwards, the EU emissions trading system will provide a further incentive for renewables. The above measures are being pushed forward in consultation with industry. A new Renewables Advisory Board – comprised of representatives of the relevant industries, the government, and the devolved administrations – has been set up with a remit to provide expert independent advice to the U.K. Department of Trade and Industry (DTI) on renewable issues.

Progress Towards National Targets

The United Kingdom is still on track to meet its Kyoto targets to cut greenhouse gases and its domestic goal of reducing carbon dioxide, according to figures published in March 2003. Greenhouse gas emissions dropped by 3.5% in 2002. The drop is in line with the trend needed to ensure the United Kingdom meets its Kyoto target to reduce greenhouse gases to 12.5% below 1990 levels by 2012.

Carbon dioxide emissions fell by 9.0% from 1990 to 2001, keeping the domestic Climate Change Programme goal – reducing carbon dioxide to 20% below 1990 levels by 2010 – firmly on the agenda. The carbon dioxide drop came at the same time as a 30% growth in gross domestic product (GDP), proving that economic growth does not have to be at the expense of a cleaner environment. The figures also suggest the proportion of the U.K. electricity generation accounted for by all renewables in 2002 was approximately 3%, up from 2.6% in 2001.

20.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Between 1 January 2003 and 31 December 2003, the United Kingdom installed a total of 58 wind turbines – 28 onshore and 30 offshore – with a total capacity of 95.42 MW. The average capacity of the turbines installed onshore during 2002 was 1.3 MW. The average capacity of turbines installed offshore was 2 MW. This brings the total number of turbines in the United Kingdom to 1,057, generating some 647.6 MW of power.

Rates and Trends in Deployment

The rate of deployment in 2003 was the highest ever achieved in the United Kingdom, with more than 95 MW of capacity installed, just beating the previous highest ever of 87 MW installed in 2002. Even so, 2003 was not as good a year as the British Wind Energy Association (BWEA) anticipated. The initial projection for 2003 showed more than 300 MW identified for commissioning. However, a number of factors listed below caused this to fall to 100 MW.

Against this background, the BWEA reported that a total of more than 1,300 MW won planning permission in 2003, almost exactly double the total amount built during the previous 12 years combined. Of the 1,300 MW, some 943 MW (discrepancies may occur between capacities consented and capacity that will be built, with particular reference to offshore), representing 75% of the total consented is to be installed offshore. This brings the total of built, under construction, and planned projects with consents to 1,163 MW.

The average size of turbine currently installed offshore is 2 MW, which will increase to 3.5 MW, taking into account turbines to be installed in the next few years. This clearly demonstrates the move towards bigger machines.

Contribution to National Energy Demand

Figures for 2003 are not available.

20.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

Three sources of financial support for electricity generated from renewable sources have already been mentioned: the RO, the Emissions Trading Scheme, and the CCL. The RO has been described as the cornerstone in delivering the nation's target for renewable energy. Introduced in April 2002, it has prompted an unprecedented level of interest in the renewables, and particularly wind, sectors.

By way of illustration, in the first year of operation of the RO, the U.K. wind industry effectively doubled, with consents for an additional 525 MW of capacity, which is equal to the combined total built during the previous 11 years. This success was repeated in the first quarter of 2003 when a further 567 MW of capacity was granted permission. Planning consents have been steadily won throughout the year such that the U.K. wind industry has just less than 650 MW of capacity installed up to 2003, but an amazing total of well over 2,000 MW of consented schemes awaiting construction.

Following a 2003 consultation, the Renewable Energy Guarantee of Origin (REGO) scheme came into force on 27 October 2003. It now enables renewable energy producers to show that their electricity comes from a green source. It will encourage the development of renewable energy projects by enabling generators to provide their buyers with an assurance of the greenness of their product. The scheme will be particularly helpful to small generators that do not generate enough electricity to qualify for Renewable Obligation Certificates (ROCs).

Originally launched in October 2001, the Capital Grants Scheme for offshore wind had the primary aim to stimulate early development of a significant number of offshore wind farms. This was desirable in order to do the following:

1. Deliver an early contribution to the RO and emissions trading
2. Underpin development of the industry and the equipment supply chains
3. Provide a learning experience that can improve confidence
4. Help reduce future costs and enable future projects to proceed without the need for grant support

In round one of the scheme, as reported last year, the first two grants were announced in October 2002 for the offshore wind farms planned to be developed at North Hoyle in Wales and at Scroby Sands in Norfolk. Each grant was for 10 million UKP.

Following closure of the second round at the end of 2003, an additional 38 million UKP in capital grants was announced by the energy minister on 26 March 2003 for offshore developments around the British Isles. The projects awarded grants as follows:

1. Warwick Offshore Wind for the Barrow Offshore project, Cumbria – 10 million UKP
2. GREP UK Marine for the Kentish Flats project, North Kent – 10 million UKP
3. Offshore Energy Resources and Solway Offshore for the Robin Rigg project, Solway Firth (two projects) – 18 million UKP

These projects are among six sites to have been awarded planning consent from the 19 identified for offshore development by the Crown Estate. Together the projects will create more than 500 wind turbines, generating 1,500 MW of electricity, or 1.5% of the United Kingdom's energy needs. The minister used his speech as an opportunity to outline how the DTI would be allocating a portion of the 60 million UKP in additional funds promised for renewables in the *Energy White Paper* and the 38 million UKP allocated in the chancellor's 2002 Spending Review, with offshore projects receiving approximately 40 million UKP.

The third round closed on 30 June 2003, and on 28 October 2003 the minister announced an additional 59 million UKP of funding for offshore wind farms. Six offshore wind farms will share the capital grant. They are as follows:

1. Burbo, in Liverpool Bay, 6.5 km from the Wirral Coast – 10 million UKP
2. Rhyl Flats, North Wales – 10 million UKP
3. Lynn, 5 km offshore from Skegness, Lincolnshire – 10 million UKP
4. Gunfleet Sands, 7 km off Clacton-on-Sea, Essex – 9 million UKP
5. Cromer, 7 km north of Cromer – 10 million UKP
6. Inner Dowsing, 7 km north of Cromer – 10 million UKP

A further renewable energy initiative for communities and households was launched in January 2003 by the DTI. It is known as the Clear Skies initiative and is a campaign worth up to 10 million UKP. Its aim is to encourage homeowners, schools, and communities across the United Kingdom to take the initiative in developing and installing their own renewable energy schemes and to capture the imagination of individuals and local communities that want to play their part in the renewables revolution.

Unit Cost Reduction

As in 2002, no clear cost reduction has been observed in the last year. In the United Kingdom, a wind farm built today would typically cost about 675.00 UKP/kW installed, including infrastructure. Costs as low as 550.00 UKP/kW are possible where accessibility is good and grid connection costs are very low. Developers continue to be optimistic that onshore costs will fall further, to as low as 500.00 UKP/kW for some sites – due to larger, more efficient turbines and economies of scale.

North Hoyle began generating in November 2003, adding to the first offshore wind farm at Blyth in 2001. The extrapolated figure for Blyth was 834.00 UKP/kW. Official figures are not available for North Hoyle, but it is suggested that the costs are close to 1,000.00 UKP/kW. However, opinion is that there is considerable room for cost reduction coming from greater experience, improved installation techniques, larger wind turbines, and larger schemes. Indeed, several offshore contractors are currently pursuing various schemes that, if successful, will bring the cost down to between 650.00 UKP/kW and 700.00 UKP/kW.

20.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

A total of only six new projects, including one offshore wind farm and one extension to an existing site, started generating electricity to the grid in 2003. These projects are outlined in Table 20.1.

Figure 20.1 provides a graph of wind farm planning application success and failure rates by declared net capacity. It can be seen that there was a marked improvement in the application success rate, illustrating the recent successes of developments gaining permission.

Main Constraints on Market Development

The United Kingdom has historically had difficulty obtaining planning consent for wind farms in particular, and for renewable energy schemes in general. To date, there has been a radical difference between planning approval rates for wind farm development between countries in the United Kingdom and within England. This has led to uncertainty for developers and poses a potential problem for the government's 10% target.

Over the last five years, England has had an average approval rate at the local level of just 50%, compared to more than 90% in Scotland (Figure 20.2). This is testament to the strong policy guidance set out in Planning Policy Guidance Note (PPGN) 6 in Scotland in 2000. Not only has the English approval rate been below average, but there has also been massive inconsistency in decisions made between different parts of England. It is unlikely that there are any other forms of development that produce such an inconsistency of planning response across England. It was recognized that this needs to be addressed, and the white paper requires planning to be "streamlined and simplified" to remove it as one of the key obstacles to renewable energy development.

Since February 1993, *PPGN 22: Renewable Energy* has set out the government's national land-use planning policies for England. Following consultation on the government's *Planning Green Paper* published in December 2001, the government announced, on 18 July 2002, its intention to review and reform the national planning policy guidance. In this context, the United Kingdom's Office of the Deputy Prime Minister (ODPM) – in close consultation with the DTI and the Department for Environment, Food, and Rural affairs (DEFRA) and other relevant government

Online	Wind Farm	Location	Manufacturer & Rating (kW)	No	Project Capacity (MW)	Operator
Nov-03	North Hoyle - Offshore	North Wales Coast	Vestas 2MW	30	60	National Wind Power
Jul-03	Swaffham extension	Norfolk	Enercon E-66	1	1.8	Ecotricity
May-03	Altahullion	Londonderry	Bonus 1300	20	26	B9 Energy
April-03	Forss	Caithness	Bonus 1300	2	2.32	RES
Jan-03	Burra Dale II	Shetland	Vestas 850	2	1.7	Shetland Aerogenerators
Jan-03	Moel Maelogen	Conwy	Bonus 1300	3	3.6	Cwmni Gwynt Teg Cyf / EnergieKontor

Table 20.1 New projects that began generating electricity in 2003

departments – has carried out a review of PPGN 22. This resulted in the publication of a consultation paper on draft *Planning Policy Statement (PPS) 22: Renewable Energy*, in November 2003.

In brief, the key principles in PPS 22 stated the following:

1. Regional planning bodies and local planning authorities should accommodate renewable energy developments, and their plans should contain criteria-based policies designed to "promote and encourage," rather than restrict, the development of renewable energy resources. There will no place for planning policies that rule out or place con-

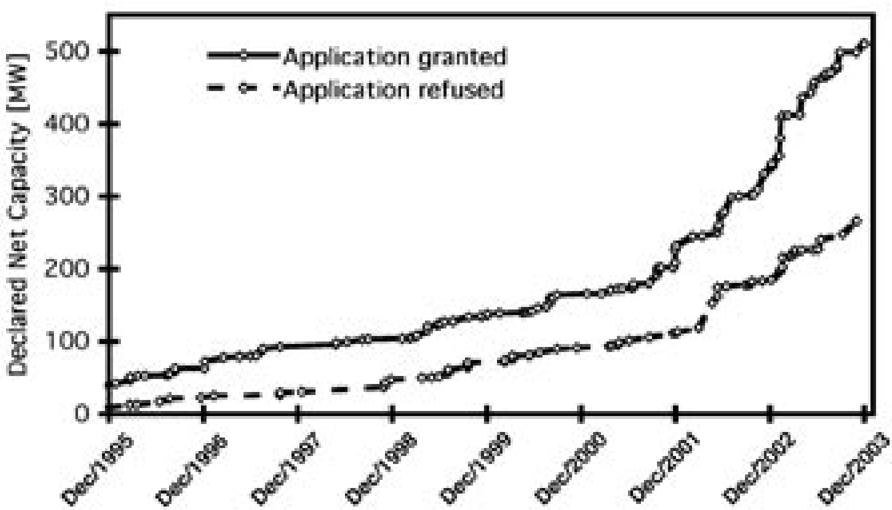

Figure 20.1 Wind farm planning application success and failure rates by declared net capacity

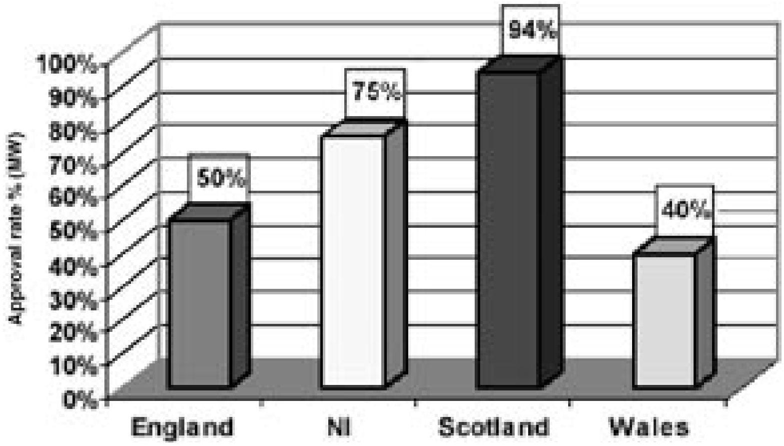

Figure 20.2 Local approval rates by country 1999 to 2003

straints on the development of renewable energy technologies.

2. Regional renewable energy targets should be introduced in regional plans as minimum targets to be monitored and increased if and when they are met.

3. When assessing proposals for renewable energy, the wider environmental and economic benefits are material considerations that should be given significant weight in determining whether proposals should be granted planning permission.

4. Planning authorities should foster community involvement in renewable energy projects and seek to promote knowledge of, and greater acceptance by, the public of prospective renewable energy developments that are appropriately located.

For renewable energy developers and planning authorities, locational considerations have been clarified for sites in the following designated areas: international and national designations, green belts, and buffer zones and local designations, and other locational considerations.

For wind turbines in particular, PPS 22 states, "Regional planning guidance and development plans should not include policies relating to the impact of wind turbines on radar and aircraft nor relating to separation distances from power lines, roads and railways. It is the responsibility of developers to address any potential impacts, taking account of Civil aviation authority and Ministry of Defence guidance in relation to radar and the legislative requirements on separation distances, before planning applications are submitted."

Consultation on draft PPS 22 closes on 30 January 2004. Following final publication of PPS 22, it is the government's intention to publish a companion guide to PPS 22. This document will contain technical advice and guidance on the various individual renewable technologies and examples of good practice within development plans and developments.

The limitations of the U.K. transmission system have long been understood. There is a net flow of power from the north to the south. The existing onshore electrical transmission infrastructure effectively tapers off as it progresses north, and the ability to transmit additional loads also reduces as it progresses north. In April 2003, Scottish Power and Scottish and Southern

Energy, together with Ofgem, announced plans to prepare the transmission grid for dealing with the expansion in renewable power. Both energy companies outlined major investment plans that will upgrade the transmission networks they operate and allow renewable energy generated in the northern regions of the British Isles – including the Highlands, Western Isles, Shetlands, and Orkney – to be transmitted to the rest of the United Kingdom.

One constraint not common to the rest of Europe, and of increasing prominence over the year, comes from the effect that wind farms may have on aviation, both in terms of radar systems and low flying. In order to ensure development of the wind industry – but recognizing that such development must take account of national defense and air safety – the DTI set up the Wind Energy, Defence & Civil Aviation Interests Working Group. The group includes representatives from defense and civil aviation as well as DTI and U.K. industry. The aim of the working group was to provide information and advice to developers, planners, military, and civil aviation personnel on potential effects of wind turbines on radar systems.

As one of its first tasks, the working group put together a document, *Wind Energy and Aviation Interests – Interim Guidelines*. The guidelines were launched on 2 October 2002 at BWEA 24 at Brighton. The working group has also commissioned various specific studies to further assist in the understanding of the effects of wind farms on radar systems. Rotating turbine blades might affect both military and civil radar in ways that could seriously compromise their operation.

20.6 ECONOMICS

Trends in Investment

Financing 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 RO, utilities and conventional power generators have become increasingly involved in wind farm development. Because of the high value the obligation places on renewables, corporate investment will yield high returns through an expansion of the core business whilst reducing exposure to penalty payments.

Wind has found particular favor because of its economics, its maturity, and its ability to deliver relatively quickly. However, research carried out during the summer of 2003, and presented to a House of Lords Select Committee in October, showed that because of the structure of the current RO, there is a high degree of uncertainty over the value of wind generated electricity after 2010. This is making it extremely difficult for projects planned for later this decade to obtain necessary financing. The wind industry is in a critical phase of development as it approaches the scheduled review of the RO in 2005 and 2006.

Recognizing the importance of the research and the reluctance of the financial community to take risks on projects with financing periods of 10 to 15 years, the government announced, on 1 December 2003, that it was proposing to increase the level of the RO to 15% by 2015.The proposal was warmly greeted by both the industry and financial community. The increased certainty provided by the higher target will be vital in securing the necessary financing for building large-scale wind projects, particularly those proposed offshore.

Trends in Unit Costs of Generation and Buy-Back Prices

In the existing U.K. market it is extremely difficult to decipher a typical generation cost from wind. Projects have been developed for less than 0.03 UKP/kWh under long-term, fixed price power purchase contracts where wind speeds are high (more than 9.0 m/s at hub height). The value of wind energy in the new climate – with electricity traded under the New Electricity Trading Arrangements (NETA) and the RO – can most easily be seen through auctions of the power generated from NFFO contracted wind farms.

The latest NFPA online auction of green electricity from NFFO contracts was completed on 14 August 2003. The auction began on Tuesday 12 August, and contracts were finally awarded to a total of ten successful bidders. In all, 256 contracts representing approximately 701 MW of green electricity generating capacity were successfully auctioned. The contracts are for electricity produced between 1 October 2003 and 31 March 2004. The average price, at 0.0681 UKP/kWh, was more than that of the previous auction, held in February 2003, when the average price was 0.0626 UKP/kWh. The price for wind was 0.0670 UKP/kWh, somewhat higher than the 0.0641 UKP/kWh from the previous auction.

20.7 INDUSTRY

Manufacturing

The United Kingdom continues to supply a wide range of components to the wind turbine industry, including blades, rotors, turbines, castings, towers, pitch bearings, and elastomerics. There are now two overseas companies with turbine manufacturing bases in the United Kingdom, along with U.K. companies expanding their current activities.

The United Kingdom now has well-established expertise in consultancy for site exploration, performance and financial evaluation, planning applications, and environmental impact statements. Growing interest in the offshore market has attracted new business for consultants in environmental assessment, meteorology, and oceanography. In addition, the increase in offshore activity has resulted in a number of offshore oil and gas contractors to redirect their offshore experience to the development of offshore foundations and installation techniques for offshore wind turbines.

Industry Development and Structure

As already mentioned, Renewables UK was set up in 2002. Its very simple sounding goal is to maximize the nation's involvement in renewables projects, both at home and abroad, in terms of jobs and investment in manufacturing services and suppliers. Renewables UK is a route for U.K. business to information on funding, business opportunities, and market analysis.

U.K. suppliers to the offshore oil and gas industry have decades of experience in operating within a demanding and difficult environment but lack the experience of operating effective, low-cost electricity generation systems. However, the oil and gas industry has a wealth of solutions in design, management, and construction that can have a positive effect on the viability of many of the new and innovative renewable energy concepts being pursued by developers. By combining this expertise with the developers' expertise in operating onshore renewable energy schemes within tightly regulated markets, the United Kingdom now has the potential to develop a new and distinct industry in offshore wind energy.

Renewables UK, Scottish Enterprise, Highlands and Islands Enterprise, and the

Scottish Executive have initiated a study to ascertain the health of the supply chain for the entire renewables market. The aim of the study is to determine the capability of the U.K. industry to rise to challenge of developing and maintaining a viable, long-term, globally active renewable energy industry. The United Kingdom has been split into two study areas: Scotland and the Rest of the United Kingdom. Key objectives of the study are as follows:

1. Identifiy the participants in the renewable industry in the United Kingdom and map them along the supply chains of the technologies under review
2. Determine the size of the current market and the potential size and structure of future markets within the context of the *Energy White Paper* goals
3. Assess the gaps in existing supply chains
4. Determine opportunities for the United Kingdom and identify the main constraints

20.8 GOVERNMENT-SPONSORED R,D&D

The main program for R&D is the DTI's New and Renewable Energy Programme. Approximately 1.7 million UKP was spent on the wind program area of the program in 2003 out of a budget for R&D support of renewables of 19 million UKP. The DTI's program supports industry-led and shared-cost R&D work into new and renewable energy technology. The work must be categorized as either industrial research or pre-competitive activity under the European Community State Aid rules. The principal requirement for all proposals is that they should include innovation that (1) offers the prospect for reduced cost and/or improved performance of new and renewable energy, with the goal of improving its competitiveness and the competitiveness of U.K. industry, or (2) helps the DTI to further understand the prospects for new and renewable energy.

Priorities

The DTI has identified certain specific topics that should be addressed as priorities. These priorities have been developed from the Technology Route Maps, developed by the DTI in consultation with industry, academia, and key stakeholders. Proposals for R&D projects that address these priorities are therefore expected to make a significant contribution to the Technology Route Maps. Greater attention is now being directed to the development of the offshore resource. This includes the following:

1. Reducing the cost of operation and maintenance (O&M)
2. Improving the availability and reliability of wind turbines
3. Developing innovative materials, processes, and components
4. Providing access
5. Improving installation techniques
6. Offering innovative designs
7. Mitigating the effect of wind farms on radar and other aviation

Proposals for developments specifically focussed on onshore wind technology are also considered, but with a lower priority.

New R,D&D Developments

Recent developments in R,D&D in the United Kingdom include projects looking at the design and manufacture of radar absorbent wind turbine blades, opportunities for reinforced thermoplastic composites in offshore wind structures, and the Merlin offshore wind turbine system.

Offshore Siting

In 2003, a total of eight offshore wind farms covering nine sites gained consent from the U.K. government: Barrow, Kentish Flats, and Robin Rigg in March; Burbo in July; and

Gunfleet Sands, Cromer, Inner Dowsing, and Lynn in October. Added to the three already granted consents in 2002 (Scroby Sands, North Hoyle, and Rhyl Flats), this brings the total offshore capacity to well over 1 GW. These are the first of the original 19 sites to be granted leases by the Crown Estate in what has become known as Round 1 of the United Kingdom's leasing for offshore wind farms.

Following the success of round 1, the DTI issued the Future Offshore consultation document in November 2002. This set out a preferred strategy for additional rounds of offshore wind farm development to be concentrated on three specific areas. It stated the intention to undertake Strategic Environmental Assessment (SEA) of the three areas to inform future rounds ahead of the introduction of the EU SEA Directive in 2004. It proposed new exploration licenses beyond the territorial sea limit and it also proposed a new bidding process for wind farms to enable best use of the seabed.

In May 2003, DTI issued the SEA for round 2 of leasing. This focused on three specific areas, which are as follows:

1. Thames estuary – the area between the Kent and Essex/Suffolk coasts extending in to the southernmost part of the North Sea
2. Greater Wash – extends from the Wash along the Norfolk and Lincolnshire coasts up towards Flamborough Head and out into the Southern North Sea
3. North West – extends from the north Wales coast to the Solway Firth and out into the Irish Sea

It was the DTI's intention that round 2 projects would provide as much capacity as the conclusions of the SEA would allow.

On 14 July, the DTI requested the Crown Estate to launch the competition for round 2. At the same time, DTI published responses to the Future Offshore and SEA consultation. The conclusions of the SEA resulted in the issue of guidance to the industry on the environmental restrictions that need to be adhered to for site selection within the three strategic areas. Following the issue of the tender, developers were required to submit project site coordinates by noon on 12 September and a full tender by noon on 15 October. Tenders were assessed by a panel of representatives from the Crown Estate and DTI, with consultation with other government departments where appropriate.

Details of the sites, together with the developers chosen to build them, were revealed on 18 December 2003, by The Crown Estate. They can be viewed in figure 3. The wind farms, which are expected to be producing electricity by the end of the decade, will provide between 5.4 GW and 7.2 GW of generating capacity, enough electricity for more than one in six U.K. households.

The new energy bill, which is currently going through parliament, will enable developers to build wind farms more than 12 nautical miles out to sea, beyond territorial waters. Of the 15 wind farms, three are fully outside territorial waters. They include the world's largest proposed offshore wind farm, in the Greater Wash area, 30 km to 40 km off the Lincolnshire Coast, which could have up to 250 or more turbines and provide up to 1.2 GW of generating capacity.

Author: Mike Payne, Future Energy Solutions, the United Kingdom

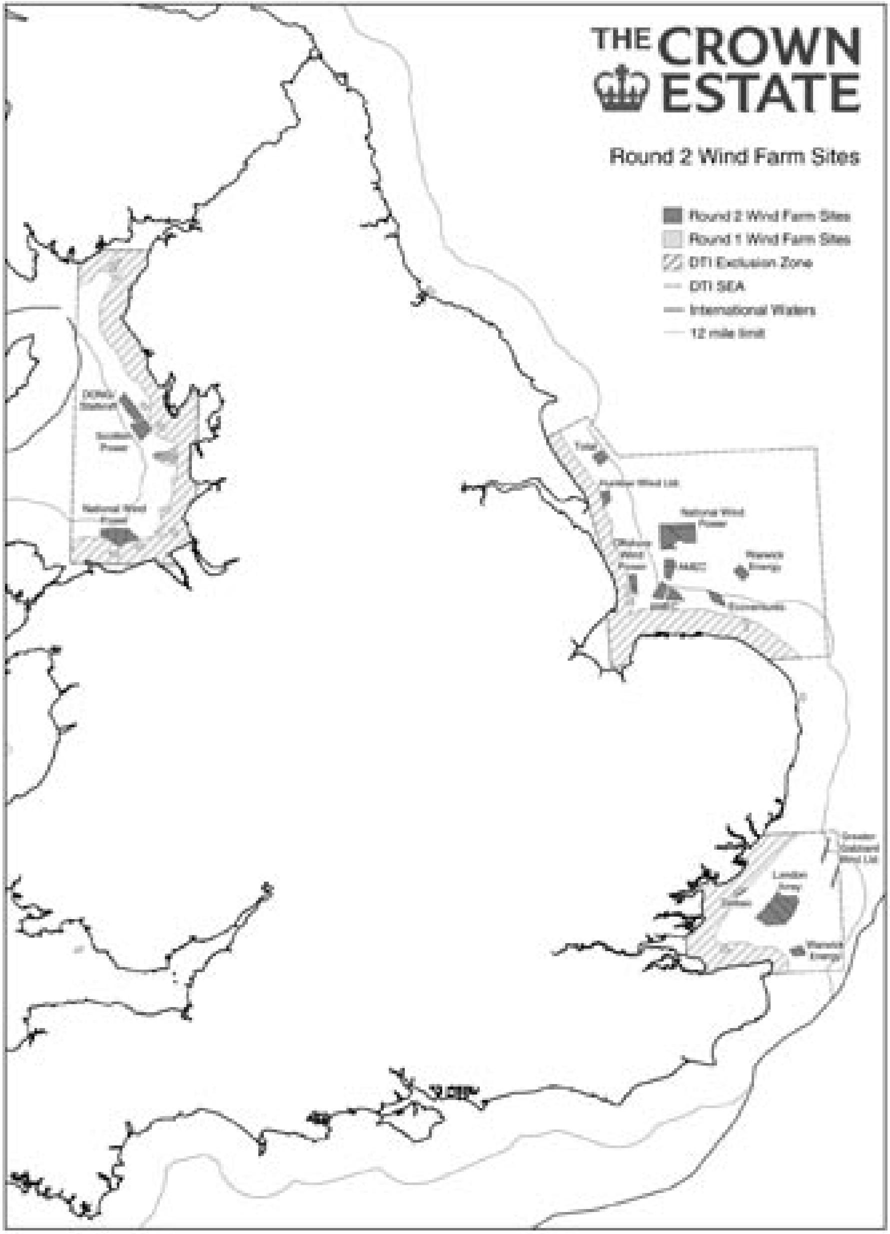

Figure 20.3 Position of the 15 newly announced Round 2 offshore wind farms

Chapter 21
United States

21.1 INTRODUCTION

The U.S. wind industry has experienced phenomenal growth during the past five years with an average growth rate of 28%. Although wind energy is the fastest growing source of electricity generation today, it comprises less than 1% of the national electricity supply. The goal of the U.S. wind industry is to increase that percentage to 6% (100 GW) by 2020.

However, according to the American Wind Energy Association (AWEA), achieving that goal will require steady supportive policies, including proactive regional transmission planning. To support the industry goal, the U.S. Department of Energy (DOE) is working with industry members to further advance the technology, reduce the cost of production, and facilitate national and state policies that will enable widespread deployment.

This report describes the current status of the U.S. wind industry, recent technology developments, market trends, and national and state policies that affect the deployment of wind energy in the United States. Because the majority of the technology research and development is conducted by the DOE Wind

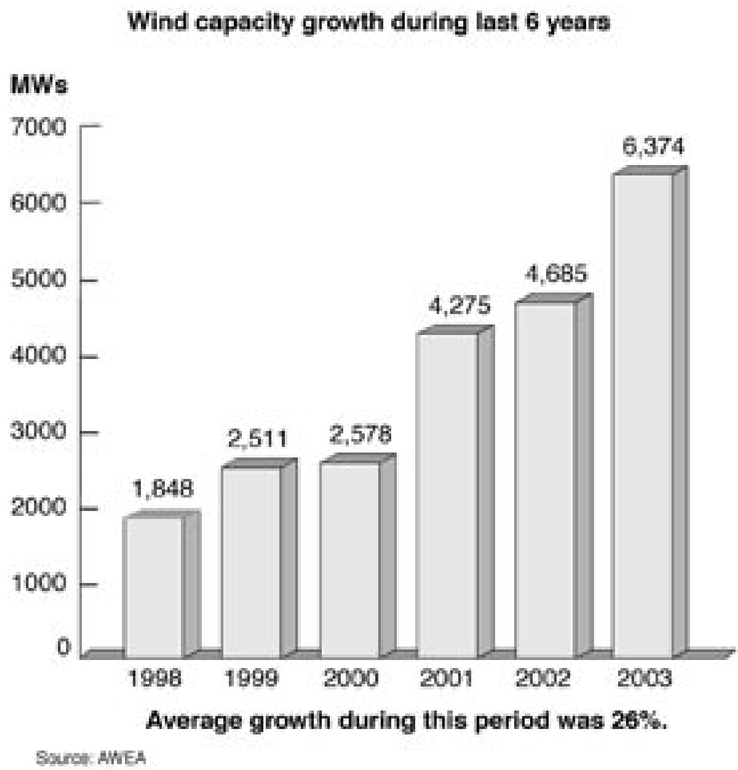

Figure 21.1 Growth in U.S. wind energy capacity for the past six years

and Hydropower Technologies Program, the content of this report is based on work conducted under that program.

21.2 NATIONAL POLICY

The U.S. National Energy Policy released in 2001 has several key objectives. They include increasing the nation's energy supply through increased domestic production, moving toward clean affordable energy sources, and ensuring the nation's energy security by strengthening the electricity grid and infrastructure that supports the production and delivery of energy.

To help meet those and other objectives, DOE published a Strategic Plan in 2002 that contains nine strategic goals. The goals include reducing dependence on foreign oil, reducing the burden of energy prices on the disadvantaged, increasing the efficiency of buildings and appliances, reducing the energy intensity of industry, and creating a domestic renewable energy industry. Most relevant to the DOE Wind Program is the priority to increase the viability and deployment of renewable energy technologies by improving performance and reducing costs, and to facilitate market adoption of renewable technologies.

Strategy

The mission of the DOE Wind Program is to support the president's 2001 National Energy Policy by increasing the viability and deployment of renewable energy and the departmental priorities by leading the nation's effort to improve wind energy technology through public/private partnerships that enhance domestic economic benefit from wind power development and coordinate with stakeholders on activities that address barriers to the use of wind energy.

To increase the viability of wind energy technology, government and industry researchers are working together to increase technology efficiencies to further reduce the cost of production and enable the machines to operate cost effectively in low-wind-speed resource environments. The current cost of wind energy produced by utility-scale systems is 0.04 United States Dollars (USD)/ kWh to 0.06 USD/kWh in Class 6 resource areas.

The goal of the DOE Wind Program is to decrease that cost to 0.03 USD/kWh in Class 4 resource areas onshore and to 0.05 USD/ kWh for offshore applications by 2012. The goal for distributed wind technology is to reduce the cost of electricity from distributed wind systems to between 0.10 USD/kWh and 0.015 USD/kWh in Class 3 wind resources, the same level that is currently achievable in Class 5 winds.

To increase the deployment of both utility-scale and small, distributed wind systems, researchers are looking for new areas for development and new applications for the technology. One area they are currently focusing on is the development of the nation's low-wind-speed resources. The wind farms that have been built to date take advantage of the best wind resources – Class 6 areas where the annual average wind speed is 6.7 m/s at a height of 10 m (15 mph at a height of 33 ft).

However, as the wind industry continues to grow, areas with the best wind resources located close to transmission lines will dwindle. To ensure continued growth, industry is working to develop technologies that can take advantage of lower Class 4 resources where the average wind speed is 5.8 m/s at a height of 10 m (13 mph at a height of 33 ft) in areas closer to the load centers throughout the nation as well as offshore.

While much of today's research focuses on utility-scale turbine development, government officials believe that small, distributed wind systems can also make a significant contribution to the nation's energy security. The small wind turbine industry estimates that 60% of the United States has enough wind resources for small turbine use, and the use of small wind turbines for residential, farm, and business applications is becoming increasingly popular as traditional energy prices climb and power fluctuations become more frequent.

In addition to stabilizing energy supplies and reducing utility bills for consumers, grid-connected, small-wind electric systems can help displace carbon emissions from traditional fuel sources. If the wind industry succeeds in reaching its goal of 100 GW of wind electricity by 2020, it will displace about 3 quadrillion Btu of primary energy per year and 65 million metric tons of carbon equivalent per year.

To support growth in both the large and small wind turbine industries, researchers are working to resolve issues that impede industry growth. These issues include state policies, intermittent supply, utility integration, and public acceptance. They are also looking into innovative applications, like offshore deep-water development, the use of wind energy to clean and move water, and the development of new technologies that will enable wind energy to work in synergy with other renewable resources, such as hydropower and hydrogen.

Another government strategy for increasing the deployment of wind energy is to require federal agencies nationwide to obtain a portion of the energy they use from renewable resources. According to an executive order issued in 1999, federal agencies are required to obtain 2.5% of their electricity from renewable resources by 2005. To help federal agencies meet the requirements of the directive, DOE's Federal Energy Management Program (FEMP) works with facility managers to evaluate their renewable energy options.

One option for increasing the deployment of wind energy is through the development of federal lands. The federal government controls nearly 650 million acres, or about 28%, of the land in the United States. Although large tracts are set aside for wilderness areas, wildlife refuges, and parks, a large portion of federal land is available for development.

Another option is to increase agencies' use of renewable energy through the purchase of green power or green tags (Figure 21.2). Green power is electricity generated by renewable energy technologies like wind power, for which the utility charges a small premium. If green power is not available, agencies can purchase green tags. In a green tag transaction, the agency continues to purchase electricity from its utility and also purchases green tags or renewable energy "credits" from another supplier, thus supporting and gaining credit for the environmental benefits of renewable energy generation.

Federal procurement regulations make it difficult for federal agencies to purchase electricity generated by renewable energy technologies when purchases involve premiums. However, the savings generated by energy-efficiency measures can be used to offset those premiums. To help agencies understand the procurement process and how it allows for the purchase of green power or green tags, Wind Powering America Program, and FEMP conduct workshops and meetings for federal facility managers nationwide.

Figure 21.2 Wind turbine on the Rosebud Sioux Reservation in South Dakota. Ellsworth Air Force Base purchases green power generated by this turbine

As a result of those efforts, 74 government agencies purchased 455 million kWh of green power in 2003. Green power purchases represent nearly one-half of the renewable energy resources acquired by the federal government since 1990 to meet the executive order. The Department of Defense (DOD) alone has at least 19 agreements to purchase renewable energy or renewable energy credits, totaling approximately 200 million kWh annually. For example, Ellsworth Air Force Base signed up for a multiyear agreement to purchase green power produced by the wind turbine on the Rosebud Sioux Reservation in South Dakota.

Progress Towards National Targets

Since the 1970s, DOE researchers and their industry partners have sought ways to produce competitive electricity using wind power. In the past 30 years, their efforts have reduced the cost of production by more than 80%.

In the early 1990s, the objectives of the Wind Energy Program were to (1) improve today's wind power plant technology and further the development of advanced wind turbines, (2) facilitate the adoption of wind power outside the state of California, and (3) promote the competitiveness of U.S. businesses in world wind energy markets. At that time, researchers projected that the cost of wind energy production would drop from between 0.06 USD/kWh and 0.09 USD/kWh to between 0.035 USD/kWh and 0.05 USD/kWh. They also predicted that operating lifespan would increase from 20 years to 30 years, availability would increase to more than 95%, and the size range of the turbines would be 300 kW to 1,000 kW.

Since the 1990s, the wind industry accomplished and surpassed the objectives established by the Wind Energy Program. In 2003, the U.S. wind energy industry grew 36%. There are now wind farms in 31 states, in addition to California (Figure 21.3), that produced 6,374 MW of wind energy, 16% of the worldwide wind energy capacity. In many areas of the United States, the projected cost of energy (COE) for utility-scale production has been accomplished with current COE from 0.04 USD/kWh to 0.06 USD/kWh, and the size of the turbines now exceeds 1,000 kW.

In 2003, DOE released a Multiyear Technical Plan that established specific program goals for 2010 and beyond. In addition to reducing the COE to 0.03 USD/kWh in Class 4 resource areas onshore and to 0.05 USD/

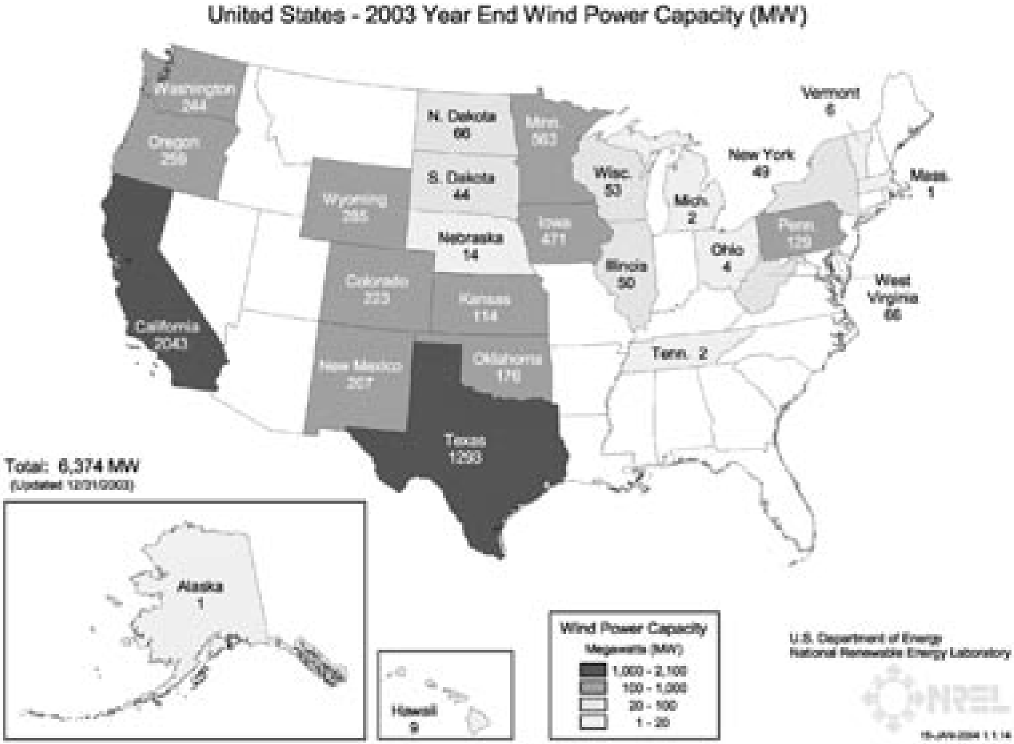

Figure 21.3 Wind power capacity in the United States by the close of 2003

kWh for offshore applications by 2012, DOE Wind Program goals include the following:

1. Increase the number of states with at least 20 MW of wind capacity to 32 by 2005 and the number of states with at least 100 MW of wind capacity to 30 by 2010

2. Complete activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to compete without disadvantage to serve the nation's energy needs by 2012.

To ensure progress toward its goals, the DOE Wind Program has established a technical assessment activity. The activity's purpose is to monitor the current status of wind technology and progress in achieving program cost goals, to evaluate that status within the context of the needs of the marketplace, and to identify technological pathways that will lead to wind's successful competition in the marketplace.

The program also uses a formal peer review process to benefit from the guidance of industry and the research community and to provide an external perspective. The technical assessment process ensures that every research activity supported by the program can be demonstrated to have a direct link to the top objectives and goals established by DOE.

Figure 21.4 New Mexico wind farm that contains 136 GE wind turbines of 1.5 MW and contributes 204 MW to the national wind energy capacity

21.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 2003, installed U.S. wind capacity increased by 1,689 MW, bringing the nation's total to 6,374 MW of wind energy, 16% of worldwide wind energy capacity. Industry growth in 2003 can be attributed to a continued decline in the cost of production and the extension of a production tax credit in 2002.

Rates and Trends in Deployment

Although the wind industry experienced a decline in production during 2002, with the extension of the federal production tax credit (PTC) in 2003 the rate of production once again accelerated, returning the industry to its record breaking 2001 production levels. Fifty projects experienced growth in 2003, and 1,210 turbines were installed. The turbines ranged in size from 660 kW to 3,000 kW.

Twenty-six states have 1 MW or more of wind energy capacity, 18 have more than 20 MW, and 16 have more than 50 MW. The four states experiencing the largest growth rate in wind energy capacity were California with 212 MW, Minnesota with 226 MW, New Mexico with 205 MW (Figure 21.4), and Texas with 204 MW.

Leading states in cumulative capacity at year's end were California with 2,043 MW, Texas with 1,293 MW, Minnesota with 563 MW, Iowa with 472 MW, and Wyoming with 285 MW. The states of Oklahoma, Illinois, and Ohio received their first utility-scale wind projects in 2003. Three projects with 113 turbines and a total 176 MW of capacity were completed in Oklahoma. One 50-MW project was completed in Illinois with 25 turbines, and one 3.6-MW project with two turbines was completed in Ohio.

Contribution to National Energy Demand

Energy generation from wind systems in the United States during 2003 was approximately 19,500 GWh. This assumes that early, pre-1990 turbines operate at an average capacity factor of 22%, that machines built during the 1990s operate at a 30% capacity factor, and that newer units operate at a 35% capacity factor. The aggregate capacity factor is estimated to be 29%.

Electricity produced by wind currently provides less than 1% of the national electricity supply. Nevertheless, industry members believe that with advancing technologies and policy development, as much as 6% of the nation's electricity requirements could be met by 2020.

21.4 MARKET DEVELOPMENT AND STIMULATION

To help develop new markets and stimulate industry growth nationwide, DOE works with industry members, state and local governments, wind interest groups, utilities, and community members to stimulate market development, identify barriers to technology use, and provide options for overcoming the barriers, primarily at the state and regional level. Goals for market development include:

1. Increase the number of states with at least 20 MW of wind capacity to 32 by 2005
2. Increase the number of states with 100 MW of wind capacity to 30 by 2010.

To achieve its goals, DOE formed a national strategy team and held a series of stakeholder group meetings to gather input on the opportunities, benefits, and challenges faced by the wind energy industry. The key outcome of the meetings was the formation of state wind working groups with a set of priority activities to encourage wind development in each state. The groups are composed of members representing key user communities, such as farmers and ranchers, Native Americans, federal facility managers, rural electric cooperatives, and consumer-owned utilities. The groups work with DOE's regional offices to build the local presence required to accelerate wind's widespread adoption.

Main Support Initiatives and Market Stimulation Incentives

Although dramatic cost reductions have allowed wind power to become the least-cost energy option in some regions of the United States, researchers and industry members alike agree that federal and state policies will play a critical role in achieving the industry goal of 100 GW by 2020.

Federal Incentives and Policies

Current federal incentives that support industry growth and stimulate market development include an energy PTC, and federal and tribal grant programs. Of the federal incentives, the PTC, enacted in 1992, has had the greatest impact on utility-scale wind energy development. The PTC provides a 0.015 USD/kWh credit (adjusted for inflation) for electricity produced from wind technology. Although the PTC expired in December 2003, pending energy legislation includes a three-year extension.

State Policies and Incentives

State incentives for utility-scale wind energy development include renewable energy purchase mandates, renewable energy funds, tax incentives, resource planning, and green power programs. Of all the state incentives, renewable energy purchase mandates will likely have the largest impact on wind development.

Renewable Energy Purchase Mandates - Renewable energy purchase mandates include traditional set-asides directed at individual utilities in a regulated setting and renewables portfolio standards (RPS) that require all retail suppliers to serve a minimum portion of their load with eligible renewable energy. Set-asides and RPS policies are attractive in some states because they create a strong demand for wind-generated electricity, offer incentives for wind power cost minimization through a competitive process, can be used in regulated and restructured market settings, and rely on the private market to make renewable energy investment decisions. In other states, however, political considerations make purchase mandates difficult to legislate.

Renewable Energy Funds - Most often funded through system-benefits charges (a small surcharge on electricity rates) but occasionally through regulatory or merger settlements, state renewable energy funds provide major support for utility-scale wind development. Present in 15 states (most are restructured), these funds are expected to generate 3.5 billion USD for the development of renewables from 1998 through 2012. Production incentives (USD/kWh supplemental financial payments) are the most common form of incentive employed by renewable energy funds in support of utility-scale wind power – although up-front grants, forgivable loans, and subordinated debt have also been used.

Green Power Markets - Green power marketing can provide a supplemental revenue stream to support the development of utility-scale wind energy facilities. For example, wind power purchases by universities and other customers in the Mid-Atlantic states are helping to support about 150 MW of new wind projects in the region. In the Pacific Northwest, about 400 MW of new wind projects are being supported in part through premiums paid by green power customers.

Wind represents 93% of the capacity installed to meet consumer demand for green power. Nearly half of utility green pricing programs are supplied exclusively with wind power, and 80% include wind in their green pricing supply portfolios. Of the green pricing programs with the highest participation rates, seven out of ten offer wind power. Of the green pricing programs with the lowest price premiums, seven out of ten are marketing wind power.

State Policies and Incentives for Small Wind Systems

In addition to incentives for utility-scale wind energy production, many states have policies and incentives for small wind electric systems. These incentives include net metering, investment tax credits, investment incentives, revolving loan funds, and tax reductions.

Net Metering - Net metering is an easily administered mechanism for encouraging direct customer investment in renewable energy. Under this policy, electric customers installing 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.

Tax Credits - Historically, tax credits such as investment (personal income tax), property, and sales tax credits have been predominant approaches taken at the state and federal levels to stimulate renewable energy development. State investment tax credits (ITCs) can be used to increase wind development by reducing the state income tax burden of wind power investors. The credit allows the investor to reduce its tax obligation by some portion of the amount invested in a wind project. Property tax credits can be in the form of full exemptions, reductions in tax rates, or changes in assessment methods, and are typically levied as a percentage of the assessed value of a facility or parcel, including improvements. Sales tax incentives could be in the form of full exemptions or reductions in tax rates. By exempting renewable energy facilities from sales taxes or reducing the tax rates, the installed and levelized cost of wind power can be decreased.

Unit Cost Reduction

R&D efforts, increased turbine production volume, larger projects, and improved construction methods have all helped to reduce the cost of wind energy. Large, land-based wind plant installations are currently estimated to cost between 900.00 USD/kW and 1,000.00 USD/kW. These estimates are based on data from actual projects and include the turbines, electrical system interconnection, and substation costs. Costs depend on many things, including turbine type, size, quantity, terrain, transportation access, grid-connection voltage and distance, and other variables.

21.5 DEPLOYMENT AND CONSTRAINTS

The deployment of wind energy has increased substantially in the United States during the last decade. Nevertheless, transmission constraints, operational policies, and a lack of understanding of the impacts of wind energy on utility grids are three of the toughest barriers facing future deployment.

DOE is working to remove these barriers and further the deployment of wind energy by working with utilities and utility groups like the American Public Power Association, the National Rural Electric Cooperative Association, power marketing authorities, the National Wind Coordinating Committee's (NWCC's) transmission working group, and the Utility Wind Interest Group to identify grid integration issues and analyze transmission constraints.

Lack of sufficient transmission to meet market demand for wind energy is one of the most significant barriers facing wind energy development today. In some cases, high-quality wind resources are located far from load centers.Existing transmission is controlled by owners of competing generation resources, usually utilities

Market overview

	Past (1980s)	Present	Future
U.S. Market Size	500 MW	5,000 MW	20,000 MW (2010)
Size of Turbine (Rotor motors)	50–200 kW (12–27)	1,000–2,000 kW (60–80)	3,000–5,000 kW (80M+)
Suppliers	All small manufacturers except MHI Vestas NEG Micon	GE MHI Vestas NEG Micon	Consolidation?
Production Price	$80–$100/MWh	$30–$50/MWh	$20–$30/MWh
Tax Credits	ETC ITC 5 year ACRS	50% bonus depreciation 5 year MACRs PTCs	50% bonus depreciation 5 year MACRs PTCs

Figure 21.5 Overview of market factors in the United States, 1980 to 2010

or government agencies. Because the existing transmission was built for current generation and load levels, very little excess transmission capacity is available to serve the development of wind resources.

Since the Energy Policy Act (EPAct) of 1992 was enacted, open access has been an issue before the Federal Energy Regulatory Commission (FERC). The open access tariffs that transmission providers have filed at FERC limit services available to wind, maintain high costs for transmission services, and include penalties that adversely affect wind economics and require unrealistic controls. These limits on service, high rate levels, and penalties can make the cost of transmission services prohibitive. FERC is working on a standard set of rules for interconnections between generators and the transmission system. Although interconnection agreements can consume substantial time and effort, FERC is seeking to streamline the process.

In addition to grid integration and transmission constraints, the deployment of wind energy in the United States may be hampered by siting issues that include land use, noise and visual impacts, and impacts on wildlife. Although these issues may not affect the development of wind projects in many areas of the United States, in some areas one or more may be so important that the project could be halted.

Early assessment of the site by the developer is critical to determining how many and which of these topics could be issues that need to be addressed. To assist developers in evaluating future projects, the NWCC produced a guidebook to siting issues, *Permitting of Wind Energy Facilities: A Handbook*. The guidebook is available online at http://www.nationalwind.org/pubs/permit/permitting2002.pdf.

21.6 ECONOMICS

Trends in Investment

In 2003, two new investment trends surfaced within the U.S. wind industry. One of these trends is the partial displacement of traditional strategic investors by passive institutional investors. Strategic investors are companies like Florida Power and Light (FPL), American Electric Power (AEP), Pacificorp Power Marketing (PPM), and Shell that are interested in developing capabilities and investment in the wind sector and are more likely to accept project risks because of their knowledge and active management.

Although strategic investors remained the principal source of capital for the industry, in 2003 institutional investors are showing an increasing interest in wind energy investments. Institutional investors are mainly passive investors that are not interested in being an active participant in the industry per se, they are instead motivated by tax benefits and overall return and may have experience investing in other tax-advantaged industries. These passive players are investing in projects developed by other companies.

Examples include traditional leveraged lease investors, regional banks, industrial finance subsidiaries, utility finance subsidiaries, and insurance companies. In 2003, several transactions were closed with institutional investors. If the production tax credit is extended beyond 2005, this largely untapped market will become critical for the future of the industry because it will unleash substantial new capital that is able to take advantage of the PTC.

Another trend in investment is for the traditional strategic investors, such as FPL Energy, to seek out new financing options. In 2003, FPL Energy invested in wind energy, and the company controls more than 42% of the U.S. market share. Although FPL has traditionally used balance-sheet financing, they explored a new option for project financing in 2003 by initiating the first wind industry portfolio bond offering.

Although financial analysts predict that the U.S. wind industry will experience an annual growth rate of 15% to 30% during the next five years that will require an annual capital investment in excess of 1.5 billion USD, that growth will be highly dependent on the extension of the PTC.

Trends in Unit Costs of Generation and Buy-Back Prices

Since 1980, the cost of electricity from wind systems without subsidies at good wind sites has been reduced from 0.80 USD/kWh (in year 2000 dollars) to between 0.04 USD/kWh and 0.06 USD/kWh. In the best wind areas, some project bids are running as low as 0.02 USD/kWh, including available tax credits. Although costs have decreased significantly, researchers believe that further improvements could reduce costs an additional 30% or more.

The current cost of wind energy (Figure 21.6) produced by utility-scale systems is 0.04 USD/kWh to 0.06 USD/kWh in excellent resource areas. The goal of DOE's Wind Program is to decrease that cost to 0.03 USD/kWh in lower-wind-speed resource areas onshore and to 0.05 USD/kWh for offshore applications by 2012. The goal for distributed wind technology is to reduce the cost of electricity from distributed wind systems to between 0.10 USD/kWh and 0.15 USD/kWh in Class 3 wind resources, the same level that is currently achievable in Class 5 winds by 2007.

21.7 INDUSTRY

Manufacturing

Seven U.S. companies are currently manufacturing wind turbines, and numerous businesses are building components, developing projects, and providing engineering services and related equipment. Two companies are building wind turbines larger than 50 kW and five are building turbines smaller than 50 kW. Information about U.S. firms is available on the AWEA web site at http://www.awea.org.

Industry Development and Structure

The U.S. market was dominated by GE Wind Energy's 1.5-MW machine, which provided more than half of the new capacity in 2003. Vestas provided machines for ten projects with a combined capacity of 386 MW – and the company installed its 3-MW turbine in Texas, the first 3-MW machine to be installed in the United States. Mitsubishi, NEG Micon, and Bonus also claimed a portion of the U.S. market, while Suzlon of India and Gamesa of Spain installed their first turbines on U.S. soil.

FPL Energy built nearly half (811 MW) of the 2003 capacity. PPM Energy completed projects totaling 117 MW and is purchasing output from three additional projects with a combined capacity of 387 MW. Shell Wind Energy completed projects in Colorado and Texas with a total capacity of 322 MW and partnered with Padoma Wind Power to develop the project in Texas.

21.8 GOVERNMENT-SPONSORED R,D&D

The mission of the DOE Wind and Hydropower Technologies Program is to support the president's National Energy Policy and departmental priorities for increasing the viability and deployment

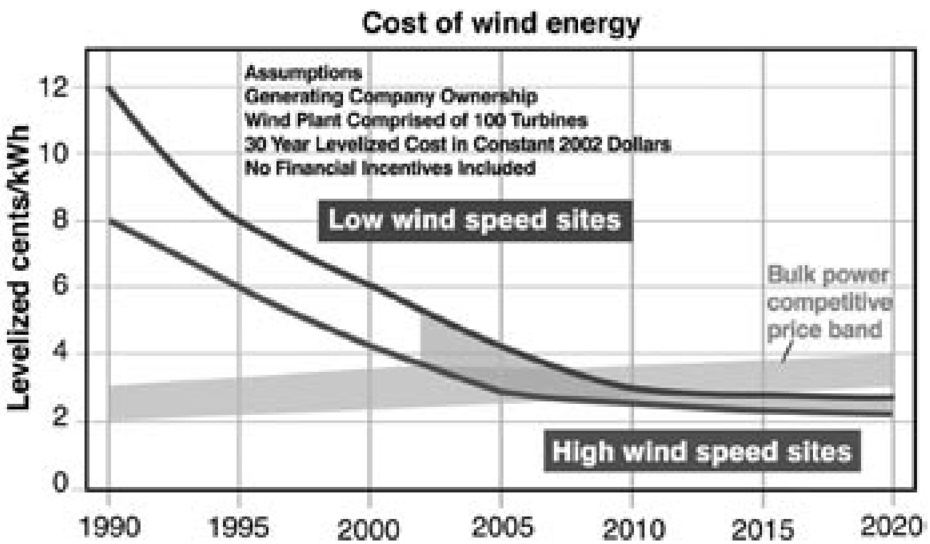

Figure 21.6 Cost of wind energy the United States, 1990 to 2020

of renewable energy; lead the nation's efforts to improve wind energy technology through public/private partnerships that enhance domestic economic benefit from wind power development; and coordinate with stakeholders on activities that address barriers to use of wind energy.

Priorities

The DOE Wind Program focuses its research in two areas, technology viability and technology application. Under technology viability, researchers work with industry members to increase efficiencies and reduce the COE for both utility-scale and small, distributed wind systems for low-wind-speed regions. Industry partnerships are formed through the award of cost-shared technology development subcontracts.

These subcontracts concentrate on three technical areas: (1) concept design studies, (2) component development and testing, and (3) full turbine prototype development and testing. The funding provided by the program enables industry to develop high-risk, advanced wind technology that it would not be able to fund on its own, and explore the effects of increased turbine size on performance and cost.

Under technology application, researchers are assisting industry partners with a number of projects aimed at increasing utilities' understanding of integration issues and gain confidence in the reliability of new wind turbine products. Information gained from the projects will be distributed through a national outreach effort to investor-owned utilities, electric cooperatives, public power organizations, and energy regulators to encourage the inclusion of wind power in generation portfolios and ensure the continued growth of the wind energy industry.

New R,D&D Developments

Turbine Prototype R,D&D

In 2003, DOE researchers worked with Clipper Windpower Technology, Inc., and GE Wind Energy to develop prototypes for multi-megawatt wind turbines. Clipper Windpower is developing a 1.5-MW-to-2.5-

MW Quantum prototype turbine that will incorporate advanced turbine components projected to achieve DOE's low-wind-speed COE goal of 0.03 USD/kWh at Class 4 wind sites.

The company is reducing capital costs through innovative approaches to design and manufacturing processes. Clipper's innovative design will include a multiple-generator drivetrain and advanced controls. The company is also exploring a variable-diameter rotor for improved performance in low-wind-speed areas and considering including a self-erecting tower.

Researchers at DOE's National Renewable Energy Laboratory (NREL) are planning to work with GE Wind Energy to develop an advanced multi-megawatt turbine that can approach DOE's low-wind-speed goals. The prototype will incorporate a host of pioneering features, including multi-piece rotor blades constructed of advanced materials and optimized for low noise levels, advanced controls, diagnostic systems, an innovative drivetrain, and taller towers with load reducing features.

Advanced Component Development

DOE also worked with several companies in 2003 to develop more efficient, advanced components. These include new, lighter weight, high-efficiency drivetrains, power converters, and rotors.

A preliminary analysis of a single-stage, permanent-magnet (PM) drivetrain designed by Global Energy Concepts shows high efficiency at low wind speeds and annual energy production estimates that are 3% higher than baseline. Production costs for the single-stage PM drivetrain are estimated to be 22% lower than for the baseline drivetrain, and it shows potential for reducing overall turbine COE by 10%.

Clipper Windpower produced a new, distributed generation drivetrain (Figure 21.7) that is 30% lighter weight and potentially more efficient than conventional drivetrains. The drivetrain includes variable-speed power electronics, eight generators, and a gearbox. It was designed to fit most 1.5-MW scale platforms and can be used as a retrofit for new turbines.

Northern Power systems has also designed a 1.5-MW, direct-drive, permanent magnet generator and has designed and fabricated a novel, full-power converter that will allow variable-speed operation. The direct-drive configuration, which has broad commercial appeal and eliminates the gearbox leading to real improvement in reliability and reductions in COE.

DOE also worked with industry and university partners to design and fabricate two 9-m carbon-hybrid blades. One blade has carbon/glass fiber hybrid materials on a conventional lay-up, and the second has a carbon and glass laid off-axis to optimize bend-twist coupling effects. Preliminary analysis of both designs show that the weight of the carbon-hybrid blade is decreased 20% from the baseline, and the weight of the twist-coupled blade decreased 10% to 15%. In addition, the incorporation of twist-coupling should reduce fatigue loads by about 10% to 20%.

Advanced Testing Methods

Researchers at NREL developed a new, hydraulic-resonance blade-test system that replaces the conventional method of using a hydraulic actuator. The old method uses a hydraulic actuator to push the blade up and down for millions of cycles over a period of up to four months. The new system uses a 700-pound to 1,000-pound weight housed in a stand attached to the end of the blade. The amount of weight used depends on the size of the blade. The weight is precisely

Figure 21.7 Clipper Windpower developed a new, 8-generator, 1.5-MW-to-2-MW drivetrain

controlled to oscillate up and down, which excites the blade at its natural flap frequency. The new test uses one-third of the energy that the conventional method uses, and the blade oscillates at more than twice the rate. Instead of taking up to four months to apply three million cycles to fatigue test a blade, it can now be done in less than two. The new system, capable of testing blades up to 70 m in length, is the only one of its kind in the world.

Offshore Siting

Interest is increasing in offshore development, and although there are no current offshore wind installations in the United States, there are several proposed applications for offshore projects along the east coast from New England to Virginia. 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 ease of transportation and installation are a few of the advantages drawing attention to offshore wind energy development. In the U.S. onshore markets, where the burden of electric transmission is great, the development of offshore wind would reduce the burden of supplying electricity to coastal cities from the inland transmission system.

To develop offshore wind resources, especially deep-water resources, researchers are turning their attention to developing technologies such as floating platforms cabled to the ocean floor as well as technologies that will overcome the challenges facing offshore development. These challenges include higher investment and development costs, severe environmental conditions, more complicated offshore construction, and higher maintenance costs.

Despite the difficulties of offshore development, it holds great promise for expanding wind generation capacity, and DOE has initiated a research effort to assess offshore wind resources. Meso-scale modeling, used to determine the onshore wind resource for many of the coastal states, has provided preliminary estimates of wind resources out to 50 nautical miles offshore for recently mapped regions of the United States.

These estimates indicate that for the United States, there is more than 800 GW of offshore wind resource in deeper water (30 m to more than 100 m), compared to less than 100 GW in shallow water (0 m to 30 m). NREL will lead an effort to develop a series of coastal maps indicating offshore wind resources in the Northeast, the Mid-Atlantic, the Great Lakes, and the Gulf of Mexico.

Figure 21.8 Researchers at the U.S. Department of Energy National Renewable Energy Laboratory (NREL) developed a new hydraulic resonance blade test system

In 2003, DOE and NREL held a workshop in Washington, D.C., to discuss deep-water technologies with about 50 U.S. and European experts in wind engineering, oil and gas structures, and marine measurements. (See http://www.nrel.gov/wind_meetings/offshore_wind/ for more information.) Participants identified significant engineering challenges, including the downsizing of oil and gas platforms by two orders of magnitude while designing for turbine dynamic inputs. Workshop findings included the following:

1. The oil and gas technology community has strong analytic and computational resources that can serve as resources for the wind engineering community.

2. There is a general consensus that economical, floating offshore applications are achievable.

3. Next steps include obtaining environmental data needed to characterize operating conditions, developing models to understand system dynamics, and determining whether the turbine and the platform can be dynamically modeled separately.

Author: Compiled by Kathleen O'Dell, NREL, the United States

Figure 21.9 There is an increasing interest in offshore development, and several proposed applications for offshore projects along the east coast from New York to the Virginia have been submitted

Appendix A

Attendees of the 52nd Executive Committee meeting at Prince Edward Island, Canada.

Appendix B

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Appendix C

Currency conversions rates for IEA 2003 review

Country	Currency	1 Euro	1 USD
Australia	AUD	1.6758	1.330
Canada	CAD	1.62792	1.292
Denmark	DKK	7.4529	5.915
Finland	Euro	1.000	0.79365
Germany	Euro	1.000	0.79365
Greece	Euro	1.000	0.79365
Ireland	Euro	1.000	0.79365
Italy	Euro	1.000	0.79365
Japan	JPY	134.9838	107.130
Mexico	MXP	14.16492	11.242
Netherlands	Euro	1.000	0.79365
New Zealand	NZD	1.9215	1.525
Norway	NOK	8.39916	6.666
Portugal	Euro	1.000	0.79365
Spain	Euro	1.000	0.79365
Sweden	SEK	9.0657	7.195
Switzerland	CHF	1.55988	1.238
United Kingdom	GBP	0.70623	0.5605
United States	USD	1.260	1.000

Source: Federal Reserve Bank of New York www.x-rates.com 31 December 2003

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Wind energy is playing an ever more important role in the worldwide generation of electricity. In 2003, the world's wind generating capacity grew by more than 8.3 gigawatts (GW) to a total of around 40 GW by the close of the year. Of this world capacity, a full 90% is installed in the countries that participate in the IEA R&D Wind agreement. By the end of 2003, the total installed capacity in the IEA R&D Wind countries reached 35 GW and included 493 MW of offshore generation, about 1.4% of the total.

In addition to the widely recognized environmental and energy benefits of wind-generated electricity, many countries see that wind energy can offer economic and social benefits as well. The value of the global market for wind turbines in 2003 was estimated at over 7 billion US dollars (USD). On top of this, the value of related services for the operation of installed plants was estimated at an additional 1 billion USD.

Along with benefits, the growth of the wind energy sector has generated new issues. The member countries of IEA R&D Wind are always considering new opportunities for international collaboration to increase knowledge and understanding to deal with new issues as they arise. For example, grid integration issues are a challenge to the expansion of wind power in some countries. The IEA Wind Annex XXI *Dynamic models of wind farms for power system studies* builds on current research and is accelerating the learning process for participating countries.

IEA R&D Wind began in 1977 to facilitate development of wind energy technology. Under this agreement, parties from 20 countries and the European Commission exchange information and collaborate in wind energy research and development. This Annual Report reviews the detailed activities and policies within each member country, as well as the progress of the joint research projects conducted during 2003.

IEA WIND ENERGY ANNUAL REPORT 2003

2003

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