IEA Wind Energy Annual Report 2002

International Energy Agency
Executive Committee for the

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

April 2003

Front cover photo: Windfarm Etten Leur, Netherlands, Credit: Hans Pattist, courtesy Novem.

Back cover photos: Nerefco Refinery, Rotterdam, the Netherlands, Courtesy Novem.

Foreword

The twenty-fifth IEA Wind Energy Annual Report reviews the progress during 2002 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 21 contracting parties from 19 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 24 of the 29 OECD member countries. IEA R&D Wind was one of 42 implementing agreements of IEA in 2002.

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 Canada, Denmark, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Mexico, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

Jørgen LEMMING
Chair of the Executive Committee
(2002-2003)

Patricia WEIS-TAYLOR
Secretary to the Executive Committee

Web sites for additional information on IEA R&D Wind
www.ieawind.org
www.iea.org/techno/impagr/index.html

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Message from the Chair

The global growth of wind generation capacity continued its strong performance in 2002, and expectations are high for the coming years. By the end of 2002, global wind capacity reached 31 Gigawatts and 90% of this capacity is in the IEA Wind member countries. Installed capacity grew almost 28% in the reporting member countries of the IEA Wind agreement. In these countries, wind turbines generated 47 Terawatt hours of electricity providing electricity nearly equivalent to the entire needs of Greece. Although growth in wind energy installations did slow slightly in 2002, increases in capacity are high compared to other industries. The value of the global wind energy market in 2002 was estimated at over 6 billion U.S. Dollars.

Jørgen Lemming, Chair 2002-2003

For most countries actively involved in implementing wind energy, the primary values of this energy source are the economic and environmental benefits. Wind turbines can be brought online quickly, and can help reduce or limit greenhouse gas emissions. In countries where emissions reduction is a high priority, the primary benefit is the very low lifetime emissions that the technology offers. But the value of wind energy goes far beyond this. With the liberalization of electricity markets, countries are placing more importance on benefits such as increasing the diversity and security of electricity supply and removing cost uncertainties caused by fuel supply price fluctuations.

However, there are key issues to resolve on the way to expanding the contribution of wind generation to the world electricity supply. For example, the high dependence of markets on government policies is a concern. To create a viable market, stability is needed to enable investment. For several countries where wind power investment is attractive, the issues of planning and grid integration need to be addressed before the potential and national targets can be realized. The integration of large-scale wind energy into electricity networks is an issue that can be addressed with technical solutions where there is the political will to make the investment in infrastructure.

Continuing to address issues that slow the expansion of wind generation, IEA Wind conducted a full schedule of work in 2002. In addition to ongoing work of the agreement and its tasks, the members initiated three new tasks to coordinate research on important topics. This year we began our end-of-term evaluation to develop a strategic plan for our next five-year term. To consolidate our communication via the

Internet, we launched a public Web site, www.ieawind.org, And we celebrated the 25th anniversary of international cooperation on wind energy research.

I hope you will find this 25th anniversary issue of the IEA Wind Energy Annual Report both interesting and informative. In this report, the 2002 IEA Wind Energy Overview (Chapter 4) provides a synthesis of activities in our member countries. A special chapter, Twenty-Five Years of International Cooperation (Chapter 3), reviews three topics explored over the years of the IEA Wind agreement and draws some conclusions about effective strategies for international co-operation. Your comments on this report and our work are appreciated and can be sent to the Secretariat, pwtcommunications@compuserve.com.

Jørgen Lemming
Chair, IEA R&D Wind
(2002-2003)

Chapter 1
The Implementing Agreement

1.1 INTRODUCTION

IEA's commitment to wind energy dates back to 1977, when the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind) began. The past 25 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. (See Chapter 3 for a history of the IEA R&D Wind agreement.)

When the contracting parties extended the IEA R&D Wind implementing agreement through 2003, they adopted a Strategic Plan 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. Specifically, members agreed to work toward the following objectives.

- Conduct cost effective international cooperation on advanced wind energy-related research and development,
- Exchange of information and state-of-the-art assessments on wind energy technology, policy, and deployment,
- Extend cooperation to non-participating OECD countries, as well as promote wind energy in developing countries and Eastern Europe, preferably in cooperation with the World Bank and other international financing institutions.

1.2 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 2002 is presented in Chapter 4 of this Annual report. Individual county activities are presented in Chapters 5 through 21.

At present, 21 contracting parties from 19 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, Spain, Sweden, Switzerland, the United Kingdom, and the United States are now members. (See Table 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.

1.3 COLLABORATIVE RESEARCH

Participants in the IEA R&D Wind Agreement are currently working on six cooperative research tasks, which are approved by the Executive Committee as Annexes to the original Implementing Agreement. (See Chapter 2 for progress in cooperative research.) Tasks are sometimes referred to by their annex number. Countries choose to participate in tasks that are relevant to their current national research and development programs. Additional tasks are planned when new areas for cooperative research are identified by Members. (See Table 1.2.)

The level of effort on a task is typically the equivalent of several people working for a period of three years. Some tasks have been extended to continue the work. The projects are either cost-shared and carried out in a lead country, or task-shared, when the participants contribute in-kind effort, usually in their home organizations, to a joint program coordinated by an Operating Agent. To date,

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	**The Government of Japan**
Mexico	**Instituto de Investigaciones Electricas (IIE)**
Netherlands	**The Netherlands Agency for Energy and the Environment (NOVEM)**
New Zealand	**The New Zealand Wind Energy Association**
Norway	**The Norwegian Water Resources and Energy Directorate (NVE)**
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 1.1 Contracting parties to the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems in 2002

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 2002)**
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. (2002 to 2005)**
Task XXI	**Dynamic models of winf farms for power system studies. OA: Sintef Energy Research, Norway. (2002 to 2005)**
Task XXII	**Market development for wind turbines. On hold.**

Table 1.2 IEA R&D Wind tasks defined in Annexes to the Implementing Agreement

14 tasks have been successfully completed and one task has been deferred indefinitely. (See Table 1.3.)

To obtain more information about these activities described in Chapter 2, contact the Operating Agent Representative for each task listed in Appendix B.

1.4 EXECUTIVE COMMITTEE

Overall control of information exchange and the R&D tasks is vested in the Executive Committee (ExCo). The ExCo consists of a Member and an Alternate Member 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 Member if there is 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 2002, Mr. J. Lemming (Denmark) served as Chair, Mr. P. Goldman (United States) served as Vice-Chair. At the 50th Executive Committee (ExCo) meeting, the Chair and Vice-Chair from 2002 were elected to continue in 2003 and Mr. S-E Thor was elected to begin as an additional Vice-Chair in 2003.

Participants
In 2002, Ireland and Switzerland accepted invitation to join the agreement bringing total membership to 21 participating organizations. See Appendix B for an updated list of Members, Alternate Members, and Operating Agent representatives. During the year, the Executive Committee invited representatives from France, India, and Portugal to attend ExCo meetings 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 49th ExCo meeting was hosted by the Forschungszentrum Jülich GmbH, in Magdeburg, Germany, 17 to 19 April 2002. There were 26 participants from 12 of the contracting parties and three operating agent representatives of the tasks. The ExCo agreed to invite the government of Switzerland to join the implementing agreement; reviewed and approved progress reports of ongoing tasks XI, XVI, XVII, XVIII, and XIX; and approved three new annexes contingent on several steps being completed within one year. The new tasks are XX, Horizontal Axis Wind Turbine 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; and XXII, Wind Energy Market Acceleration. The audit report of 2001 accounts of the Common Fund was approved. On 19 April 2002, the ExCo visited the Enercon factory where the 4.5-MW machine was built.

The 50th ExCo meeting was hosted by the Ministry of Economic Affairs, Den Haag, the Netherlands on 22 to 24 October

2002. There were 26 participants from 13 of the contracting parties, three operating agent representatives of tasks, and several observers, including one from IEA Headquarters in Paris. The ExCo welcomed Ireland and Switzerland which formally joined the agreement. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2003. The new budget included expenses to meet IEA requirements for renewing the implementing agreement for another five years (2003 to 2008). A contractor (Mr. Dan Ancona) was selected to draft an End-of-Term report for ExCo consideration and contractors made presentations about how they could assist with writing a strategic plan. In addition, the ExCo finalized its earlier decision to commemorate the 25th anniversary of the agreement by publishing a poster and adding a chapter to the Annual Report recounting the history of the agreement. The requested proposal from the

	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	x				x		
Austria							
Canada	x	x		x	x		
Denmark	x	x	OA	x	x	x	x
European Commission	x						
Finland	x			OA		x	
Germany	x					x	
Greece	x	x			x		
Ireland	x						
Italy	x						
Japan			x				
Mexico	x						
Netherlands	x		x		x	x	
New Zealand							
Norway	x		x	x	x	OA	
Spain	x					x	
Sweden	OA		x	x	x	x	
Switzerland				x			
United Kingdom	x					x	
United States	x	OA	x	x	OA	x	x
Start Date	1987	1995	1999	2001	2002	2002	2002
End Date	Ongoing	2002	2003	2004	2005	2005	On hold

Table 1.3 Participation of countries in cooperative research tasks for 2002. OA indicates operating agent for the task.

Secretary to develop a public Web site was also approved. On 24 October 2002, the ExCo visited the new ECN test site and the wind farm Etten Leur.

The 24th issue of the *IEA R&D Wind Annual Report* was published in May 2002.
The new public Web site was posted December 2002: www.ieawind.org.

Chapter 2
Cooperative Research

The benefits of past research and development in the wind energy sector have been demonstrated by the increasing sizes of wind turbines (now up to 4 megawatts) and the lower prices per installed production capacity of electricity (as low as 0.047 Euro per kilowatt hour). The cost of wind energy in 2020 has been projected to be as low as 0.025 Euro. This projection assumes continued technology research and development that takes account of social and environmental issues. Participants in the IEA Wind agreement are working to make this projection a reality. The following sections describe the cooperative research underway in 2002.

2.1 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 Research and Development (R&D) topics of common interest. These particular activities have been part of the agreement since 1978. The annex was extended in 2001 for the years 2002 and 2003.

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 listed in the International Energy Agency's (IEA) Wind Energy Annual Report 2001. (See Table 2.2.1)

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

Over the 23 years since these activities were initiated, 40 volumes of proceedings from expert meetings (see Table 2.2.2) and 23 volumes of proceedings from Joint Action Symposia (see Table 2.2.3) have been published.

The following activities were conducted in 2002.

- Topical Expert Meeting 38: Material Recycling and Life Cycle Analysis (LCA).
- Topical Expert Meeting 39: Power Performance of Small Wind Turbines not Connected to the Grid.
- Topical Expert Meeting 40: Environmental Issues of Offshore Wind Farms.
- First Joint Action Symposium on Wind Forecasting Techniques.

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	See also IEC 614000-1, ed2
6	Structural Safety	1	1988		no	See also IEC 614000-21 FDIS, Measurement and assessment of power quality of grid connected wind turbines
7	Quality of Power Single Grid-Connected WECS	1	1984			See also IEC60030-413 International Electrotechnical vocabulary: Wind turbine generator systems
8	Glossary of Terms	2	1993	1987		See also IEC60030-413 International Electrotechnical vocabulary: Wind turbine generator systems
9	Lightning Protection	1	1997		yes	See also IEC 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 MT 13, updating power performance measurement

Table 2.2.1 List of Recommended Practices

Topical Expert Meeting 38: Material Recycling and Life Cycle Analysis

Topical Expert Meeting 38 revealed a number of common observations and recognized problems that should be addressed in order to meet the challenges that the predicted deployment of wind energy will constitute. It was agreed that although wind energy is in general more "friendly" to the environment than energy production from fossil fuel when looked upon over total lifetime production, it is important to try to reduce the adverse effects of wind turbine system manufacturing and decommissioning. The adverse effects connected with wind turbine operation and maintenance are negligible, so there is no need to look at that period of energy production.

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)**	**Risoe, Denmark**	**2002**
37	**Structural reliability of wind turbines**	**Risoe, 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 2.1.2 List of Topical Expert Meetings held since 1990. For a complete list of meetings see www.ieawind.org.

Topical Expert Meeting 39: Power Performance of Small Wind Turbines not Connected to the Grid

Topical Expert Meeting 39 was a successful sharing of information by 16 participants from 12 organizations representing seven countries. The meeting covered the following three main topic areas.

- Recent findings on methods to measure power performance of non-grid connected wind turbines.
- Present activities being conducted by other participants.
- Feedback on the current proposal for the International Electrotechnical Commission (IEC) standard.

No	Year	Host	Place	Country
Aerodynamics of wind turbines				
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 characteristics				
2	1999	Risø	Roskilde	Denmark
1	1994	GL	Hamburg	Germany
Wind forecasting techniques				
1	2002	SMHI	Norrköping	Sweden

Table 2.1.3 List of Joint Action Symposia
***Meetings prior to 1994 not listed here.**

It was concluded that quite extensive work is conducted within the IEC MT12 subgroup on non-grid connected wind turbines. However, there is still a need to exchange information and discuss different topics with a broader group of people. The group decided that this can be achieved through an e-mail group operated by a moderator. Future developments in this area will therefore be communicated using a limited e-mail group, and another meeting will convene if appropriate.

Topical Expert Meeting 40: Environmental Issues of Offshore Wind Farms

The aim of Topical Expert Meeting 40 was to make an inventory of the existing and available information on environmental aspects of offshore wind energy. Another aim was to give recommendations to the Concerted action for Offshore wind energy Deployment (COD) project on how to proceed within the work package regarding the following issues.

- Collection of information on activities (projects) from participating countries, including birds, ethnic flora and fauna, sub-sea noise, visual intrusion, and coastal impacts.
- Composition of a coherent overview with identification of white spots.

The meeting mainly focused on the following initiatives.

- National programs to enforce offshore wind energy.
- Studies and experiences of influence on birds and sea mammals.
- Experience and application of the Environmental Impact Assessment.

First Joint Action Symposium on Wind Forecasting Techniques

The First Joint Action Symposium on Wind Forecasting Techniques gathered 23 people from 11 different countries. Participants came mainly from universities, research institutes, "met offices," and consultant companies. A primary goal of the meeting was to give the participants a good overall view of the current state of wind forecasting efforts.

As wind energy makes significant penetration into electric grids in various places around the world, the need for accurate predictions of available wind electric potential for a variety of time scales is increasing in importance. Accurate wind forecasts are required to best integrate wind electric potential into scheduling and dispatch decisions made by energy providers.

Accurate wind forecasts will also help overcome the perceived barriers of wind intermittence and unpredictability that make some energy providers reluctant to pursue wind as an energy resource. Furthermore, the move towards electric industry deregulation is likely to increase the importance of accurate wind forecasts.

Forecasting electricity production has become a means of increasing the value of electricity with wind turbine technology. An example of the increased interest for such methods is clearly demonstrated by the amount of commercial software available on the market. These programs are used by utilities with wind power plants within their grids.

All documents produced under Task XI are available from the Operating Agent representative (see Appendix B) and from representatives of countries participating in Task XI (see Table 2.2).

More information can be found on the Internet at www.windenergy.foi.se/IEA_Annex_XI/ieaannex.html

Author: Sven-Erik Thor, FOI, Sweden.

2.2 TASK XVI

WIND TURBINE ROUND ROBIN TEST PROGRAM

The objectives of this program are to validate wind turbine testing procedures, analyze and resolve sources of discrepancies, and to improve the testing methods and procedures. The participants are:

- Risø Test Station for Wind Turbines, Denmark
- Center for Renewable Energy Sources (CRES), Greece
- Atlantic Wind Test Site (AWTS), Canada
- National Renewable Energy Laboratory (NREL), United States of America

The Operating Agent is Hal Link at the National Renewable Energy Laboratory (NREL) in the United States.
A series of round robin comparison tests at participating national laboratories 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.

After the kickoff meeting, in April 1996, participants began detailed preparations for testing. These included drafting of test plans, anemometer wind tunnel calibrations, and site calibration measurements.

Wind tunnel calibrations were conducted in cooperation with a European Wind Turbine Standards program, MEASNET, in

Figure 2.2.1 This standard turbine has been tested at sites in four countries.

which anemometers from eight countries are being calibrated in ten wind tunnels. Final calibrations have been completed. Annex participants agreed to conduct a follow-on calibration of anemometers at CRES. These tests were complete in March 1999 and results were presented at the European Wind Energy Conference in Nice.

NREL and Risø have completed site calibration measurements, which quantify wind speed differences between the anemometer tower and the wind turbine. Other participants plan to conduct ed these tests in 2000.

The windturbine selected for testing is an AOC 15/50, 50 kW free-yaw turbine, that is relatively easy to transport and install. Participants will complete tests, one at Canada's AWTS, one at the United States' NREL, and one at two test stations in Europe.

The first two turbines have been in operation for several years with both NREL and AWTS engineers having completed several operational tests of their turbines. NREL has also completed noise, power performance, and structural loads testing of their turbine. AWTS completed power performance and loads testing in spring 2000.

The third turbine was shipped to Denmark and began operation at Risø in early December 1997. Risø completed power performance and loads tests in June 1998.

The turbine was then shipped to CRES where testing continued through 2001.

Final reports are expected to be completed by 2002.

Author: Hal Link, NREL, United States

2.3 TASK XVII

DATABASE ON WIND CHARACTERISTICS

INTRODUCTION

In 1996, the EU-DG XII (JOULE) project, Database on Wind Characteristics, was started. The project was concluded at the end of 1998 and has 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 International Energy Agency (IEA), has been formulated with Sweden, Norway, the United States, the Netherlands, Japan, and Denmark as active participants. The Annex began on 1 January 1999, and an initial annex 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 has agreed to run the annex for an additional two and a half years. The continuation of Annex XVII covers the period of 1 July 2001 to 31 December 2003.

The main purpose of the annex is 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 continuation of the annex beyond the initial period, the scope has been widened to include support for international wind turbine standardization efforts.

OBJECTIVES

The specific objectives of Annex XVII are as follows.

- Assure that current and future users will have access to the database through the Internet.
- 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.
- Attract even more users by a continued effort on dissemination and development of the database facilities.
- Support the 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.
- 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 161,000 hours of high-sampled meteorological time series data from 57 sites in Europe, Egypt, the United States, and Japan that represent a wide variety of wind

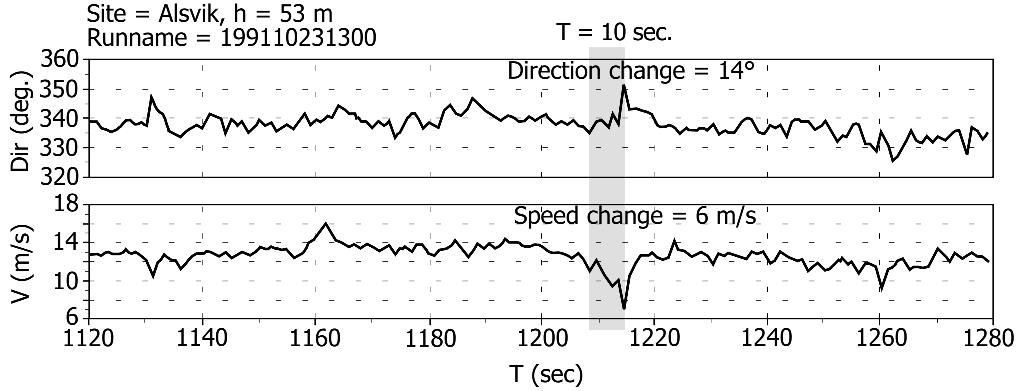

Figure 2.3.1 Example of simultaneously extreme wind speed (down) gust and wind direction change identified using database search and analysis tools

climates, terrain types, and wind turbine wake situations. For two of the sites, the meteorological time series data is supplemented by structural time series data recorded at nearby standing turbines. In addition to the time series data, more than 555,000 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 thus 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 World Wide Web. 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 accomplishments achieved in 2002, within each of the defined work tasks, are summarized below.

Maintenance

Maintenance of the database includes both routine software updates and routine hardware updates. The following activities were performed during 2002.

- Including links to available wind resource maps.
- Updating web pages.
- Installing a new hard disc.
- Changing the software platform (InterBase & IntraBuilder (r) MYSQL & XML) in order to improve performance and support a new generation of search facilities.

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. A notable activity was the inclusion of a new wind farm data category. A description of the efforts performed within upgrade of the database facilities as well as within extension of the amount of available wind field time series appears below:

Database Utilities

- A small software package (WDFC), used for conversion of data in the standard database format to HOMER format, has been included.
- An interactive plotting facility of turbulence intensity versus wind speed (for resource data where information on turbulence intensity is available) has been included.
- A new wind farm data category has been implemented.

Database Bank Implementation

- Ainswort site time series data (Nebraska, U.S.A.; scrub; hill; 5,421 hours).
- Equinox site time series data (Equinox Mountain, Vermont, U.S.A.; scrub; hill; 72 hours).
- Flowind site time series data (Horned Hills, California, U.S.A.; scrub; hill; 5,947 hours).
- Gorgonio site time series data (San Gorgonio Pass, California, U.S.A.; scrub; hill; 1,399 hours).
- Holland site time series data (Minnesota, U.S.A.; scrub; hill; 6,525 hours).
- Horns Rev site additional wind field data (Denmark; offshore; flat; 4,891 hours);
- Lyse site additional wind field data (Sweden; coastal; mountain; 31,355 hours).
- Oak Creek site additional wind field data (California, U.S.A.; scrub; hill; 3,264 hours).
- Orkney site time series data (Burger Hill, Orkney, U.K.; coastal; flat; 6,083 hours).
- Rosiere site time series data (Wisconsin, U.S.A.; scrub; hill; 4,681 hours).
- Jericho site time series data (Texas, U.S.A.; scrub; hill; 6,349 hours).
- Tug Hill site time series data (Tug Hill Plateau, New York, U.S.A.; pastoral; hill; 2,983 hours).
- Calwind site resource data (Oak Creek, California, U.S.A.; scrub; hill; 17,303 hours).
- Hanford site resource data (U.S.A.; pastoral; flat; 8,625 hours).
- Lyse site resource data (Sweden; coastal; mountain; 31,479 hours).
- Orkney site resource data (Burger Hill, Orkney, U.K.; coastal; flat; 9,707 hours).
- Tjaereborg site additional resource data (Denmark; coastal; flat; 11,355 hours).
- Windland site resource data (Cameron Canyon, Tehachapi, California, U.S.A.; scrub; hill; 17,090 hours).
- Structural load measurements from the 2-MW, 60-m wind turbine at Tjaereborg, Denmark (60 hours).
- Horns Rev site additional wind field time series data (Denmark; offshore; flat; 8,878 hours).
- Gedser Rev site wind field time series data (Denmark; offshore; flat; 702 hours).
- Detailed 3-D wind field time series data from an array of sonics covering a fictitious, 42-diameter rotor plane at the test site of the National Renewable Energy Lab (NREL) (U.S.A.; pastoral; flat; 24 hours).
- Marsta site 3-D wind field time series data (Sweden; rural; flat; 2,975 hours)
- Ainswort site resource data (U.S.A.; scrub; hill; 7,249 hours).
- Equinox site resource data (U.S.A.; scrub; hill; 3,223 hours).
- Flowind site resource data (U.S.A.; scrub; hill; 15,204 hours).
- Gorgonio site resource data (U.S.A.; scrub; hill; 6.580 hours)

- Holland site resource data (U.S.A.; scrub; hill; 3,797 hours).
- Jericho site resource data (U.S.A.; scrub; hill; 6,567 hours).
- Rosiere site resource data (U.S.A.; scrub; hill; 6,497 hours).
- Tughill site resource data (U.S.A.; scrub; hill; 10,521 hours).
- Capel Cynon site resource data (U.K.; pastoral; flat; 55,523 hours).
- Delabole site resource data (U.K.; pastoral; flat; 8,038 hours).
- NTUA site resource data (Greece; scrub; hill; 49,587 hours).
- Ventosa site resource data (Mexico; scrub; hill; 12,432 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 Annex XVII has a high priority. Inititatives taken in 2002 are listed below.

- Eight electronic newsletters were issued.
- The Database on Wind Characteristics was used in a number of ongoing research projects (the JOULE project ENDOW, the JOULE project ADAPTURB).
- In March 2002, an online presentation of Database on Wind Characteristics was given at the ENDOW Workshop, Risø, Denmark.
- In April 2002, two papers (*Analysis of Extreme Wind Shear Events* and *Constrained Simulation of Critical Wind Gusts by Means of Wavelets*) based on data originating from the database were presented at the Global Windpower Conference, Paris.
- Leaflets were distributed at Risø Vinddag 2002 (Risø, Denmark, 3 December 2002) and the ENDOW Workshop 2002 Global Windpower Conference.
- In September 2002, a presentation of Database on Wind Characteristics was given at the WINDENG kickoff meeting, Risø, Denmark.
- Leaflets were distributed at Windpower 2002, Oregon, June 2002 and at the Danish Ministry of Energy's Wind Energy Conference, Fredericia, May 2002.

Part of the success criteria for the dissemination effort is the number of users attracted. At present, the database has approximately 180 registered users. The database is available on the web server (www.winddata.com) and usage is free for users from IEA Annex XVII participating countries.

SUPPORT FOR INTERNATIONAL WIND TURBINE STANDARDIZATION EFFORTS

This task comprises a rational calibration of load-critical parameters in existing International Electrotechnical Commission (IEC) design codes. The activity is closely coordinated with the IEC-TC88/MT1 committee, working on a revision of the IEC 61400-1 safety code for wind turbines.

During 2002, the focus has been on the Extreme Operating Gust (EOG) load case. Based on a combined wavelet and extreme value analysis of data originating from the database, succeeded by a convolution of the resulting extreme value distributions (conditioned on the mean wind speed) with the mean wind climate classes specified in the IEC 61400-1 code, the TC88 committee has been given a revision of the IEC EOG load case.

COMMERCIALIZATION OF THE DATABASE

To ensure that the database will be online and available through the Internet in the future (beyond 2003) for the benefit of a steadily increasing number of users, a need for funding of basic maintenance activities will occur. An opinion poll among potential customers has been performed in order to clarify user preferences concerning fee models. Initially, five possible fee models have been formulated addressing the following customer segments.

- An annual fee for a general, single-user class.
- A semester account, which is a single-user account for university use during one semester and in one project.
- An XML web service, which is a single-user account for customers who want to get pure data via XML and then subsequently manage it on another server.
- A partner account, which is a single-user account for customers that supply data to winddata.com.
- A company account, which is a multi-user account for companies operating in the field of wind energy.

A preliminary conclusion, based on the available user response, shows an annual fee, a partner account, and a company account as the most practical fee models.

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

2.4 TASK XIX

WIND ENERGY IN COLD CLIMATES

INTRODUCTION/OBJECTIVE

Wind energy is increasingly being used in cold climates, and technology has been adapted to meet these challenges. As turbines that incorporate new technology are being demonstrated, the need grows for gathering experiences in a form that can be used by developers, manufacturers, consultants, and financiers. In order to supply needed information on the operation of wind turbines in cold climates, Annex XIX to the International Energy Agency (IEA) research and development (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 objectives.

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

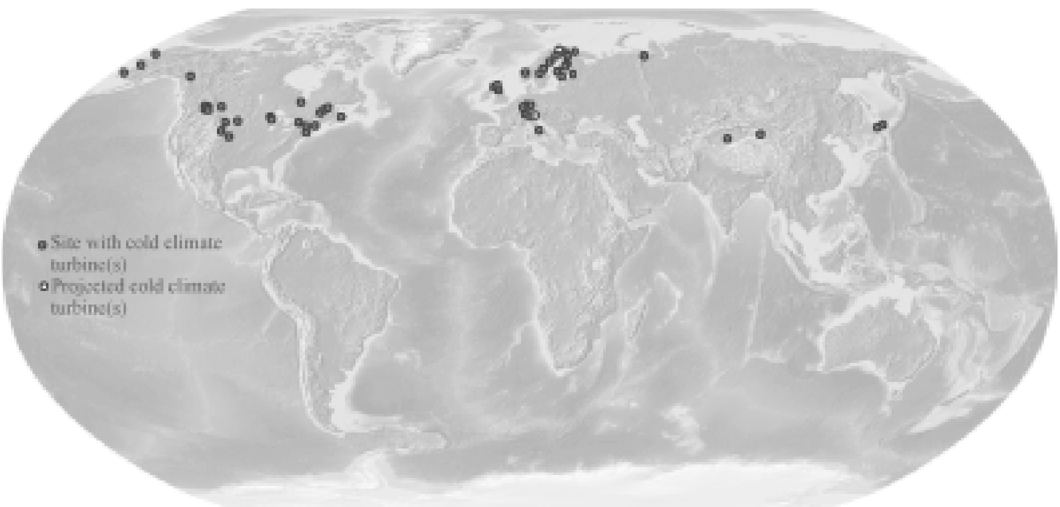

Figure 2.4.1 Wind turbines, totaling 500 MW, operating in low temperatures or/and in icing climates

Figure 2.4.2 Since 1999, a long-term measurement campaign, including monitoring of adapted technology suitable for severe icing climates, has been carried out at the Olostunturi-fjeld wind farm.

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 from 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 the reliability of turbines in cold climates. 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 also 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 annex develops 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, and elevated).
- Site accessibility (urban or sparsely populated areas).

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 at arcticwind.vtt.fi in order to disseminate general information and operational experiences, as well as gather more information, 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 standardization of wind turbines (i.e., icing and low temperature related features that need to be recognized in standards).

STATUS

Participants have launched their national projects. Switzerland and Canada joined the annex at the beginning of 2002. Two meetings will be organized per year. The first meeting will be held in Finland on 8 April 2003 at Pyhätunturi in connection with the Boreas VI, Wind Energy in Cold Climates conference. The second meeting of 2003 will be held in Switzerland; the date is still to be decided. Due to changes in governmental funding, Sweden has had financing problems for its national project.

The Internet project pages located at arcticwind.vtt.fi have been available for a year and contain general information such as project information and participants, literature, links, and forms for reporting events or for asking cold climate related questions. These pages are available for public use, and project material is contained in password-restricted pages for participants. Unfortunately, forms that were created for collecting operational experiences have not attracted as many as was anticipated, and the Internet page will need additional advertising in order to attract more people.

A state-of-the-art-report will be published on the Internet during the spring 2003. This report is a summary of the wind turbine technologies intended to be used in low temperatures and icing climates. The report will focus on site classification and forming of recommendations.

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

2.5 TASK XX

HAWT AERODYNAMICS AND MODELS FROM WIND TUNNEL MEASUREMENTS

INTRODUCTION

Comprehension of wind turbine aerodynamics and formulation of accurate, reliable predictive aerodynamics models historically have been impeded by experimental uncertainties. Over the past decade, the accuracy and precision of turbine aerodynamics instrumentation have been improved substantially. This has permitted attention to shift to other sources of experimental uncertainty and has highlighted a long-standing dilemma. Full-scale turbines can be densely instrumented, but physical size mandates testing in the field. As a result, overriding uncertainties are introduced into the aerodynamics data by atmospheric fluctuations and anomalies. Alternatively, the wind tunnel offers uniform and controlled inflows. However, as the turbine is scaled down to fit the wind tunnel test section, severe Reynolds number mismatches occur. This results in uncertainties associated with extrapolating measurements to larger blades and faster air flows.

To resolve this impasse, the NREL (National Renewable Energy Laboratory) UAE (Unsteady Aerodynamics Experiment) wind turbine was tested in the National Aeronautics and Space Administration (NASA) Ames 80-ft by 120-ft (24.4-m by 36.6-m) wind tunnel. This test was designed to provide accurate and reliable experimental measurements with high spatial and temporal resolution, for a realistic rotating blade geometry, under closely matched Reynolds number conditions, and in the presence of strictly controlled inflows. Completed in

Figure 2.5.1 Wind tunnel experiments at NASA Ames Research Center in 2000 generated data that will be used by participants in Task XX.

Photo Credit: Lee Fingersh

2000, the test included 22 turbine configurations and produced more than 2,100 data files containing nearly 100 GB (gigabytes) of high-quality data.

Shortly after test completion, select data were employed as a reference standard in a blind comparison designed to evaluate wind turbine aerodynamics code fidelity and robustness. In this exercise, participants were given the UAE geometry and structural properties and then attempted to predict aerodynamic response for a modest number of test cases representing diverse aerodynamic regimes. Code comparison participants did not have access to the experimental aerodynamics data until well after their model predictions were completed and submitted to NREL. 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, no consistent trends were apparent regarding the magnitudes or the directions of these deviations.

The need for improved wind turbine aerodynamics models is clear, and the potential benefits are readily apparent. This annex 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. When 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.

ANNEX STRUCTURE

Objectives and Work Areas

Annex 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. The objectives and work areas are as follows.

- Acquire accurate, reliable, high-resolution experimental aerodynamic and structural loads data for horizontal axis wind turbines representative of full-scale machines.
- Analyze these data using methodologies designed to reveal the flow physics responsible for phenomena observed on horizontal axis turbines.
- Formalize this understanding in hierarchically structured, physics-based model subcomponents, with appropriate consideration for computational efficiency.
- Integrate model subcomponents into comprehensive models in an incremental fashion as a basis for accurate, robust prediction of horizontal axis wind turbine aerodynamics and structural loads.

Participants

At present, the following organizations have indicated firm intent to participate in Annex XX.

- Center for Renewable Energy Systems (CRES), Greece
- Energieonderzoek Centrum Nederland (ECN), the Netherlands
- Institutt for Energiteknikk, Norway
- National Center for Renewable Energy (CENER), Spain
- National Renewable Energy Laboratory (NREL), the United States
- National Technical University of Athens, Greece
- Risø National Laboratory, Denmark
- Swedish Defense Research Agency Aeronautics Division (FFA), Sweden
- Technical University of Delft, the Netherlands
- University of Quebec, Canada

ANNEX STATUS

Following extended discussion in the wind energy technical community and then in the Executive Committee, this collaborative research effort was provisionally approved as Annex XX in April 2002. Provisional approval enabled the Operating Agent representative to submit the annex text for International Energy Agency (IEA) legal review, and to solicit operating budgets and formal letters of intent from participating countries. Shifting government programs and uncertain funding priorities compelled many countries to postpone formal commitments until 2003. It is anticipated that formal commitments and documentation will be submitted by early 2003, and that IEA legal review will be completed in the same timeframe. This will facilitate formal initiation of Annex XX by the Executive Committee and will launch research that will culminate three years thereafter. A kickoff meeting for Annex XX is planned for Spring 2003.

Author: Scott Schreck, NREL, United States.

2.6 TASK XXI

DYNAMIC MODELS OF WIND FARMS FOR POWER SYSTEM STUDIES

INTRODUCTION

The worldwide development of wind power installations now includes planning of large-scale wind farms 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, 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. As a result, users are left to build their own wind farm models. This is not at all trivial and certainly not efficient. Rather, a coordinated effort is expected to enhance progress – consequently, Annex XXI, under the International Energy Agency (IEA) Wind Research and Development (R&D) agreement, was proposed and approved in April 2002 with SINTEF Energy Research (Norway) as Operating Agent.

MEANS AND OBJECTIVES

This annex is carried out on a cost-shared 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 annex 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.

- Establishment of an international forum for exchanging knowledge and experience within the field of wind farm modeling for power system studies.
- Development, description, and validation of wind farm models. (The individual participants of the annex are expected to develop wind farm models. However, the description and validation will be coordinated by the annex in order to provide the state of the art and to pinpoint key issues for further development.)
- Set-up and operation of a common database for benchmark testing of wind turbine and wind farm models as an aid for securing good quality models.

STATUS

Annex XXI was approved in April 2002 on the condition that the proposal text was made more detailed and approved by IEA legal review and that formal notice of participation was collected from each participant. To facilitate this, an initial annex meeting was organized in Oslo, Norway, in June 2002 with participants from ten countries. At the meeting, participants gave brief presentations indicating their potential contributions to the annex, and the work plan of the annex was further detailed. The proposal text is now in for legal review, and formal commitment of participants from Denmark, Sweden, Finland, and Norway (Operating Agent) have been received. However, additional work will be kept on hold until at least one more country commits to the annex, which is expected by the end February 2003.

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

2.7 TASK XXII

WIND ENERGY MARKET ACCELERATION

Status: On hold
Operating Agent: To be determined

The Executive Committee recognized a need for work in this area and approved this Task, but it is now on hold. So far, only two countries have decided to join the Annex, and it was agreed that broader representation was needed for the Task to be effective.

This proposed Task is aimed at conducting programs to assist in development of new markets for wind power, especially in non-OECD countries. It could be useful in forming policies and plans in countries where the demand for electricity is growing. It will be useful where there is a need to tap indigenous energy sources that are sustainable (like wind power) and that do not require the use of expensive imported or environmentally sensitive fossil fuels.

Work on starting this Task has been deferred pending the outcome of discussions at the IEA headquarters regarding a possible new implementing agreement on this topic. Such an agreement might cover multiple renewable energy technologies for applications in developing countries or regions. Work on Task XXII was also deferred because no general agreement was reached on how to approach and pay for the work. Additional discussion on this important Task area is planned.

Author: Peter Goldman, U.S. Department of Energy, United States

Chapter 3
Twenty-Five Years of International Cooperation

3.1 INTRODUCTION

Many government research programs were exploring the use of wind energy to generate electricity in the early 1970s. However, communication among people working on technology for wind turbines was limited, because few mechanisms were available to share results. Several countries were building prototype machines and performing tests, but research and development budgets were limited, and the results of these activities were slow to reach other researchers. Relying mostly on scholarly journals, those working on wind turbine technology received information months or even years after the fact, and each country set research priorities based on its own budget limitations.

This situation was soon to change. Pressure to accelerate the development of alternative energy sources mounted after the oil embargo of 1973. In March 1978, after months of planning and effort, two groups of experts from ten countries met to begin the work we now call the International Energy Agency Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA Wind).

In the beginning, there were two groups, working on Implementing Agreements, to advance wind energy technology. One agreement, The IEA Programme for Research and Development on Wind Energy Conversion Systems (R&D WECS), began with four research tasks addressing wind energy development in general. The R&D WECS group held its first meeting in Paris on 7 March 1978. The original nine members were Austria, Canada, Denmark, Germany, Ireland, the Netherlands, New Zealand, Sweden, and the United States. Soon after, Japan, Norway, and the United Kingdom joined the R&D WECS agreement. The group began work on four research tasks identified by the participants—Task I, Environmental and Meteorological Aspects of WECS; Task II, Evaluation of Models for Wind Energy Siting; Task III, Integration of Wind Power into National Electricity Supply Systems; and Task IV, Investigation of Rotor Stressing and Smoothness of Operation of LS WECS.

The other agreement, the IEA Co-operation in the Development of Large-Scale Wind Energy Conversion Systems (LS WECS), focused on the design of megawatt-scale wind turbine systems. The LS WECS agreement was signed on 6 October 1977. Original members of LS WECS were Denmark, Germany, Sweden, and the United States. Soon after, Canada, Italy, the Netherlands, Spain, and the United Kingdom joined the LS WECS Agreement. The objectives were to further development of wind energy by cooperative R&D within the IEA framework and to coordinate the planning and execution of their national LS-WECS research, development, and demonstration programs. They worked to develop national activities that were mutually supportive and complementary while meeting national needs and requirements.

Credit: Courtesy Lou Divone.

Figure 3.1 Meetings of the Executive Committee representatives from each country have played a continuing role in information exchange. The ExCos of both wind agreements are pictured here in 1984, Edinburgh.

In 1991, the two wind agreements were combined under the title "Implementing Agreement for Co-operation in the Research and Development of Wind Energy Systems." The information-gathering work being carried out under the LS WECS agreement was continued under a new Annex to the combined IEA Wind agreement, Task XIII, Co-operation in the Development of Large Wind Turbine Systems.

By the end of 2002, the IEA R&D Wind agreement had 21 contracting parties from 19 countries and the European Commission. In addition to a continuing Task XI that sponsors Topical Experts Meetings, Joint Action Symposia, and an Experts Group on Recommended Practices, there are four other active task groups exploring issues of current interest to members: Task XVII, Database on Wind Characteristics; Task XIX, Wind Energy in Cold Climates; Task XX, Horizontal Axis Wind Turbine Aerodynamics and Models From Wind Tunnel Measurements; and Task XXI, Dynamic Models of Wind Farms for Power System Studies.

Since the IEA Wind groups began their co-operation, wind turbine technology has advanced from a few prototype machines at government test sites to an important commercial industry with installed generating capacity exceeding 31 GW worldwide. Over the years, the IEA Wind agreements

> **"Collectively the member countries of the LS WECS agreement developed some 20 different turbine configurations of large-scale turbines. No single country could have afforded such a comprehensive R&D program. Each country learned from the successes and mistakes of the others."** – *Ezio Sesto, former Chair and member, Italy, 2002.*

CHAIRS OF THE IEA R&D WIND EXECUTIVE COMMITTEE

1978-1979	Lars Rey (Sweden)
1980-1981	Louis Divone (USA)
1982-1983	Emon Kinsella (Ireland)
1984-1985	B. Maribo Pedersen (Denmark)
1986-1987	Daniel F. Ancona (USA)
1988-1989	Steffan Engström (Sweden)
1990-1991	H. Jos M. Beurskens (Netherlands)
1992-1993	William.G. Stevenson (UK)
1994-1995	Ezio Sesto (Italy)
1996	Daniel F. Ancona (USA)
1997-1998	Raj Rangi (Canada)
1999-2001	Jaap 't Hooft (Netherlands)
2002-2003	Jrrgen Lemming (Denmark)

CHAIRS OF THE LS WECS EXECUTIVE COMMITTEE

1978-1979	R. Neumann (Germany)
1980	Lars Rey (Sweden)
1981	Leif Brandels (Denmark)
1982-1983	Louis Divone (United States)
1984-1985	Marc Chappell (Canada)
1986-1987	B. Maribo Pedersen (Denmark)
1988-1989	Daniel F. Ancona (USA)
1990	William Stevenson (Scotland)

Secretaries of the Executive Committees

1978-1993	Bengt. Pershagen
1993-1996	Karine Steer-Diederen
1997-present	Patricia Weis-Taylor

Newsletter Editors

1992-1998	Jack Templin
1999-2001	Marc Chappell

facilitated international cooperation that accelerated development of advanced technologies, avoided costly duplication of effort in national research programs, and increased the research labor hours available to any single national program.

3.2 TOOLS OF COOPERATION

As the participants in the agreement worked together, they developed several important mechanisms to enhance information exchange and cooperative R&D. Over time, these tools have evolved to accommodate changing research and development interests.

Executive Committee Meetings, Minutes, Newsletters, and Annual Reports

The regular meetings of the Executive Committees (ExCo) have always been an important vehicle for managing work conducted under the Agreement and for information exchange among participants. The ExCo of an agreement consists of a member and alternate member from each contracting party to the agreement, usually one per country. The ExCo meets two times per year to conduct business and examine facilities in the host country. Until the two agreement groups merged, they met at the

Caption: Credit: Rolf Windheim

Figure 3.2 During technical tours that follow ExCo meetings, members view test facilities, factories, and commercial wind farms. This 1979 tour of the Risø National Laboratory showcased a vertical axis machine undergoing tests.

same place and conducted their meetings on two consecutive days. By the close of 2002, there had been 50 meetings of the Executive Committees.

For the R&D WECS agreement, meeting presentations revolved around cooperative research tasks. Research results were shared freely at the meetings, even though not all countries worked on each task. For the LS WECS agreement, participants shared detailed research results from their national programs for development of large-scale wind turbines and planned meetings of experts on topics of common interest.

Minutes of each meeting of both agreements were circulated to all members of the ExCos. IEA Wind also published and distributed a newsletter twice each year between 1992 and 2001.

In addition, since 1978, each agreement has published an annual report every year. These reports contain detailed technical and organizational information to keep participants informed of progress in the member countries and in the cooperative research. In 2000, the ExCo of IEA R&D Wind agreed to make the annual report a public document and it was posted on IEA's public Web site.

> **"This is more than an annual report; it is a significant information resource for anyone interested in the progress of wind energy." –** *Judge's comment, Society for Technical Communication distinguished award to IEA Wind Annual Report 2001.*

Cooperative Research

Cooperative research tasks have been a vital tool for advancing wind technology. Four tasks were included in the original implementing agreement text for R&D WECS, and many more have been added over the years. Originally, tasks were cost-shared, and participants paid an operating agent organization to perform most of the work. All participants shared the results. Tasks then evolved from cost-shared to task-shared; participants contributed labor and facilities, usually in their home countries, to a joint program coordinated by the operating agent. Up to 10 labor-years of effort in each country would be applied per task. The return to each country has been those labor-years multiplied by the number of organizations working on the task. For some tasks, participants received a ten-fold increase of their labor efforts. Over the years, some research has been conducted in combined cost- and task-shared activities in which participants have paid an operating agent to synthesize data generated with labor within participants' own research laboratories. By the close of 2002, 21 official tasks had been adopted as Annexes to the R&D Wind implementing agreement. (See Table 1.2 in Chapter 1)

Topical Expert Meetings

Meetings of experts on narrow topics of interest to wind turbine researchers have been a key feature of the agreements beginning in October 1978 with the Seminar on Structural Dynamics held in Munich, Germany. Members of the ExCo invite experts from universities, research institutes, government laboratories, and industry to attend these Topical Expert Meetings (TEMs). Attendees return home with a broadened perspective. Countries that invite experts from industry pass this benefit directly into the private sector. When personnel from government and university research

"Technical Expert Meetings are important because in each country only one or two people are working on each of these problems. When they go to an experts meeting and talk to others who are working on the problem, it is a reality check for them about problems they may have thought were huge, but find out others don't think so. This kind of interaction with a wider group of experts has helped guide individual countries to set better research goals, take realistic approaches, and identify important areas that are not being explored." – *Dr. Robert Thresher, Alternate Member, theUnited States, 2002.*

groups move into industry, this broadened perspective helps improve commercial machines. The operating agent keeps a library of documents (proceedings and recommended practices) from the meetings and distributes them on request within participating countries.

Topical Expert Meetings also serve to review the state of the art and identify areas for international cooperation. Many of the tasks completed under IEA Wind began with TEMs.

Recommended Practices

In 1980, the R&D WECS ExCo recognized the need for standardized testing procedures designed especially for wind turbine systems, because standards bodies of the day were operating with other objectives. So the ExCo organized an experts group, a standing committee for recommending test procedures for the evaluation of WECS performance. The aim was to propose wind turbine testing to address the development of internationally agreed-to test procedures. In 1987, the standing committee's activity was formalized as Annex XI to the agreement.

The approved recommended practices issued by IEA R&D Wind showed the research and industrial community proper testing and operation procedures well before the International Electro-technical Commission started activities related to wind energy. IEA R&D Wind has published recommended practices approved by the member countries on power performance testing, fatigue loads testing, acoustics measurement, structural safety, power quality of single turbines, lightning protection, and wind speed measurement. Several of these recommended practices

"In the Netherlands where noise is an important issue in building and environmental permits for wind farms, the Recommended Practice number 10, Measurements of Noise Immission from Wind Turbines at Noise Receptor Locations, first edition 1997 and number 4, Acoustic Measurements of Noise Emission from Wind Turbines, 3rd edition 1994, form an integral part of the regulations to perform measurements and evaluations. These documents contain detailed information that experts in the field agree upon and would be very expensive for each separate country to generate."– *J.L 't Hooft, Former Chair, Alternate member, the Netherlands, 2002.*

have been revised and published as 2nd or 3rd editions as new information became available. Many of these provided input to the IEC standards of the 1990s. Practices of cost estimation, electromagnetic interference, noise measurement, and anemometry recommended by IEA Wind were still the accepted standards in 2002. (See Table 2.1.1 in Chapter 2.1.)

Joint Action Symposia

The ExCo decided in 1985 that certain topics deserved regular meetings, to keep experts from member countries up to date. Joint actions are set up in a specific research area of current interest for which a periodic exchange of information among experts is deemed necessary. This activity demands less time and money than an official task activity, but it results in steady advancement in the state of the art. As with Topical Expert Meetings, participation is by invitation from the national members of the ExCo. By 2002, multiple joint action meetings had taken place on Aerodynamics of Wind Turbines (15), Wind Turbine Fatigue (5), Wind Characteristics (2), Offshore Wind Systems (1), and Wind Forecasting Techniques (1).

> **"This is the place to meet the real experts in aerodynamics." –** *Alois Peter Schaffarczyk, Germany, participant in Joint Action Symposium on Aerodynamics, 2002.*

Internet

With the advent of the Internet, IEA Wind offered information to the public at a Web site hosted by the Danish Technical University, initiated password-protected pages for ExCo members, and made information available on special Web pages for participants in tasks. In 2002, a unified approach was taken and a common public homepage, www.ieawind.org, was created. This central location included descriptions of IEA Wind objectives, activities, organizational structure, accomplishments, and active tasks. It also provided links to specialized information on wind energy within the member countries.

Special Planning Documents and Publications

Throughout the 25-year history of the IEA Wind agreements, members have paused every five years or so to develop planning documents to guide the near-term and long-term research strategy of the agreement. Written by ad hoc committees and approved by consensus, these documents have titles such as Five-Year Plans, End-of-Term Reports, Strategic Plans, and Long-Term R&D Strategy Reports.

Management of the Agreement

Management for efficient progress toward objectives has been an important characteristic of the IEA Wind agreements. For example, after a 1986 comprehensive review of the first 10 years of activities, the ExCo's of the two Agreements determined that many of the functions of the Agreements overlapped. To proceed more efficiently, the agreements merged in 1991. The 10-year review also pointed out the need for multi-year planning. The first Five-Year Strategic Plan was published in 1993. Such plans continue to guide the work of the IEA R&D Wind agreement. The ExCo has overseen work performed by hundreds of participating organizations in the 19 member countries. Tasks are planned and monitored to ensure that the work is done on schedule and within budgets. Results of the work are widely published and help to encourage the development and deployment of wind energy.

3.3 CONTRIBUTIONS TO SELECTED TOPICS

In addition to the benefit to national research programs of people interacting with their counterparts in other countries, the tools described above have advanced the science behind wind turbine technology. Over the first 25 years of the agreement, continuing work in technical areas deemed important by the members has yielded significant results. These long-term efforts, often building on previous tasks within the agreement and always building on the work of the participants, have accelerated the advancement of wind turbine development. The following three topic areas are only a sample of the issues addressed by the Wind Agreement. However, they illustrate the ways progress has been made over the years and provide insight into how work can continue to advance wind energy development.

Increasing Understanding of Wind Turbine Behavior

One of the key issues facing people trying to revive the use of wind energy was an understanding of the behavior of wind turbines in response to the wind. This required integrating information from several disciplines that had not previously interacted. The early studies conducted in these programs pointed out that knowledge in meteorology, electrical machinery, and aeronautical fields could be applied in wind engineering. Initially, the wind energy research organizations were located within meteorological and aeronautical research institutes and universities. Over time, the researchers moved beyond narrow scientific disciplines and focused on specific questions relevant for wind technology, such as wind modeling, resource assessment, aerodynamics, and structural dynamics.

The new LS WECS agreement began by holding a Topical Expert Meeting (TEM) on structural dynamics on 12 October 1978, in Munich. A key presentation at the 1978 meeting described work in Denmark with the Gedser 200-kW wind turbine. This turbine, which operated from 1958 to 1967 in automatic mode and had avoided major mechanical problems, was refurbished in 1975 with funds from Denmark and the United States. These countries wanted measurements from the turbine to validate models for designing large wind turbines for their new wind energy programs. Measurements of power output characteristics and efficiency were taken,

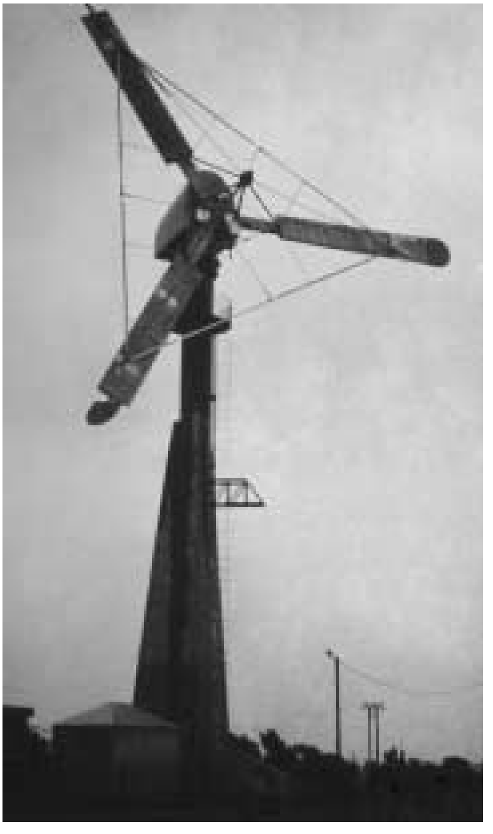

Figure 3.3 The refurbished 200-kW Gedser machine operated for 650 hours between November 1977 and April 1979, when it was taken out of service. Total power production was 39,890 kWh.

and power train oscillations were measured using strain gauges. This information was correlated to anemometer data from the 48-m-tall meteorological tower installed at the site. This work provided a foundation of data for commercial development of wind power in the four countries participating in the LS WECS agreement.

At about the same time, the R&D WECS agreement authorized a cost-shared task to improve understanding of wind turbine behavior. R&D WECS Task IV, Investigation of Rotor Stressing and Smoothness of Operation of LS WECS, was carried out by the University of Stuttgart to help designers of large wind turbines. The work was or-

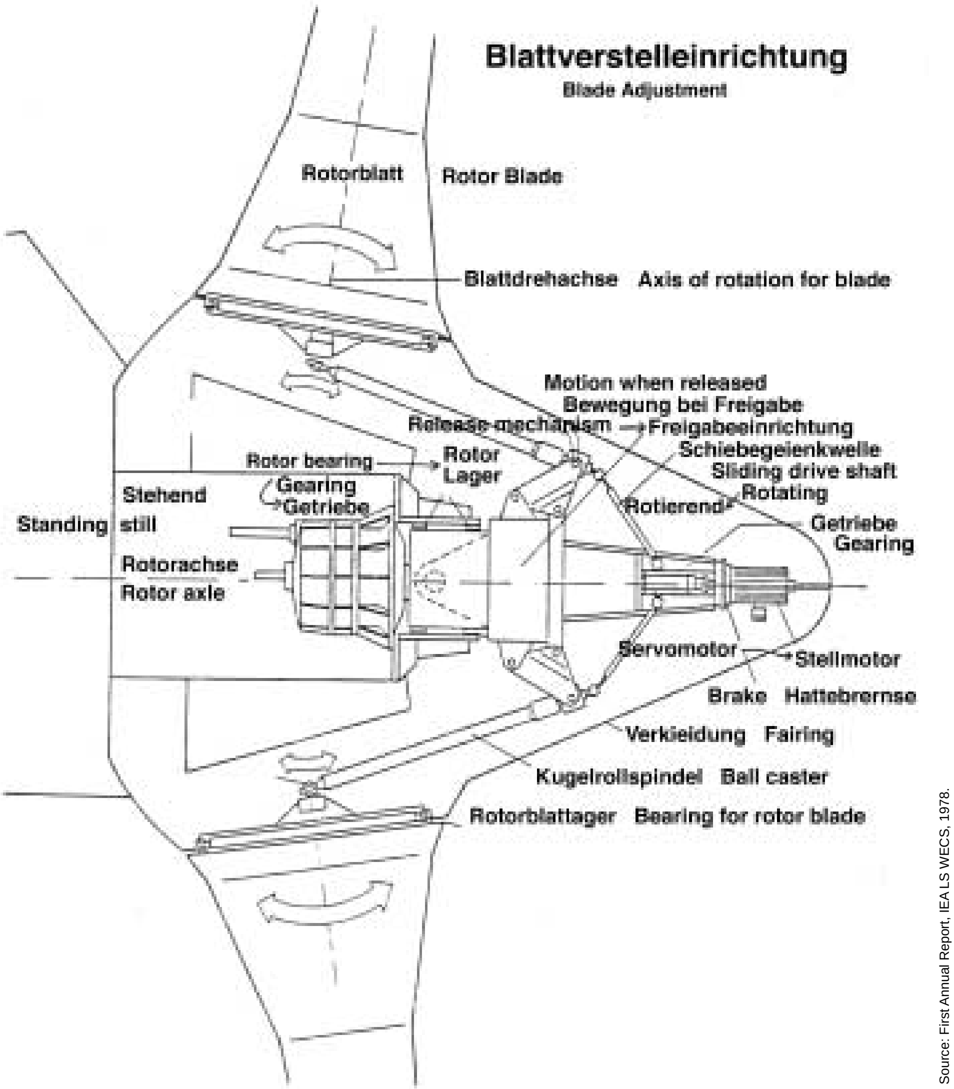

Figure 3.3 While developing the 3-MW Growian turbine, the German wind energy program worked with participants in IEA Wind task IV to explore rotor control strategies.

Figure 3.4 The UNIWEX project conduced an extensive measurement campaign, revised the ARLIS program for aeroelastic simulation, and documented operating responses during good weather and bad from May 1988 to February 1992.

ganized into 12 subtasks to study control of the rotor blades of a proposed 3-MW WECS (Growian) to reduce loads "from wind profiles, gusts, and gravity and thereby to minimize loads not required to produce the output power of the plant." The work included modeling and experiments in wind tunnels with a 7.4-m rotor model. The results of this work, completed in 1980, were publicized at ExCo meetings, Topical Expert Meetings, and in numerous papers.

Over the next few years, TEMs brought together experts working to understand the interactions of aerodynamics and loads on wind turbine structures. Structural design criteria for LS WECS were discussed at a TEM held in 1983 in Greenford, the United Kingdom. Methods of aerodynamic calculation for WECS were the topic of a 1984 TEM in Copenhagen, Denmark. Participants agreed that this topic required regular meetings to share developments, and a Joint Action Symposium on Wind Turbine Aerodynamics was set up in 1986.

Meanwhile, the government demonstration programs of megawatt-class machines in the United States, Sweden, Germany, and Denmark had problems mainly related to structural fatigue. These prototype turbines provided useful information of system behavior shared at TEMs and Joint Action Symposia and applied in industry in later years.

In 1984, the R&D WECS agreement recognized a need to apply the accumulated data on fatigue and measurement techniques to the research and commercial design of wind turbines. The Recommended Practices for Wind Turbine Testing and Evaluation group submitted a Recommended Practice for the evaluation of fatigue loads by means of measurement to the ExCo. Each participating country approved the practice, which was updated in 1990 and has become part of IEC 61400-13 TS, Measurement of Mechanical Loads.

In 1985, a TEM on Modeling of Atmospheric Turbulence for Use in WECS Rotor Loading Calculations was held in Stockholm, Sweden. This topic became the focus of the Joint Action Symposium on Fatigue Testing in 1987.

In 1987, the R&D WECS agreement group was ready to sponsor a task to address some of the issues of aerodynamics, loads, and control strategies that had been discussed in the TEMs and Joint Action Symposia. To supplement and multiply the efforts of national research programs, the ExCo approved Task XII, Universal Wind Turbine for Experiments (UNIWEX); the Institute for

Figure 3.5 The costs and benefits of full-scale fatique testing of wind turbine blades was discussed at the 23rd TEM in Golden, Colorado, 1992.

Computer Applications, Stuttgart, Germany acted as Operating Agent. In this cost-shared work, a computer-controlled, two-bladed experimental wind turbine at the Ulrich Hütter Wind Test Field at Schnittlingen, Germany, was modified and named UNIWEX. The project included experimental study of aerodynamics, operational behavior, load spectra, and control strategies, as well as validation of computer codes. Results were widely publicized in presentations at ExCo meetings, TEMs, and conferences.

After the work was completed in 1994, the UNIWEX turbine became integrated into several research projects of the Commission of European Communities, resulting in further benefit for resources invested. The experimental data and code validation activities of this project contributed to development of commercial wind turbines in the participating countries. For example, the software developed for aeroelasticity was successfully applied to seven different commercial wind turbines.

Attention focused on wind turbine blades in 1992, when a TEM on Fatigue of Wind Turbines and Full-Scale Blade Testing was held in Golden, Colorado, the United States. Later that year, work began on a task to improve the design basis for stall-controlled rotor blades. The combined cost- and task-shared work of Task XIV, Field Rotor Aerodynamics Database, was designed so that the operating agent coordinated the measurement programs of the participants and integrated their data into a functional database. All participants were operating experimental wind turbines equipped with instrumented blades to measure pressure distributions around the profiles or aerodynamic forces on blade sections. The data were used to verify aerodynamic design codes. Four years of work resulted in a well-documented database available to wind turbine designers on CD-ROM and accessible on an ftp site at ECN, Netherlands.

After more discussion of loads and blade fatigue at meetings in Sweden and the Netherlands, the ExCo followed recommendations made at the completion of Task XIV and approved Task XVIII, Enhanced Field Rotor Aerodynamics Database in 1998. Completed in 2002, this task group extended the database developed in Task XIV and disseminated the results; extensive use of this database can be expected for years to come. In 2004, a meeting will be held to discuss beginning another task to continue this important work.

By the close of 2002, the IEA Wind agreement groups had conducted 15 Joint Action Symposia on wind turbine aerodynamics and five on fatigue in wind turbines. As more test data become available and as wind turbines increase in size, Topical Experts Meetings and Joint Action Symposia are addressing the latest issues of wind turbine aerodynamics and structural response.

Out of these meetings came the request for an IEA R&D Wind task on aerodynamic modeling. After several meetings and rounds of discussion, the ExCo approved Task XX, Horizontal Axis Wind Turbine Aerodynamics and Models from Wind Tunnel Tests in 2002. Participants will use data from a full-scale wind tunnel experiment conducted in 2000 at NASA to develop and validate model subcomponents that can then be used to improve comprehensive aerodynamic models. Improving models in all the participating countries will continue the contributions of IEA R&D Wind work to an increased understanding of wind turbine behavior.

> **"To determine at which distance windmills have to be placed for optimum energy output from a group of windmills**." – *Objective of Task I Subtask A3, Study of wind wake effects, 1978.*

Studying Wind Turbine Siting Issues

One of the important issues at the beginning of the cooperation was the proper placement of wind turbines for maximum energy output and operating lifetime. Identifying high-wind areas and avoiding damaging turbulence were key objectives for all countries with wind turbine research programs.

Two of the first four tasks that began with the IEA Wind agreement in 1977 provided a way for participants to multiply the benefits of the individual efforts of each country. Task I, Environmental and Meteorological Aspects of Wind Energy Conversion Systems, was a cost-shared activity, with the Swedish Board for Energy Source Development as operating agent. The work included a study of wake effects in wind tunnel tests. The results for a model of a vertical axis wind turbine were presented at the 2nd International Symposium on Wind Energy Systems, Amsterdam, October 1978. This presentation began another tradition of the IEA Wind Agreement: presenting results to the wider research community.

Completed in 1983, Task II, Evaluation of Wind Models for Wind Energy Siting was operated by the U.S. Department of Energy's Battelle Pacific Northwest Laboratories. The participants compared selected atmospheric boundary layer numerical models with each other and with observed data to evaluate the

Figure 3.5 ExCo members gained first-hand experience with the prototypes that would evolve into the elements of today's wind farms. Here members inspect the nacelle of the 750-kW Nibe turbine in Denmark in 1980.

usefulness of the models for wind turbine siting. Participants completed cases using their own models—a way of organizing work that would be used successfully in many IEA Wind tasks. The study showed that such models can be useful at the initial stage of siting when a large area is screened for places with the best wind energy potential.

Following on the work of Task I on wake effects, IEA Wind initiated work on Task V, Study of Wake Effects Behind Single Turbines and in Wind Turbine Parks, operating agent, Stichting Energionderzoek Centrum (ECN), the Netherlands. By taking measurements at wind farms, doing experiments in wind tunnels, and refining theoretical models, participants hoped to estimate the power output efficiency as a function of spacing of turbines and number and type of machines. Starting in 1980 with field measurements on a 5-m experimental WECS, participants also measured wakes at their own installations and shared information. Each country benefited from four additional sources of data. At task completion in 1983, the participants concluded that data from wind tunnel tests and small-scale field experiments helped in developing predictive methods for single wakes, small clusters, and large clusters. However, evaluation of these methods required data from full-scale experiments. Participants recommended another task to collect these data.

In response to the recommendations from Task I participants, Task VI, Study of Local Wind Flow at Potential WECS Hill Sites, began in 1982 with an experiment carried out on Askervein, Scotland. The project participants collected field data on local variations in wind speed and turbulence produced by the 125-m-high, treeless, "ideal" hill and compared these data with model predictions. This project was a god one for cooperation because no one country had sufficient instruments to cover a full-scale hill. Results from this Task helped scientists predict the atmospheric flow and wind acceleration effects in complex terrain.

Consideration of siting issues continued under Task VIII, Decentralised Applications for Wind Energy, which began in 1984 and was completed in 1989. The many working documents that resulted from this task were circulated among member countries. A subtask on site assessment defined models and techniques for obtaining wind and load data for decentralized wind diesel systems. This work was included in the book *Wind-Diesel Systems: a guide to the technology and its implementation*, edited by Ray Hunter and George Elliot, published by Cambridge University Press in 1994. Royalties from the book sales are returned to the ExCo.

As a follow-on from the Task V study of wake and cluster effects, Task IX, Intensified Study of Wind Turbine Wake Effects, began work in 1985. The objective was to improve the knowledge of aerodynamic interactions between wind turbines operating in a windfarm. The task, completed in 1991, collected data from single turbines, pairs of interacting turbines, and full-size wind farms. The experimental data and theoretical techniques were brought together in a benchmark exercise based around the Näsudden turbine (Sweden) for the evaluation of single wakes and the Taendpipe group of turbines (Denmark) for the evaluation of wind farm models.

An activity related to wind turbine siting decisions began in 1999 with Task XVII, Database of Wind Characteristics. This task was formulated as a continuation of a European Commission project EU-DG XII (JOULE), which concluded with a unique database of quality-controlled, documented wind field time series measurements supplemented with tools for easy access and simple analysis on the Web. IEA R&D Wind Task XVII provides wind energy planners, designers, researchers, and the international engineering community a source of actual wind field data (time series and resource data) from a wide range of wind climates and terrain types.

Figure 3.6 To evaluate how wind farms affect the dynamic and transient stability of utility power systems, participants in Task XXI are developing and validating models of wind farm output.

Credit: R. Hinrichs

Figure 3.6 Information from IEA Wind tasks helped guide the layout of wind parks like this one in Spain for improved energy production and increased turbine operating life. Continuing tasks will allow forecasting the output and electrical characteristics of electricity from wind farms thereby increasing its value.

Determining Power Performance and Effects of Wind Turbines on Power Networks

From the beginning in 1977, all IEA Wind members had an interest in using wind energy for the national electricity grid. The first measurements of the refurbished Gedser turbine in Denmark generated data on the quality of power for use in the utility grid.

In 1978, Task III, Integration of Wind Power into National Electricity Supply Systems, used models of wind energy production and models of conventional energy production for the northern German coastal area to calculate the maximum admissible investment costs for wind power plants compared to the investment and fuel costs of conventional power plants. This work was then extended to Japan, the Netherlands, Sweden, and the United States. The positive conclusions of this report helped gain support for continued R&D to bring this technology to commercial status.

With the advent of commercial wind installations in the early 1980s, an important issue for developers was the accurate determination of power curves for competing wind turbines. Power curves needed to be based on standard tests and measurements so that the energy production characteristics of wind turbines available on the market could be compared. Responding to this need, the R&D WECS agreement established an Expert Group Study on Recommended Practices for Wind Turbine Testing and Evaluation. In 1982, the group issued its first recommended practice: Power Performance Testing.

Continuing to fill a need for performance testing standards, the R&D WECS agreement, in 1984, issued a recommended practice, Quality of Power for Single Grid-Connected WECS.

"While joint research and information exchange will remain the prime activities, increased emphasis will be laid on state-of-the-art assessments of wind energy technology, economics, and environmental impact. Efforts will be made to identify barriers to deployment and analyze support strategies." – *IEA Wind Energy Annual Report, 1993.*

As the size and number of wind plants increased, researchers worried that power quality, voltage profiles, controls, system protection, operating strategies, and personnel safety could be adversely affected. In 1989, the LS WECS agreement sponsored an Expert Meeting on Integrating Wind Turbines into Utility Power Systems. Participants recommended further work on wind energy forecasting and on electrical performance of wind farms.

In 1990, the Recommended Practices for Wind Turbine Testing and Evaluation group issued a revised practice for power performance testing that incorporated the improved information from experts meetings. Continuing the information exchange, a Topical Expert Meeting on wind turbine control systems also addressed the issue of power quality and wind turbines. At another TEM in 1991, Electrical Systems for Wind Turbines with Constant or Variable Speed, the special issues surrounding these two approaches were discussed.

In 1995, interest in the consistency of measurements prompted the design of Task XVI, Wind Turbine Round Robin Test Program. To ensure that turbines are tested and certified to common criteria, participants tested identical machines at their own facilities using comparable test instrumentation and data acquisition. A meeting of experts in 1997 assessed the state-of-the-art on power performance assessments for WECS. The experts concluded that dominant issues of system integration, cost-effectiveness, and certification all depend on power performance verification. In 1999, information from Task XVI and the experts meeting contributed to the 11th recommended practice issued by the R&D Wind agreement, Wind Speed Measurement and Use of Cup Anemometry. This document on wind speed measurement is used by IEC MT 13 to update the power performance measurement standard IEC TC88, Wind Turbine Systems.

As wind power contributes larger percentages of electricity to a grid, the influence of large fluctuations of power becomes important. A Topical Expert Meeting in 2001 explored the Danish and German experience with integrating large-scale wind generation facilities into their grids. The meeting concluded that it is essential to have good simulation tools and reliable dynamic electrical models of wind turbines to perform simulations of wind farm contributions to the electric system. For example, the Netherlands expects to have 6,000 MW of offshore wind power installed by 2020. Joining about 15,000 MW of conventional power, this offshore capacity will affect the dynamic stability of the grid, so it is very important to have accurate, reliable, and verified models of the detailed dynamic electrical behavior of wind farms larger than 500 MW. Given that more than 35,000 MW offshore power is foreseen in other northern European counties and the United States, it makes sense to combine these efforts under IEA R&D Wind.

In response to these conclusions, the R&D Wind signatories in 2002 approved Task XXI, Dynamic Models of Wind Farms for Power System Studies. Participants in this task will assist the planning and design of wind farms by facilitating a coordinated effort to develop wind farm dynamic electrical models suitable for evaluating the dynamic and transient stability of power systems.

Several presentations at Topical Expert Meetings have pointed out that predicting the time and amount of output from wind farms is vital. Predicting output a few hours to a few days ahead of time is important to the value of the electricity that wind farms generate and for scheduling conventional power to balance the supply and demand in the grid.

In response to this conclusion, the R&D Wind agreement established a Joint Action Symposium for (short-term) wind energy forecasting and will sponsor regular meetings on the subject. The first such symposium, in 2002, concluded that current models are inaccurate in complex terrain, that there is much room for improvement, and that discussions of progress should continue.

3.4 COMMON ELEMENTS OF SUCCESSFUL ACTIVITIES

A key factor in the success of the wind agreements over the past quarter century is the variety of mechanisms available to explore issues cooperatively. For example, after wind energy forecasting techniques were identified as important, the agreement held a TEM in 2000 and determined there was interest. An ad hoc committee drafted an annex proposal to the ExCo, but there were concerns about proprietary issues. A Joint Action Symposium was approved instead to hold regular meetings on advances in the topic beginning in 2002. If common research work is identified at one of these meetings, then a task can be approved; otherwise, interested experts will continue to meet each year.

Some essential features of successful collaborations have included the following.

1. Interested and active participants. Participants send information to the operating agent and/or perform tests and measurements as set out in the task agreement text.

2. Involvement of users. Representatives from industry, utilities, research institutes, universities, and government organizations participate in the planning and execution of tasks.

3. Well-defined scope. The number and variety of subtask topics are limited. The work of participants is defined clearly.

4. Multidisciplinary approach. Participants take work from other fields and apply it to wind.

5. Multi-national approach. Participants take a model or tool developed in one country and apply it in other countries.

6. Dissemination of results. Results are published or presented at international conferences, Topical Expert Meetings, in annual reports and on special Web pages for members and the public.

Twenty-five years ago, when the IEA Wind Agreements were initiated, technical information or data were fundamental and rudimentary at best, and there were no design guidelines or validated experimental data. Today, there is a large repository of data and experience available to assist designers and builders around the world, in large part due to the efforts of participants in the IEA Wind Agreements.

Twenty-five years ago, there was essentially no wind industry. Today, commercial developers are designing, building, and installing wind turbines around the world by the thousands. Commercially available wind turbines have grown in size from ratings under 100 kilowatts to more than four megawatts. The designs and experience behind today's large machines rests largely on pioneering efforts of the participants in the IEA Wind agreements.

At times a delicate balance was maintained between the desire of participants for cooperation and the constraints of proprietary, commercial, and national interests. Over the long run, however, the benefit of the agreements to the participants is summed up nicely by Louis Divone, original member from the United States and director of his government's research program for more than a decade.

"The leverage we got from the relatively little we spent on the IEA agreements was phenomenal. By pooling our resources, we carried out R&D projects that we could not afford individually and validated approaches that we see today in our national wind industries."

The current participants in IEA wind reinforced this sentiment in the ad hoc group report to the IEA Wind Executive Committee in 2001 by setting out an ambitious research agenda. The active program of cooperative research scheduled for 2003 and beyond promises to continue the tradition of multiplying the contributions of individual participants to advance the development of wind energy for all.

"For the mid-term time frame, areas of major importance for the future deployment of wind energy are forecasting techniques, grid integration, public attitudes, and visual impact. …For the long-term time frame, it is of vital importance to perform the R&D necessary to take large and unconventional steps in order to make the wind turbine and its infrastructure interact in close co-operation." – *Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020, ad hoc group report to IEA Wind Executive Committee, 2001.*

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Author: Patricia Weis-Taylor, Secretary, IEA R&D Wind.

Chapter 4

2002 IEA Wind Energy Overview

4.1 The International Context

The basis of this overview chapter is the national reviews of the IEA R&D Wind Implementing Agreement Member countries presented in Chapters 5 through to 21. The following overview provides a compressed analysis, focusing on the most significant changes that have occurred during the course of 2002, together with some tables, figures, and a brief policy description for comparisons across all the countries.

4.1.1 Meeting the Challenge

Much of the current market for wind energy is principally driven by the very low lifetime emission of pollutants that the technology offers. But the value of wind energy goes far beyond this. There are several benefits making wind energy increasingly attractive to existing and new markets.

- Very low lifetime emissions of harmful gasses (especially carbon dioxide), per unit of electricity generated
- Large resource at costs approaching current thermal plant
- Increased diversity and security of electricity supply
- Removal of cost uncertainties caused by fuel supply price fluctuations
- Employment and an opportunity for industry, through turbine and component supply and assembly, provision and installation of turbines, and infrastructure and ongoing plant servicing.

Areas with the better wind energy resources are often rural, where unemployment is higher and economic and social development are much needed. The strong growth of wind power is welcomed in Spain because of the industrial development and associated job creation, which it sees as the most important benefit. Several new component manufacturing factories started operation in 2002 (blades, towers, and gearboxes), and a large number of jobs were created, especially in the region of Castilla-Leon.

Currently, the IEA countries with the most installed wind capacity have a strong national commitment to environmental goals, whilst often lacking a strong hydropower resource (DE, US, DK, NL). However, even in those countries with a large hydro resource, little potential remains for additional large-scale hydro develoment and further increases in generation from renewables require the use of other resources such as wind energy, biomass, and small-scale hydro (SW, NOR).
In Switzerland and the United States, wind has been found to compliment hydropower very well. Wind generates more electricity in the winter months when the demand in cold climate areas is highest. With wind energy production, additional electricity is then available from storage (pumped hydro) power stations at peak consumption. Nuclear

energy has an uncertain future in some countries, and in the case of Sweden wind energy is seen as an important element in the replacement of nuclear plant. For many countries wind energy offers one of the better opportunities for securing a diverse, secure, and environmentally acceptable electricity supply and has formed a strong part of government forward thinking.

4.1.2 National Policies

Government policies and strategies vary because of both their circumstances and how aggressively they pursue environmental goals. These are summarized below.

1. Australia
Over the last couple of years, Australia has increased its commitment to renewables. The government has now set a mandatory target for both retailers and large purchasers to source an additional 2 % of electricity from renewables by 2010. This will be implemented through a system of tradable certificates and capping penalties. A number of interim targets have been established, to result in meeting the target of 9,500 GWh/yr from renewables at the start of 2010. This will necessitate the installation of up to 900 MW of wind turbines.

2. Canada
Canada ratified the Kyoto Protocol in 2002 and is pursuing the implementation of wind energy as part of its response. Canada has tremendous wind energy potential and federal and provincial governments support its deployment through an increasing number of incentive programs.

3. Denmark
During 2002, the main instrument for wind energy deployment on land has been an incentive motivating owners to scrap old turbines of less than 150 kW and replace them with larger and more efficient machines. Over and above this, most new capacity in Denmark is expected to come from offshore. In 2002, the government set up a committee to analyze how the future offshore development can be based on market conditions in an economically efficient way. The committee finished its work at the end of 2002 by publishing a report that will be discussed in the government in connection with a climate policy to be published in the beginning of 2003. The present strategy is based upon the governments action plan "Energy 21", and setting ceilings for carbon dioxide emissions from electricity generation. Renewable energy quotas announced in 1999 should result in 20% of the electricity consumption being covered by renewables at the end of 2003. The long-term goal is to reach 5,500 MW by 2030.

4. Finland
Finland sees a limited resource, which is predominantly offshore. A policy introduced in 1997 described wind energy as capable of reaching some percent of total power consumption after 2015. The role of all renewables is recognized, but the largest expectations are on bioenergy. The action plan for renewable energy resources 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 in 2010 and 2000 MW in 2025.

5. Germany
Germany has become increasingly concerned with the environment and this change is reflected in changing policy. It also now 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.

6. Greece

Greece recognizes a high wind energy potential and the government wishes to exploit wind energy to replace expensive imported fuel in decentralized energy production, as well as to actively involve Greek industry in creating new jobs. In spite of this, the deployment of wind energy technology has been slow. During the last two 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.

7. Ireland

The Irish government has set a target of an additional 500 MW of installed renewable electricity generating capacity in the period 2000 to 2005. Ireland also has an indicative target of increasing electricity consumption from renewable sources to 13.2% of total demand by 2010. It is recognized that wind energy will make the greatest contribution to achieving both these targets. The Electricity Regulation Act of 1999 initiated the process of electricity market liberalization and the completion of the deregulation process is planned for 2005. There have been three Alternative Energy Requirement (AER) rounds, offering 15 year fixed price power purchase contracts for wind, through a competitive tendering. The last round of AER was announced in February 2002, authorizing a total of 353 MW of new wind capacity. The design of a replacement scheme will be developed in consultation with the commercial sector.

8. Italy

Italy has progressively changed its position in favor of renewables. A white paper of August 1999 stated a goal of doubling the renewables contribution to the energy balance by 2010. Specifically, 3.4 million tons per year of avoided carbon dioxide emissions should come from wind power. This equates to about 2,500 MW or 200 MW per year. Starting from 2005 those that have not fulfilled the quota 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.

9. Japan

In April 2002, the Japanese government passed legislation for a Renewables Portfolio Standard (RPS) 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 NEDO have been supported by the utilities offering private long-term electricity purchase contracts. In 2001, the government changed its target for wind energy from just 300 MW to 3,000 MW.

10. Mexico

In emerging markets such as Mexico, specific plans for integrating a meaningful capacity of wind power into the national electricity system have yet to be established. The Mexican energy policy is aimed at securing enough electricity supply to allow expected economic development, 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 can supply a proportion of this. The Ministry of Energy is leading an 'Action plan for removing barriers to the full scale implementation of wind power in Mexico.'

11. The Netherlands
Upwardly revised targets for renewables and the expected contribution from wind energy were announced in 2001. The government also decided that it was unrealistic to reach their renewables targets purely from domestic generation and expects to import some green energy from other European Union countries. This is the first country to base its expectations partially on imported renewable energy. For the Netherlands, reducing carbon dioxide is a key objective. The policy is now to stabilize emissions by first limiting energy demand as much as possible and then to meet the remaining demand with renewable energy. For renewable energy, the target is set to a 10% contribution to energy demand, by 2020; about a third of which is expected to come form 6,000 MW offshore wind capacity.

12. New Zealand
In New Zealand, renewable sources already provide 29% of total consumer energy, and around 70% of the electricity supply, mostly from hydropower (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 government released a target for an increase of 30PJ of renewable energy by 2012. However, no quantifiable targets have been set for the electricity sector, nor specifically for the wind energy sector. On 10 December 2002, New Zealand signed the instrument of ratification for the Kyoto Protocol to the United Nations Framework Convention on Climate Change.

13. Norway
In a year with above average rainfall, Norway could be self sufficient with electricity from renewables, almost all of which is hydropower. 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 hydropower projects and in 1998 the Norwegian government stated an overall goal to reach 3 TWh/yr of electricity from wind energy by 2010.

14. 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 renewables energies as the national target. To achieve this, the Spanish government set a target contribution of from wind of 21.5 TWh/yr 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/yr.

15. Sweden
Considerable challenges face Sweden in the future. The decision to phase out nuclear power (One nuclear reactor was closed in 1999) and limitations on further hydropower make renewables, and wind energy in particular, a crucial element of the future power system.

A five-year short-term subsidiary program to promote electricity production from renewable energy sources such as biofuels, wind and small hydropower plants and to promote energy efficiency has been finalized during 2002. One billion Euros have bee allocated to a two part program. The first part of this program, accounting for some 0.6 billion Euros, will conduct R,D&D of renewables and new conversion and end use energy technologies including wind energy. The second part of the program will subsidize renewables to replace the Barseback nuclear power plant. The current wind power investment subsidy program will however continue during 2003, until the budget is exhausted.

16. Switzerland
The new Swiss Energy ten-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 to total electricity production 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 50-100 GWh from wind power by 2010. This equals 10% of the goal for all renewable energies set by the federal program Swiss Energy.

17. United Kingdom
The government published a policy in February 1999, with a number of key policy themes, including the new Renewables Obligation for England and Wales and the analogous Renewables (Scotland) Obligation. This puts an obligation on all electricity supply companies to procure a rising percentage of their power from renewables with the aim of reaching 10% of UK electricity from renewable sources by 2010. Other policy elements include exemption of electricity generated from renewables from the Climate Change Levy (a tax on 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.

18. The 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. Further, the policy includes expansion of performance-based, goal-oriented R&D focused on advanced technologies adapted to sites with lower wind speeds; extension of wind energy production tax credits; and the increased use of wind and other renewable resources on federal lands. There are no national targets for wind energy deployment established by the government. However, the U.S. wind industry has a goal to generate 6% of the nation's electricity from 100,000 MW of wind systems by 2020. DOE has established specific program goals intended to support industry by encouraging wind deployment across the United States.

4.1.3 National Targets

There were not many changes to targets during 2002. Spain and Greece were the exceptions, both with increased expectations from wind energy. In Spain the new target, 13,000 MW for the year 2011, looks to be realistic. On the other hand, the majority of the autonomies have regional wind energy programs that sum to more than 30,000 MW to be installed in the next decade. The Greek Ministry for Development set a new target for wind of more than 1,500 MW installed capacity by 2010. The installed capacity of wind turbines reached 355.4 MW at the end of 2002 fulfilling the previous target of 350 MW. In 2002, New Zealand established a renewable energy target of an additional 30PJ by 2012, though with no specific electricity or wind targets.

Although no new government target was established for wind energy in Sweden, during 2002 the parliament did establish a planning target for wind power. The purpose of the planning target is to remove planning and permission obstacles and is set at an electricity production from wind power of 10 TWh in 2015.

About half of the national governments of the participating countries in IEA Wind have announced formal targets for the amount of wind power capacity they wish to see installed, or amount of wind electricity generated. Progress towards those targets is very uneven.

4.2 THE WIND ENERGY MARKET

The value of this market globally during 2002 is estimated at over 6 billion USD. This figure is based on an average total project cost of 1,000 USD/kW installed. This excludes the routine maintenance of all the installed capacity. Germany alone reports a total sector turnover in 2002 of over 3.5 billion Euros (3.3 billion USD) and some 35,000 people employed either directly or indirectly. This covers both manufacturing and servicing the existing 12 GW of capacity, with Germany accounting for 50% of the new capacity installed world-wide in 2002, though much of this was imported.

4.2.1 Installed Capacity Growth

High sector growth sustained

Although wind energy growth slowed in 2002, it still sustains a very high level by comparison to other industries. Global growth was 26% this year and almost 28% in the reporting IEA wind countries. This is a very strong performance and expectations continue to be high for the coming years. The IEA Wind countries now account for 89% of global installed capacity and growth has now been sustained around 30% per annum since 1994. At the end of 2002, the global wind capacity reached 31 GW. The total installed capacity in the IEA countries reached 28 GW.

Growth markets

Germany and Spain sustained the very high rate seen in recent years, putting in more new wind plant than ever before. Their growth rates were 37% and 38% respectively, reflecting the strong markets, offering fixed and generous tariffs for the energy produced, combined with a high success rate within the planning process. Germany installed over 3 GW alone, which accounted for half of the global expansion in wind power.

It was also a high-growth year for the Netherlands, Japan, and Norway. By installing two new large wind farms in Norway, capacity increased from just 17 MW to 97 MW.

Steady growth

The deployment of wind energy in Finland showed a new start after no growth in 2000 and 2001. Two 2-MW wind turbines were commissioned bringing the total wind capacity to 41 MW by the end of the year, with a further 7 MW under construction. In the UK, 2002 saw 88 MW of new capacity installed, increasing the total installed capacity by about 20%. Although encouraging, this figure falls short of that anticipated for 2002, and highlights the long way to go to meet the UK target of 10% from renewables by

Table 4.1 Wind and renewables electricity generation targets

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	None.	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).
Spain	Achieve 12% of primary energy demand from renewables by 2010.	130,000 MW installed capacity by 2011, yielding 28.6 TWh/year.

(Continued) Table 4.1 Wind and renewables electricity generation targets

Sweden	**Maintain green house emissions at 1990 levels.**	**0.7 TWh/year by 2002 (= 0.5 TWh increase compared to 1997.**
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 nations electricity from wind by 2020 (approximately 100,000 MW).**

2010. Sweden has a good wind energy resource but so far the deployment has been slow. However, the last couple of years have shown some turn-up. Most of the expanded capacity in Denmark came from the replanting scheme, replacing older turbines of 150 kW capacity or less. This generated steady growth, an improvement over last year. Growth was below the high aspirations in Ireland and Greece.

Less active

The very good result achieved in Italy in 2001 was not repeated in 2002, with only 106 MW of new wind plant installed this year. Installed wind power capacity in Canada has experienced an average annual growth rate of 60% over the past 5 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), but with an estimated capacity addition of just 18 MW in 2002, growth was only 8%.

During 2002, additional wind power capacity was not installed in Mexico. The total installed capacity of wind turbines actually decreased to 2.2 MW, because a privately owned 550 kW wind turbine caught fire. No new capacity was installed in New Zealand either.

Offshore

In 2001, Elsam/Eltra was granted permission to develop a wind farm at Horns Rev at the West Coast of Jutland, Denmark. The Horns Rev farm, consisting of 80 wind turbines and a capacity of approximately 160 MW, was completed and connected to the grid in 2002. The farm is located 14 km from the coast at Blåvandshuk. The turbines are Vestas 2 MW with a total height of 110 m and occupying a total area of 20 km^2.

Outlook

Overall, the picture is for wind energy to continue to show the very strong growth now experienced for many years.

On the basis of the quantity and quality of the applicants it is expected that 2003 will be a watershed year for wind power development in Canada. The planned commencement of new projects supported by the Wind Power Production Incentive should ensure rapid growth in 2003 and for some

Country/region	Capacity at year end 2001	New capacity	Capacity at year end 2002
Australia	73.0	30	103.0
Canada	214.0	18	232.0
Denmark	2556.0	380	2,936.0
Finland	39.0	4	43.0
Germany	8754.0	3247	12,001.0
Greece	298.0	57.4	355.4
Ireland	125.7	12.6	138.3
Italy	682.0	106	788.0
Japan	250.0	84	334.0
Mexico	2.2	-0.55	1.7
Netherlands	483.0	202	685.0
New Zealand	35.4	0	35.4
Norway	17.0	80	97.0
Spain	3360.0	1275	4,635.0
Sweden	267.5	40.5	308.0
Switzerland	4.5	0.85	5.4
United Kingdom	464.0	88	552.0
United States	4260.0	425	4,685.0
Portugal*	127.0	44.0	171.0
France*	85.0	62.0	147.0
Austria*	95.0	20.0	115.0
Turkey*	19.0	-	19.0
Egypt*	125.0	-	125.0
Morocco*	54.0	-	54.0
India*	1,507.0	195.0	1,702.0
China*	401.0	67.0	468.0
Costa Rica*	71.0	-	71.0
Rest of world*	229.0	28.0	257.0
Grand Total	24,598.3	6,465.8	31,064.1
* Data from Windpower Monthly			

Table 4.2 Global installed wind capacity

time beyond. Interest in WPPI has been high; by December 2002 the program had registered project applications totaling 2,700 MW of capacity (Funding, however, is limited to supporting about 1,000 MW of wind power).

The UK expects some 300MW to be commissioned next year and perhaps double this in 2004. Part of next year's growth results from 2002 not reaching expectations, with new build slipping to 2003. In addition, there are signs that problems of obtaining planning permission are being overcome, with a total

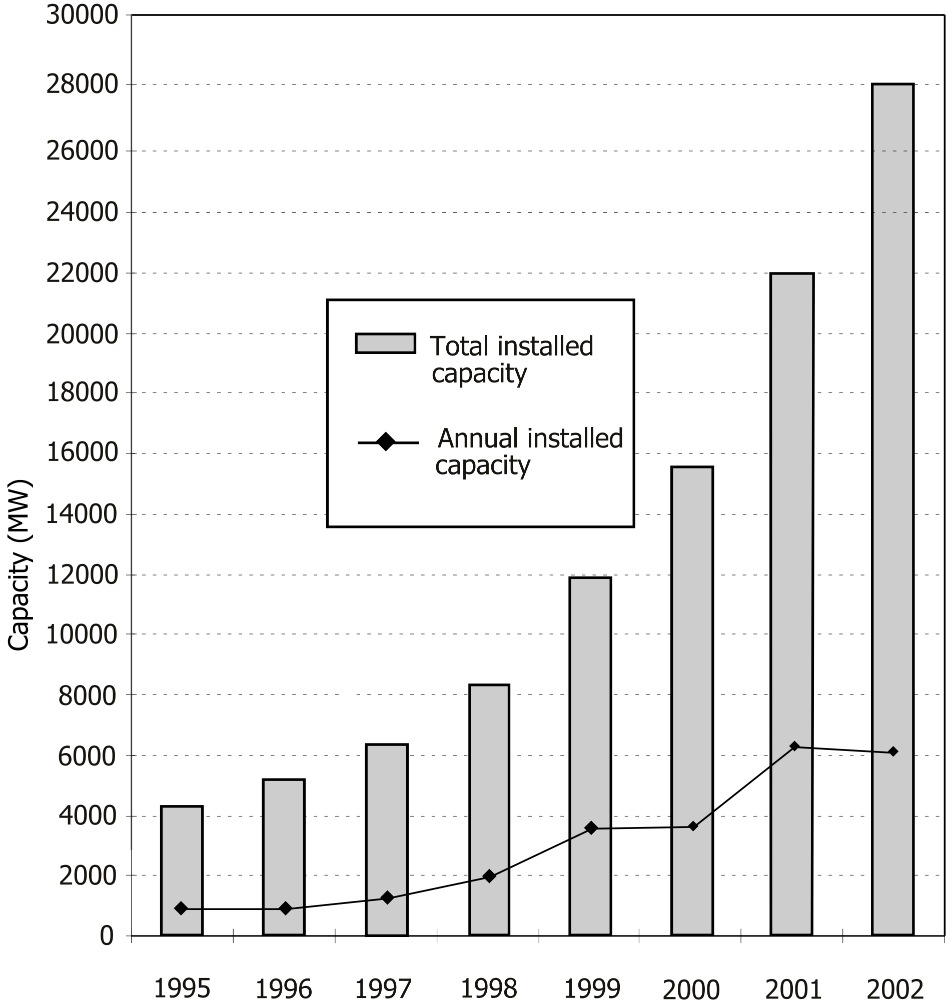

Figure 4.1 Annual installed and cumulative installed capacity in IEA Wind countries

of 535MW gaining planning permission in 2002, almost exactly the total amount built during the previous 11 years together.

Although Norway had a very good year, no other commercial wind farms received financial support in 2002, thus the next possible wind farm will be constructed in late 2003 at the earliest. In Greece during 2002, the "Regulatory Authority for Energy" (RAE) has approved wind applications totaling 595 MW. This breaks down to 407 MW for the interconnecting system of the mainland and 188 MW for the islands Evia, Andros and Tinos.

4.2.2 Energy Contribution from Wind Power

Electricity generated by wind

More electricity was generated in the IEA countries than in any previous year. This was approximately 47TWh, up 27% from last

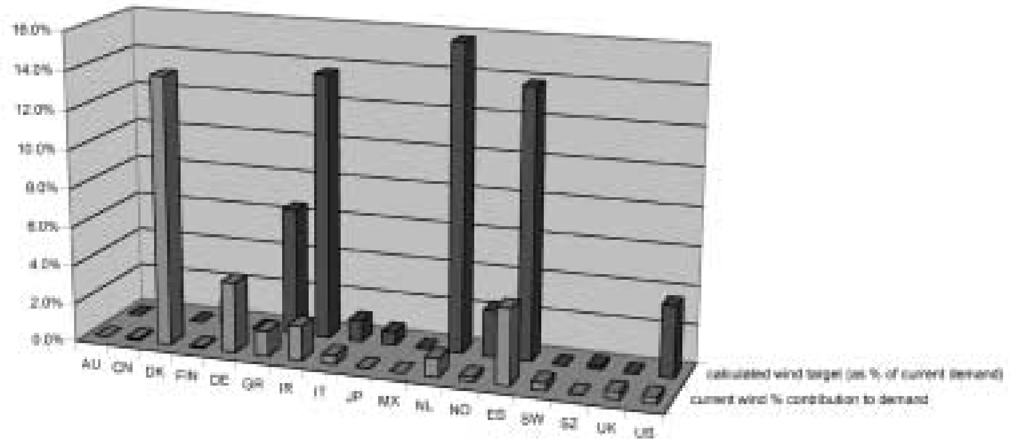

Figure 4.2 National contributions and targets for wind against electricity demand

year and providing electricity nearly equivalent to the entire needs of Greece. Globally, it is estimated that around 53TWh of electricity were generated from wind in 2002. Figure 4.2 shows the contributions from wind in 2002 to the national electricity demand for each country. Where there are wind targets, these have also been expressed as a percentage of current electricity demand. The targets are set for the year 2010 and have been calculated from targets generally stated in installed capacity, using a cross-the-board load factor of 0.25. The exception to this is Italy, Norway, and Switzerland which have actual targets in terms of electricity output.

Wind speeds

European wind speeds were reported as below average in 2002. 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 98% and 85% were given by Sweden and Denmark respectively. Finland reported that wind speeds were 10% down in 2001, which were themselves lower than for 2000.

4.3 MARKET DEVELOPMENT

4.3.1 Overview of Markets

Offshore

Interest in and expectations from offshore wind energy continues to grow, with a number of large projects gaining building permits for construction in the next few years. A recent study commissioned in the UK suggests that the total global market for offshore renewables could be worth as much as £8 billion (USD 13 billion) by 2007, with the European market accounting for 90% of this. The Cape Wind project in the United States has also progressed and been the subject of much interest this year. The next few offshore wind farms are of the order of 100 MW capacity, but looking further ahead they are likely to get larger.

Commitment to offshore wind in the UK was firmed up with consent for three offshore projects and the British Wind Energy Association predicts that about 2,300MW could be operational in the UK in 3 years time. In one of the first United States offshore projects, the Cape Wind Company is planning to use 130 of the new 3.6 MW GE Wind

Energy turbines in a 468 MW project off the south shore of the State of Massachusetts.

In Denmark this year, construction of a 166 MW offshore wind farm at Roedsand and a smaller farm of 23 MW south of Samsoe were started. No other projects have been announced. However, a government committee for future offshore estimates that even if the government decides to start tendering for the next projects in 2003, they will not be in place and grid-connected before 2007.

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 outcome 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 x 1.5 MW wind turbines.

In Germany, by December 2002 the BSH approved the wind farm "Buergerwindpark Butendiek", about 35 km west of the island Sylt. Building of the eighty 3-MW turbines is expected from 2005. This is in addition to the "Borkum West" offshore installation which received planning permission in November last year, situated 45 km north of the island Borkum, with twelve turbines to be erected starting in 2004.

In 2001, the Dutch government announced that before the end of 2003 a concession regime shall be in place to allocate areas where wind developers can build off shore wind farms. During 2002, a draft regime was discussed with developers. Discussion will continue in 2003. NoordZeeWind a consortium consisting of Shell Renewables and NUON, was announced as the winning consortium for the 100-MW demonstration near shore wind farm to be built near Egmond aan Zee. The consortium will now be entitled to apply for the building permit. The wind farm, consisting of 36 NEG-Micon 2.75 MW turbines, will be built 12km from the coast in depths of between 15m and 20m.

Ireland also continues its plans for offshore. Last year a foreshore lease was granted for a 520 MW project at Arklow Bank. This will be built in stages with the first phase of 25 MW capacity starting in 2003.

The drive to larger turbines and wind farms
The economics of offshore wind are resulting in larger projects as time progresses. This is of course coupled with the drive towards and availability of increasingly large turbines. The offshore market has applied more vigor to the trend towards larger and larger turbines, which also enables wind farms of higher capacity to be installed onshore.

The electricity markets

The development and liberalization of the electricity markets is having a great effect on the way wind energy is attributed a commercial value. As a consequence, the support mechanisms for wind are also changing. Some countries insulate generation from wind and other renewables from the wider electricity market, for instance by maintaining pre-determined fixed tariffs for the electricity (DE, ES, DK). Other countries are trying to integrate green electricity into the liberalized market. This has been done by several countries (UK, NL, AU) through trading the electricity and the green value separately, through the issuing of green certificates.

The successful deregulation of the Swedish and Nordic electricity markets has led to low electricity prices. Wind energy producers compete on the same market as conventional electricity producers (having received an initial capital subsidy) and so low electricity prices threaten the market shares of renewables. There was a recent price hike on electricity in the Nordic electricity market in the late fall of 2002 because of low rainfall reducing hydro output. This did increase the general energy interest quite dramatically, including in wind, however since the 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.

International green certificate trading

About 1.4 million Dutch households bought renewable energy at the same price as gray energy. Large-scale imports of electricity from amongst others, biomass from Sweden, hydro from Norway and Switzerland, created a flow of about 140 million Euro of tax payers' money out of the country in 2002 through the feed back ecotax for producers. During 2001 and 2002, several interesting commercial agreements were made based on export of premium price wind energy produced in Norway and it is anticipated that this international renewable energy trade will keep investment interest in Norway for several years to come.

Small turbines

The United States has seen a large growth in small and intermediate sized wind turbines for both on and off-grid applications. A record-breaking 12,000 machines of 10kW or less were estimated to be sold in 2002, having a value of around 18 Million USD. Supply security and self sufficiency has attracted home owners who value insulation from price volatility.

4.3.2 Support Initiatives and Market Stimulation Instruments

There are several recent and coming changes to the support mechanisms for wind. These changes can fundamentally affect the economics of wind power in a country and bring about a rapid change in deployment. Stability in the market is also important in generating confidence for investment and is discussed below under Constraints on Market Development.

Irish Alternative Energy Requirement (AER) to be replaced

This has been the primary market support mechanism issuing fixed price contracts with a 15-year term, through regular competitive tender rounds. The scheme has been in place since 1996 and the final round, announced in November 2002 will then be superseded. Consultation with the industry on the design of a new support scheme to succeed AER will be embarked upon in 2003.

Danish consumer's obligation to be phased out

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 remodeled as financial support of 0.10 DKK/kWh (1.4 Euro cents), corresponding to the carbon dioxide tax on electricity. Total support plus market price will be capped to 0.36 DKK /kWh (5.1 Euro cents).

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 (2.4 Euro cents) for the first 12,000 full load hours, which takes around 6 years. The replacement scheme is limited to wind turbines up to 150 kW.

Obligations come into force in the UK and Italy

In the UK the Renewables Obligation became law on 1st April 2002. This important government measure should provide an assured market for renewable energy for at least the next 25 years. Through the Obligation it is currently estimated that by 2010 the value of support to the UK renewables industry will be £1 billion per year.

The first two offshore capital grants were announced in October 2002 for the offshore wind farms planned to be developed at North Holye in Wales and at Scroby Sands in Norfolk. Each grant was for £10 million (17 million Euros).

In Italy, the green certificate system formally entered in force in January 2002. The green certificates can be sold or purchased on the basis of bilateral contracts or exchange organized by GME (Electricity Market Operator). But in practice the exchange mechanism did not operate during 2002, while it is very likely that it should finally start in 2003. GRTN fixed the supply price of its green certificates at 0.08418 Euro per kWh for the Year 2002.

Changes coming to the Netherlands and Sweden

After the elections in May the new Netherlands government decided to change the financial framework for renewable energy stimulation, announcing more details in September. This initiated intense discussions with the producers of renewable energy, the energy companies, parliamentarians, and the government, especially about the level of the reimbursement. With the government falling in October/November and new elections in January 2003, legislation will now not be finished until after the first quarter of 2003. In the mean time temporary legislation will be effective from the first of January of 2003.

In Sweden, an electricity certificate system will be introduced in 2003 to improve the position of electricity from renewable energy on the liberalized electricity market. During 2002, preparations to implement the system have been made at the Swedish Energy Agency and Svenska Kraftnät (the utility which owns and operates the national electricity grid). A new governmental quota system with Green Certificates for new renewable electricity generation will probably be implemented from 1 May 2003.

4.3.3 Constraints on Market Development

In order for wind energy to be developed, there must first be a market for the product. A strong market is created when there is demand, profit, and no fundamental barriers. The rate of deployment of wind energy in the IEA Wind countries depends on the balance of these factors. Arguably, only Spain and Germany have fully addressed all the constraints, resulting in vigorous markets. For many other countries parts of the equation are in place, such as the demand, whilst other parts are not, resulting in little or slowed implementation. The key constraints are discussed below against specific country examples.

Cost and price constraints

Demand and profit have been created through support mechanisms and measures. This provides a higher value for the electricity generated from wind (and other renewables), enabling it to compete with the conventional generation in the current economic environment. It should be noted that the current position and relative costs of different generation sources are bound up with historical policies and support and that the real costs of affects on the environment are not always fully passed on to the generators.

The level of supplement required to make wind energy competitive varies with the base cost of electricity. For several IEA Wind countries the base cost of electricity is low, in some cases compounded by an excess of capacity. New Zealand and Norway are dominated by low-cost 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 low spot prices within the 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.

Policy/market stability

The high dependence of markets on government policies is an ever-present concern. As well as creating a market, the commercial sector needs to be satisfied that a market will be in place for long enough to warrant investment. Overall, the sector benefits from the global market, smoothing the effects of single market policy changes. A number of markets have shown a lack of stability, which has affected investment.

The uncertainty about the new financial support framework for renewables in the Netherlands (see support initiatives above) has put investment decisions on hold. The market will remain static until details of the legislation become clear after March 2003.

In 2000 in Denmark, legislation on reform changing from fixed prices to a market based system with green certificates caused uncertainty on the future buy-back rates, resulting in a sharp down turn in new installations in 2001. Results in 2002 have been better, but this was due to the policy supporting the upsizing of small, old turbines, which only continues until the end of 2003. The outlook for onshore beyond that time is uncertain. The Danish Energy Authority has continued the implementation of the first phase of the Plan of Action for offshore Wind Power, wind farms at Horns Rev and Rødsand granted permission. However, the other 3 large offshore wind farms were put on hold by the government in 2002.

In the United States, the recent year-to-year fluctuation in the construction of wind energy installations was primarily caused by a delay in the extension of the federal renewable energy Production Tax Credit (PTC). Although there was strong support for the extension, the PTC expired in December 2001. In March 2002, the PTC was extended for two years, including a provision making it retroactive to the beginning of the year. This three-month delay caused many projects to be put on hold, disrupting turbine production plans and project financing. Legislators are considering extending the tax credit for longer periods to reduce these fluctuations in construction.

In Italy, the reduced deployment in 2002 is thought to be partially caused by uncertainties resulting from the delay in the introduction of the green certificates exchange organized by GME (Electricity Market Operator).

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. Objections are often on the grounds of environmental concern, in particular the visual impact of wind farms (DK, DE, IT, NL, NO, SW, UK, US, FI). Land use planning is often a local matter, which takes account of broad national guidelines. However, planning consent decisions and any imposed conditions on wind farm developments, can be highly subjective because of variations in their interpretation.

In the Netherlands, about 2/3 of all initiatives fail at an early stage because of difficulties in getting building consent. This is being addressed at a provincial level, with each province having a target to designate locations for wind turbines specified in MWs, before 2005. This spatial planning agreement required action plans before June 2002 and all but one province has generated a plan. 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 to establish regional and local spatial planning for wind. Up to half of the costs of this consultation, are paid. In certain regions of Denmark the deployment of wind energy has now reached a point of saturation with respect to spatial planning. The future inland market development will therefore mainly be tied to replacement of smaller wind turbines with new MW machines.

Visual effects have begun to generate strong opposition in Italy. Objections come from environmentalists against the installation of wind turbines on the mountains. This has also generated some uncertainty and aversion to wind in at least two regional authorities. An agreement for supporting wind energy deployment is currently under approval, which should improve and speed up the authorization process. The agreement has been made between the Ministries for Culture, Environment, and Productive Activities, and the "Conferenza delle Regioni." In Switzerland too, more and more wind energy projects are fought by landscape protectors. In 2002, the Swiss Foundation for Landscape Protection has published a position paper, whose recommendations make the effective development of wind energy impossible.

Grid limitations

The integration of large-scale wind energy into electricity networks is a purely technical issue, that can be addressed with technical solutions where there is the political will to make the investment in infrastructure. Denmark has already achieved a 16.5% contribution from wind energy nationally (in an averagely windy year), 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 (DK, DE, GR, IR, IT, JP, NL, ES, UK, US).

This is an immediate problem in Ireland, Greece, and Italy. In Ireland, high economic growth rates in the late 1990's and consequent high growth in electricity consumption outpaced electricity infrastructure development and the national electricity grid is now operating outside of transmission planning standards in many areas. Most of the potential in Greece is in remote sites at the end of transmission lines. In the area of Evia there is a great investment interest, but the high wind power potential cannot be absorbed by the existing poor electrical infrastructure. It is now planned to develop of high voltage electrical grid, enabling 550 MW of installed wind capacity to be accepted for installation in this region. In Italy, the problem of integration into weak grid areas has been compounded by difficulties in getting permission to build new electricity lines. During 2002 around 40 additional wind turbines totaling some 30 MW were installed in the Campania and Apulia regions, but are not yet connected to the grid because the high voltage line will not be completed until summer 2003.

Denmark has a slightly more unique challenge in trying to maintain the power balance and dealing with an electricity surplus. Due to the high share (~50%) of electricity from combined heat and power (CHP) and the high share from renewable electricity (mainly wind power), a substantial part of the Danish electricity production is dependent upon weather conditions (outdoor temperature and wind speed), thus limiting the system's ability to adapt to quickly changing electricity prices on the market.

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 resource 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. Previous experience shows that wind energy plants can be operated even under these extreme conditions, although the economic viability of the projects is quite 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, ES) have shown that the environmental advantages of wind power are recognized and, in general, the majority of the public are supportive of wind energy installations.

The high expectations for offshore wind have generated new interest in the potential affects on marine life. This has initiated many new research projects, described further under the following technology section. All offshore wind farms will be accompanied by an Environmental Impact Assessment, which will include a survey of the species at the individual sites. Sensitive siting will prevent undue affects on wildlife, though there is a need for greater understanding in some areas including the affects on birds. This knowledge will be gained through studies, supported by before and after evaluation of the first few installations.

Concern remains about the possibility of onshore bird strikes too, although the incidence is low. The problem of birds varies greatly from site to site and the vast majority of wind power plants report no problems. Some bird strikes were reported in Spain and the United States in the early 1990's. 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 low effect on bird life compared to other human activities.

Most countries see the assessment of noise levels from turbines at nearest dwellings as a local issue, but national statutory limits are in force in Denmark, Italy, the Netherlands, Norway, Sweden, and Germany. Developers and manufacturers in all countries regard noise emissions as an issue that can be addressed through good practice. The IEA Wind agreement has produced recommended practices on the Measurement of Noise Emission from Wind Turbines, last edition 1994 and the Measurement of Noise Imission from Wind Turbines at Noise Receptor Locations in 1997.

4.4 TECHNOLOGY AND INDUSTRY

4.4.1 New R,D&D Developments

Offshore environment

There is now much activity in this area, reflecting the increased prominence of research on the "softer" issues (planning, environmental, acceptance), both onshore and offshore. The move to offshore has created a need to better understand the potential effects on marine wildlife and major studies have been and continue to be conducted in this area. These studies are being supported by before, during and after environmental monitoring for a few of the early large offshore installations; Horns Rev in Denmark, Egmond aan Zee in the Netherlands and 45 km into the North Sea off Borkum Island in Germany .

In Sweden, a bird study is being performed at the offshore wind power plants Utgrunden and Yttre Stengrund. Radar has been used to follow bird movement in intense bird migration areas, in order to evaluate possible effects on eider duck in particular. So far, the study shows that the birds fly at a distance of 200 m or more from the nearest wind turbine, with almost no bird strikes.

New turbines

Industrial development in 2002 focused on upsizing and refining the 2 MW plus class of turbines and adapting them to offshore use. Among other things, this included upgrading the turbines with larger generators and rotors. Many manufacturers now have commercial turbines available in the 2-MW to 3-MW size range and there are prototypes running of up to 4.5MW capacity. Supported by the German government, ENERCON constructed the first largest wind turbine with a capacity of 4.5 MW. This prototype E-112 and was erected in August 2002 in a test site close to Magdeburg and was connected to the grid in October. It has a 120-m high concrete tower and the generator, weighing 500 tonnes, had to be raised to the top of the tower in several steps. This machine is being used to investigate the turbines behavior and make comparisons with computer simulations. A second E-112 is planned to be erected close to Wilhelmshaven in 2003. Another large prototype is the new GE Wind 3.6 MW machine which is currently being tested in Spain.

This year saw several prototypes based on the arrangement of direct drive and a large permanent magnet generator. Lagerwey erected the prototype of its LW70/2000 1.5 to 2-MW prototype Zephyros turbine in May, on the Maasvlakte facing the North Sea. The advanced turbine features a 3 kV, permanent magnet generator, developed in close cooperation with ABB Finland. In Japan, Mitsubishi Heavy Industries has developed a similar 2-MW machine, with the first plant to be erected in Okinawa in January 2003. Mtorres, a new Spanish manufacturer with an aeronautical background, has developed a 1.5-MW multipole direct drive machine.

A long running project for the development of a 450-kW Greek manufactured wind turbine reached the stage of grid connection at the end of 2002. Commissioning tests and monitoring are planned to take place during 2003. In 2001, Windflow Technology Ltd of New Zealand secured shareholder funding for its launch as a potential wind turbine manufacturer. The company has developed a two-bladed teetered-rotor wind turbine employing a torque-limiting gearbox, first tested in the United Kingdom by the Wind Energy Group Ltd over a decade ago. Windflow intends to have a 500kW demonstrator unit erected near Christchurch, early in 2003.

Blades

The Umoe-group, a Norwegian based investment company has decided to establish an independent blade production facility, targeting large blades. In order to be competitive, Umoe will evaluate the application of low cost vinylester materials, rather than the glass polyester or carbon epoxy typically used today. In addition, new weaving techniques allow the direct application of thick reinforcements without building up many layers. The project will be finalized during the end of 2004. The Greek organization CRES has developed and now operates a laboratory with advanced blade testing facilities for static, dynamic or fatigue testing of blades up to 25 m long.

Grid integration

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

Resource assessment and forecasting
A project, which aims at mapping the wind climate in Sweden, was started in 2002. The horizontal resolution will be 1 to 1.5 km, and the area covered will be Sweden and adjacent sea areas. A similar project was also started in Ireland and will be completed early in 2003. Digital mapping of wind resources in the United States is nearly complete and in Italy this year, work at CESI continued on fine-tuning resource maps by comparing simulated wind speeds with measured data. A full atlas of validated maps has now been generated and will be made available next year. Italy, through ENEA, is jointly involved with the Nansen Institute (Norway) and the Riso National Laboratory (Denmark) in a European project (WEMSAR) evaluating the use of Synthetic Aperture Radar (SAR) images. So far SAR images have been obtained and analyzed to derive wind speed in the test sites in Norway, Denmark, and Italy and will be compared with in-situ meteorological data.

In many countries, the price paid to electricity generators is partially dependent upon prior agreement of the amount to be supplied (firm) within a given period. Variations to this amount then receive lower prices in the case of over-supply , or penalties in the case of under-supply. Several R&D programs recognize that the value of wind power is increased if the output can be more accurately predicted, and have started research in this area (including US, UK, NL, DK, GR, ES).

Autonomous systems

CIEMAT, the main public R&D wind organization Spain, has established a new test plant in Soria. At the end of 2002, seven small wind turbines, ranging from 1 kW to 50 kW were installed and under test for power performance, durability and noise emissions. CRES, in co-operation with the Greek market, has designed and developed a pilot autonomous hybrid (wind & PV) reverse osmosis system for seawater desalination. The possibility of using wind power for hydrogen production has been investigated by researchers at three Italian universities, stimulated by the increasing interest in the application of hydrogen, for remote autonomous power systems. NEDO of Japan conducted two demonstration programs on power stabilization technique and battery-back-up systems. Though much data has been gathered, practical solutions have yet to be found and are needed to help Japan reach its national target for 2010.

Government programs

All the IEA Wind member countries are currently providing underlying support through national and regional R,D&D programs, covering a wide range of topics. As well as continuing research on underlying R&D such as on aerodynamics, countries such as Denmark, the Netherlands, Germany, and the UK are looking especially towards offshore topics. Sweden notes that more emphasis is needed on the softer topics such as planning, the environment and public acceptance.

The total R&D budget across the IEA Wind countries was nearly 60 million USD in 2002.

Significant increases in R&D spend were seen this year on the Dutch and New Zealand programs. The change in Government in Denmark has resulted in a cut in the energy research program (EFP), which covers many technologies in both conventional energy and renewable energy. The budget for the entire EFP program in 2002 has been 40 million DKK (6 million Euro), almost one third of previous years. Out of that budget, two wind energy projects were supported with at a total cost of 4 million DKK (0.6 million Euro). However, an agreement reached this year suggests a an increased budget devoted to strategic renewable energy research projects of 20 million DKK (3 million Euro) in 2003 and 45 million DKK (6.6 million Euro) in 2004 and 2005.

4.4.2 Operational Experience

Availability

In general, the installed turbines have performed well with few operational difficulties. On average, commercial plants operate with availabilities over 98%. Finland reports lower availabilities, resulting from the turbines operating in extreme cold climates having higher down times. Capacity factors, the fraction of continuous full production, are typically between 0.20 and 0.35, depending on the wind speeds at the sites and degree of plant optimization. Italy reported an average capacity factor of a little under 0.3 for 2002. The wind farm at La Venta in Mexico, having high wind speeds, reached a capacity factor of 0.43 this year.

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 1 to 3 years. Parts of the yaw system might be replaced every 5 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 Programmed 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. Norway reported one serious incident in 2002, in which a MW sized turbine nacelle fell 80 meters whilst under construction. No one was hurt. The incident is reported to be due to a human error in use of the control system.

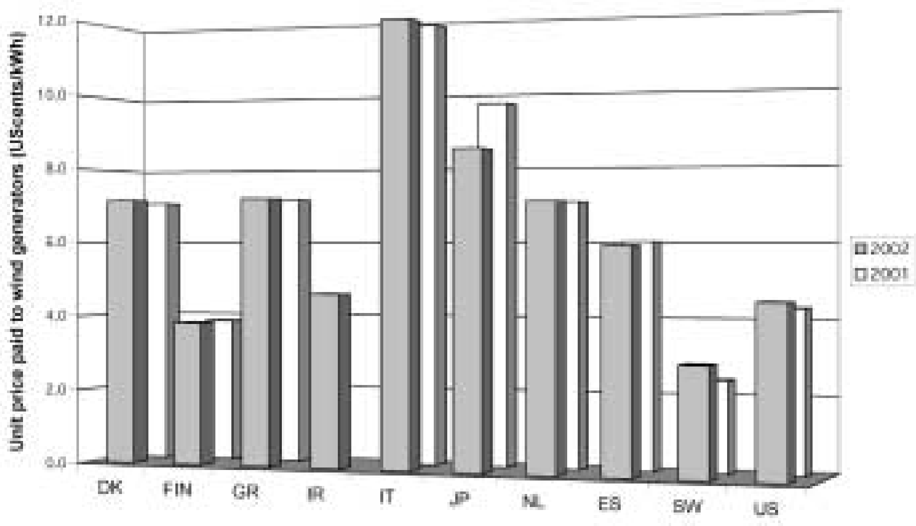

Figure 4.3 Unit price paid to wind generators (USD/kWh)

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.

4.4.3 Costs

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. There has been a consistent relationship between machine size and balance of plant costs, with larger machines reducing the cost of the remaining infrastructure on a per unit installed capacity basis.

Capital costs

Because of the commercial nature of wind farms there is very little firm cost data available, though most countries provide estimates. For complete wind farms the estimates of average cost vary according to country, between about 900 to 1,100 USD (940 to 1150 Euro)/kW of installed capacity, with 1,000 USD (1,050 Euro)/kW 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 600 to 850 USD (630 to 890Euro), with 760 USD (800 Euro) typical. These costs show a split of roughly 70% for the turbine (including tower) and 30% for the balance of plant comprising primarily of 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 are often improved because of a greater energy yield, resulting from the higher rotor hub heights.

Maintenance costs

Reported maintenance costs also vary widely, but the average is close to 0.01 USD/kWh.

Generation costs

Figure 4.3 shows the typical prices paid to wind energy generators for those countries able to provide this information. The wide variation in prices arises partly because the level of incentives does vary widely between countries, but also because the graph does not represent any additional support measures or reflect the variation in costs to the generators.

It should be noted that in the countries where the lowest prices are paid for the electricity alone (FIN, NO, SW) there are also capital subsidies to support wind energy. Overall, there has been little movement in the prices paid since last year. Japan has seen a fall of about 10%, though the price remains high and Sweden has seen healthy rise, though the price remains low.

4.4.4 Developments In Industry

In May 2002, the global giant GE Power Systems announced that they had purchased some of the assets of the Enron Wind Corporation. The new company is GE Wind Energy, a subsidiary of GE Power Systems. Worldwide, GE Wind Energy employs over 1,500 people with wind turbine factories in Spain and Germany, as well as in California.

Manufacturing industry

Some of the larger European wind turbine and component manufacturers are establishing assembly and manufacturing plants in the United States. The Danish firm NEG Micon has a large turbine assembly facility in Illinois. This reflects expectations in the future US market and the mobility of wind turbine manufacturing with the markets. In December, NEG-Micon Holland also announced that it would stop production of wind turbines in the Netherlands.

The buoyant market in Spain continues to see growth in manufacturing with new component factories starting operation during 2002 (blades, towers, and gearboxes), and a large number of jobs being created, especially in the region of Castilla-Leon.

In Italy, there is only one wind turbine manufacturer, IWT, a Vestas subsidiary, involved in the production of blades and assembly of components, which, as a consequence of the fall in the internal market in 2002, reduced personnel significantly from 349 to 250.

Turbine size

The average new turbine size increased dramatically in several countries this year, continuing a year on year trend, though the size of machines typically deployed does vary between the various markets. The increase this year is possible because of the rapid increase in available machine sizes from many manufacturers aiming for the offshore market.

In the largest markets in 2002, Germany and Spain, machine size increased by 9% and 12% respectively, resulting in average machine sizes of 1,395 kW and 808 kW. For Denmark and the Netherlands the increase was more dramatic at around 45% and 87%. The Netherlands installed machines averaging over 1.5 MW. Finland and Norway saw more dramatic increases still, but this results from the installation of just one or two new wind farms of much increased turbine size. The average new turbine deployed, using data from the countries reporting size data (CN, DK, FIN, DE, GR, IT, IR, NL, NO, ES, SW, SZ, UK) was around 1,170 kW. In 1995 the average new turbine had a capacity of just 440 kW. The most recent offshore installation in Denmark used 2-MW turbines.

The move to larger machines is driven by both economics and project size. In countries where space at sites is at a particular premium (DE, NL, DK) using larger machines has the benefit of increasing the total capacity that can be installed in a given area.

Country	**Total installed capacity**	**Offshore installed capacity**	**Annual capacity growth**	**Total No. of Turbines**	**Average new turbine size**	**Wind generated electricity**	**2001 National electricity Demand**	**Typical wind system costs**	**Price paid to wind generators**	**R&D spend**
	(MW)	**(MW)**	**(MW)**		**kW**	**GWhrs/yr**	**TWhrs/yr**	**USD/kW**	**US Cents/kWh**	**USD m**
Australia	**103.0**	**0.0**	**30.0**	**n/a**	**n/a**	**n/a**	**192**	**n/a**	**n/a**	**n/a**
Canada	**232.0**	**0.0**	**18.0**	**330.0**	**1,060.0**	***530.0***	**542**	***949***	***3.8 - 5.1***	**0.76**
Denmark	***2,936.0***	**210.0**	**380.0**	***5,571.0***	***1,337.0***	**4,877.0**	**35.2**	***924***	***6.1 - 8.2***	**0.56**
Finland	**43.0**	**0.0**	**4.0**	**65.0**	**2,000.0**	***63.0***	**81**	***954***	**3.81**	**0.57**
Germany	**12,001.0**	**0.0**	**3,247.0**	**13,759.0**	**1,395.0**	***17,260.0***	**476**	**n/a**	**n/a**	**n/a**
Greece	**355.4**	**0.0**	**57.4**	**685.0**	***820.0***	**650.0**	**50**	***1,001***	**6.40 - 7.4**	**n/a**
Ireland	**138.3**	**0.0**	**12.6**	**227.0**	**850.0**	***426.0***	***24***	***954***	**4.62**	**n/a**
Italy	**788.0**	**0.0**	**106.0**	**1,346.0**	***773.7***	***1,400.0***	***305***	***858***	**11.83**	**0.95**
Japan	***334.0***	**0.0**	**84.0**	**n/a**	**n/a**	**348.2**	**982**	***1,095***	**8.42**	**6.08**
Mexico	**1.7**	**0.0**	**-0.6**	**8.0**	**n/a**	**6.0**	**197**	**n/a**	**n/a**	**0.48**
Netherlands	**685.0**	**2.0**	**202.0**	**1,472.0**	***1,603.2***	***1,006.0***	**104**	***1,049***	**6.5 - 7.6**	***4.77***
New Zealand	**35.4**	**0.0**	**0.0**	**56.0**	**n/a**	**145.0**	**n/a**	***1,048***	**2.46**	**0.26**
Norway	**97.0**	**0.0**	**80.0**	**65.0**	**2,220.0**	***292.0***	**125.4**	***1,196***	**n/a**	**0.59**
Spain	**4,635.0**	**0.0**	**1,275.0**	**7,814.0**	**808.0**	***8,000.0***	**205.4**	**n/a**	**5.91**	**n/a**
Sweden	**308.0**	**22.5**	**40.5**	**610.0**	**950.0**	**565.0**	**149**	***1,016***	**2.90**	**2.65**
Switzerland	**5.4**	**0.0**	**0.9**	**n/a**	**800.0**	**5.4**	**53.7**	**n/a**	**10.01**	**0.34**
United Kingdom	**552.0**	**3.8**	**88.0**	**999.0**	**1,020.0**	***1470.0***	**394**	***1,086***	***10.70***	**2.38**
United States	**4,685.0**	**0.0**	**425.0**	**n/a**	**n/a**	***12,000.0***	**3,602**	**n/a**	***0.03 - 0.06***	**38.20**
Totals	***27,935***	**238**	***6,049.8***			**49,043.6**				**58.60**

Table 4.3 National statistics of the member countries of IEA Wind

Germany has traditionally used the larger machines, but other countries are now catching up. Spain and Italy are different, in that the remote and elevated sites being exploited do not favor the use of very large machines, because of the difficulty in transporting the machines to site and in getting large cranes on site for erection. However, the trend was still present in Italy, in spite of the mountainous terrain of most sites. In Sardinia the first turbines in Italy over 1 MW were installed in a 12-MW wind farm of seven 1,750-kW Vestas V-66 units.

Offshore industry structure

The increasing prospects for offshore wind energy are producing some company positioning and investments, especially in dedicated offshore wind installation vessels. A new Dutch joint venture has built a jackup installation barge. The joint venture company is called Mammoet Van Oord and is between offshore heavy lift specialist, Mammoet, the dredging and marine construction works contractor Van Oord ACZ, and other shareholders including Hovago Cranes and Marine Construct.

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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.

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 new Wind Power Production Incentive (WPPI) program ensures the provision of economic incentives for 1,000 megawatts (MW) of new installed capacity by 2007. 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

A total of 92 MW of wind power has been installed in the province of Alberta. Though much activity took place in 2001 and earlier, no new installations were made during 2002. The locus of activity has been in southern Alberta, with the majority of installations situated at Cowley Ridge (40.1 MW) and Pincher Creek (39.5 MW). The largest developers in the province are Canadian Hydro Developers, with installations totaling 47.5 MW, and TansAlta/Vision Quest Windelectric, with 42 MW.

Saskatchewan added 5.9 MW of wind power in 2002, bringing installed capacity in the province to 16.9 MW by the end of the year. All of this generation is located at Gull Lake in southern Saskatchewan.

Ontario added about 10.8 MW of capacity in 2002, which brings that province's total to 13.9 MW. The most significant installation was the 9.0-MW Huron Wind project, which is located on the shore of Lake Huron.

In Quebec, no new wind power was added in 2002, though at year-end the province still had the largest installed capacity in the country, 103 MW. The 100-MW Le Nordais project, at Matane in the Gaspesie area, forms the vast majority of this wind capacity.

In eastern Canada, two provinces have wind-generating capacity. Nova Scotia installed its first two commercial wind turbines in 2002, for a total installed capacity of 1.3 MW. Prince Edward Island also has one wind project, the 5.3-MW PEI Energy Corporation's installation at North Cape, though it was installed a year earlier, in 2001.

Two wind turbines, with a total capacity of 0.8 MW, also operate in Yukon Territory, northwestern Canada.

The total installed capacity in Canada by the end of 2002 was 232 MW.

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, the planned commencement of new projects supported by the WPPI should ensure rapid growth in 2003 and for some time beyond.

Contribution to National Energy Demand

The national electrical energy demand in Canada in 2002 was 560 terawatt-hours (TWh). Total installed generation capacity at the end of 2000, the most recent year for which statistics are available, was 111 gigawatts (GW), which includes hydro-power, coal, nuclear, natural gas, oil-fired, wood-fired, tidal, and wind plants. The installed wind capacity was 232 MW by the end of 2002, and an estimated 530 gigawatt-hours (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 probably 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 per kilowatt-hour (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 10 years of production and helps to provide a long-term stable revenue source. The program is intended to help address climate change and improve air quality.

Interest in WPPI has been high – by December 2002, the program had registered project applications totaling 2,700 MW of capacity. (Funding, however, is limited to supporting about 1,000 MW of wind power.) On the basis of the quantity and quality of the applicants, it is expected that 2003 will be a watershed year for wind power development in Canada. Provincial and territorial governments are being encouraged to provide additional support, and several provinces have begun to develop their own complementary programs. For example, Quebec has announced its own firm target of 100 MW per year of additional installed wind power capacity, commencing in 2004 and continuing for 10 years. Ontario has also recently announced support for renewables, in this case through a significant tax rebate program. So far, though, none of the provincial programs offers the same level of incentive as that provided by WPPI.

4.2 Unit Cost Reduction

Does not apply.

5.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The following wind turbines are operational in Canada.

- 57 US Windpower (Keneteck) 360-kW
- 375-kW wind turbines
- One NEG-Micon 900-kW and 136 NEG-Micon 750-kW machines
- 20 Nordex 1.3-MW wind turbines
- Five Vestas V44-600-kW, 87 Vestas V47-660-kW, and 7 Vestas V80-1.8-MW wind turbines
- One Enercon E 40-600-kW machine
- One Turbowinds 600-kW wind turbine
- One Tacke 600-kW unit
- In addition, a handful of turbines with capacities of 150 kW and less are operational.

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.

Trends in Unit Costs of Energy and Buy-Back Prices

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

In all other Canadian jurisdictions, the buy-back price is generally set by the local utility and is 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

• Dutch Industries produces water pumping units in Regina, Saskatchewan
Wenvor-Vergnet of Guelph, Ontario, and Plastique Gagnon of Quebec are developing small wind turbines in the 20-kW to 30-kW size; Vergnet Canada of Montreal, Quebec, is developing wind turbines ranging from 10 kW to 275 kW (these small to mid-sized units are aimed at grid-connected applications, remote communities, and stand-alone installations).

• Novelek Technology of New Brunswick has developed 10-kW, 25-kW, and 100-kW inverters for the commercial wind turbine market.

• Bolwell Corporation of Huron Park, Ontario, is manufacturing 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 items listed here.

• 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

Does not apply.

Authors: Raj Rangi and Frank Neitzert, Natural Resources Canada, Canada.

Chapter 6
Denmark

6.1 INTRODUCTION

In the 1980s and 1990s, with broad political support, Denmark implemented vigorous energy policies involving a broad range of actors: energy companies, industry, municipalities, research institutions, NGOs, and consumers. A continuous effort since the beginning has led to an installed wind energy capacity of approximately 2,936 megawatts (MW) by the end of 2002. In a year with normal wind conditions, this capacity will cover about 16.4% of Denmark's electricity demand.

In the following, the development and the status of wind energy in Denmark at the end of 2002 are presented.

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 (such as certification schemes and R,D&D programs) have been used as tools in the strategies.

During 2002 the main instrument for wind energy deployment on land has been an incentive motivating owners of old and less than 150-kilowatt (kW) turbines to scrap those and invest in capacity in larger and more efficient machines. The technology push instruments have been reduced in steps with the development of a liberalized market for electricity including wind energy. Also the government has changed the 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. Instead, the government has introduced a new overall strategy for research also covering renewable energy, which will be implemented over the coming years. Additionally, 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 at sites 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 will take place offshore. After 2005 the wind turbine capacity on land will be affected, among other things by renovation of wind turbine areas as well as by removal or replacement of existing wind turbines in accordance with regional and municipal planning.

In spring 1999, an electricity reform was introduced unbundling the electricity sector. The reform also contributes to ensuring the fulfillment of the long-term, international environmental commitments in 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 development of renewable energy.

For the period 2000 to 2003 a ceiling for carbon dioxide emission was established for the electricity sector expressed in carbon dioxide quotas. In 2000 it was 23 million tons;

in 2001, 22 million tons; in 2002, 21 million tons; and in 2003, it will be 20 million tons. The ceiling was split among the electricity production companies. If the annual quota is exceeded, the production companies must pay the sum of 40.00 DKK per ton carbon dioxide to the state.

The renewable energy quotas announced by the government mean that all consumers are obliged to purchase a share of electricity from renewable energy. The quota laid down means that 20% of the electricity consumption should be covered by renewable energy at the end of 2003. Since wind power is the most developed and one of the cheapest ways to save carbon dioxide, a major part of renewable energy has come from wind power. It is predicted that, with the full deployment of the new offshore wind farms, electricity from wind energy alone will cover about 18% of electricity consumption in 2003.

A rising share of electricity consumption will in the future be covered by electricity produced from renewable energy sources. It is the Danish government's policy that a more competition-based market mechanism should ensure the cost-effective development of future renewable energy production.

Progress Towards National Targets

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 only little growth in future capacity on land after 2003.

Several investigations of offshore wind resources have been conducted since 1977. As a result, two demonstration projects have been finalized. In July 1997 a Plan of Action for Offshore Wind Farms was submitted to the Minister of Environment and Energy. The plan was prepared by the two utility associations, Elkraft and Elsam, and the min-

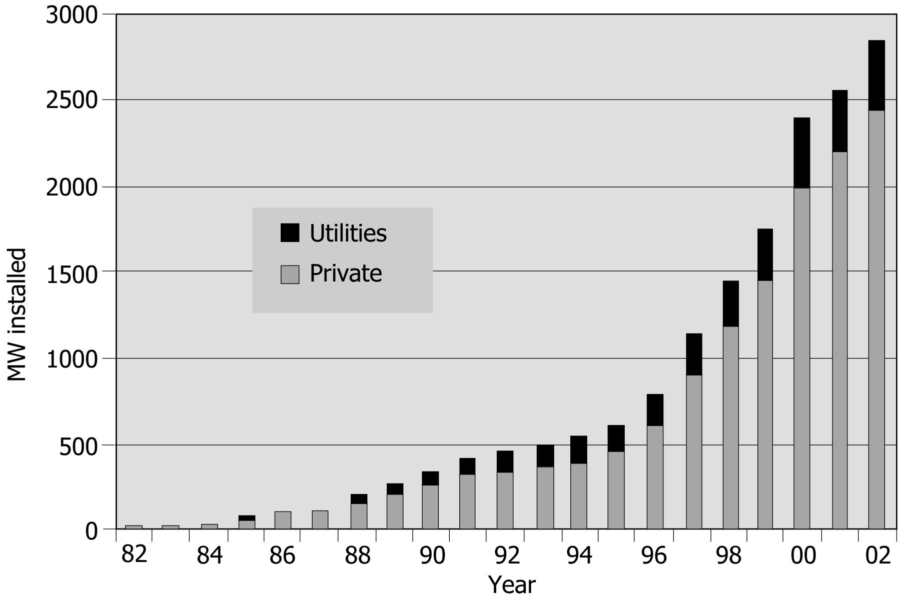

Figure 6.1 Accumulated wind turbine capacity in Denmark (1982 to 2002)

Year of installation	Number	Power (kW)	Average power (kW)
Before 1990	2,601	258,169	99
1990	385	81,913	213
1991	372	74,136	199
1992	217	45,230	208
1993	142	36,399	256
1994	135	48,604	360
1995	191	92,017	482
1996	400	205,853	515
1997	536	300,445	561
1998	462	312,925	677
1999	415	311,355	750
2000	675	600,365	889
2001	131	117,100	894
2002*	366	490,000	1,335

Table 6.1 Installed wind turbine capacity and development in size (*Year 2002 estimated). Source: E&M-Data until 2000

istry's Energy Authority and Environmental Protection Agency.

The plan shows how a total capacity of 4,000 MW of offshore wind power in Denmark could be established by 2030. The corresponding annual electricity production would be 12 to 14 terawatt-hours (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 Reef in the North Sea was installed in 2002, and a second is under construction in the Baltic Sea south of the island of Lolland. Future offshore installation will be decided based on economic possibilities and needs specified by the government's future climate policy.

6.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

According to the Danish Wind Turbine Owners' Association, the total capacity of wind power in Denmark was 2,556 MW by the end of 2001. By February 2003, final statistics for year 2002 were not yet available. However it is estimated that the capacity has increased by about 380 MW in 2002, bringing the total up to 2,936 MW. The accumulated wind turbine capacity of private and utility wind turbine installations is shown in Figure 6.1.

Rates and Trends in Deployment

The deployment rate in Denmark in numbers and electrical capacity is shown in Table 6.1.

The deployment has been almost constant from 1996 to 1999, adding approximately 300 MW wind-power capacity onshore annually. In 2000 an extraordinarily 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 newly installed wind turbines has grown gradually, being 750 kW in 1999, approximately 889 kW in 2000 to 2001, and an estimated 1.34 MW in 2002.

Contribution to National Energy Demand

The total electricity production from wind energy in 2002 was 4,877 GWh, corresponding to about 14% of the total electricity demand in Denmark. The wind's energy index in 2002 describing the energy in the wind of a normal year was relatively low (approximately 85%). The wind energy production with a wind index 100 would correspond to about 16.5% of the electricity demand. The development in the wind energy index is shown in Figure 6.2.

6.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The owners of the power grid are in most cases obliged by law to connect wind turbines to the grid and to receive and pay for wind-generated electricity. Different arrangements have existed over the years. Since 1993, the payment for wind-generated electricity has been related to the utilities' tariffs. A law has obliged the power grid owners to pay wind turbine owners a kilowatt-hour (kWh) rate of 85% of the standard selling prices (85% of 0.37 to 0.45 DKK/kWh in 1998). Up to 2002, 0.10 DKK/kWh carbon dioxide tax has been reimbursed to wind turbine owners and 0.17 DKK /kWh has been added in direct subsidy. As a result, in 2001 the average purchase price for electricity from private wind turbines was between 0.43 DKK/kWh and 0.58 DKK/kWh.

On 19 June 2002, the government entered into an agreement with the opposition about future conditions for wind turbines. Consumers' obligations to purchase electricity from wind turbines are to be phased out. The support will be remodeled as financial support of 0.10 DKK/kWh, corresponding to the carbon dioxide tax on electricity, and 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 that have

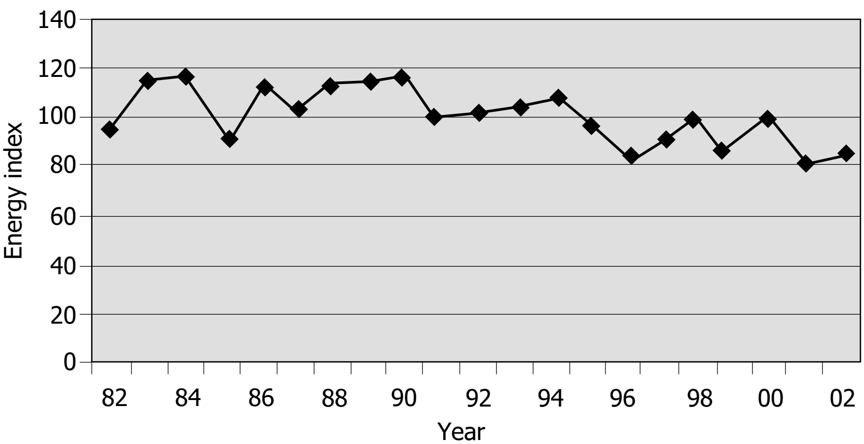

Figure 6.2 Energy in the wind energy index in Denmark, 1982 to 2002

not been installed in fulfillment of the obligations of the power companies is shown in Table 6.2.

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 receives 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 below 100 kW, the additional support can be had for three times the scrapped capacity, whereas 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 wind turbines less than 100 kW, which will also be scrapped.

Small wind turbines up to 25 kW used for households will still receive 0.60 DKK for surplus electricity delivered to the grid.

Earlier regulations limiting private wind developments were withdrawn in 2000. Favorable taxation schemes were used earlier to stimulate private wind turbine installations. Today, income from wind turbines, by and large, is taxed 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 web site, www.dawt.dk.

Danish wind turbines power purchase prices:	Wind turbines bought until 31 Dec 1999	Wind turbines bought after 1 Jan 2000.
Until end of 2002	0.60 DKK/kWh until end of assigned full load hours, then 0.43 DKK/kWh. Purchase obligation.	0.43 DKK/kWh for 22000 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.
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.	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 6.2 Prices and subsidies as per end of 2002.

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 International Electrotechnical Commission (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. See Table 6.3.

6.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Wind turbines are typically installed in clusters of three to seven machines. Clusters of wind turbines are preferred in the spatial planning by local and regional planning authorities. At a few places, larger wind farms

Service	Authorized 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 6.3 Bodies authorized by the Danish Energy Authority to provide services under the Danish scheme for certification and type-approvals for wind turbines (Dec 2002)

are also allowed. Denmark's largest wind farm on land (in capacity) is still Rejsby Hede from 1995 with 39 600-kW machines. The largest offshore wind farm is the new 160-MW Horns Rev, consisting of 60 2-MW wind turbines placed in the North Sea 14 to 20 kilometers (km) offshore Blaavands Huk.

Different entities own wind turbines: private individuals, private co-operatives, private industrial enterprises, municipalities, and 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 increased slightly, 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 the regulation, the ownership has become more mixed.

The 160-MW offshore wind farm at Horns Rev (see Figure 6.3) is owned by the utilities alone (Elsam), whereas the 40-MW Middelgrunden offshore wind farm is a 50-50 shared ownership between a private corporation and a utility. Construction of a 166-MW offshore wind farm at Roedsand and a smaller farm of 23 MW south of Samsoe was started in 2002.

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. The results are published in the association's magazine Vindstyrke.

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 at shorter intervals. Consumables such as oil in gearbox, braking clutches, etc., are often replaced at intervals of one to three years. Parts of the yaw system might be replaced at intervals of five years. Vital components exposed to fatigue loads such as main bearings and bearings in gearboxes might be replaced halfway through the total design lifetime. This is dealt with as a reinvestment.

Operation and maintenance 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 operation and maintenance costs. The model is based on statistical surveys and analyses in 1991, 1994, and 1997. The model includes a large reinvestment after the tenth operational year on 20% of the cost of the wind turbine. This reinvestment is distributed over operational years 10 to 20. (See Table 6.4.)

In an ongoing project, both the technical and the economical lifetime of wind turbines are being investigated. The work is concerned with machine sizes of 55, 150, 225, 300, 500, 600, 660, and 750 kilowatts, and it is based on empirical data from a major questionnaire that has been sent to approximately 2,500 wind turbine owners in Denmark. The returned data have been merged with the database mentioned previously. The first results on the operational experience are gathered in Table 6.5. The first part of this table shows the costs of repair and maintenance, while the second part presents the total operation and maintenance (O&M) costs, i.e., including costs from insurance, service, administration, site rental, etc.

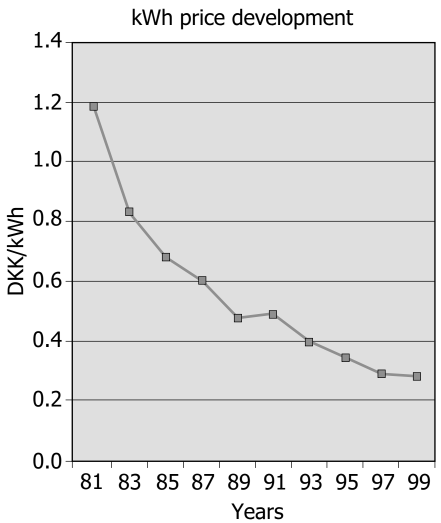

Figure 6.3 Offshore wind farm at Horns Rev, 160 MW (Pubished with the permission of EL-SAM)

It is normally expected that O&M costs increase over time. Nevertheless, the empirical costs for the 55-kW turbine actually decreased after 10 years of operation, as can be observed in Table 6.5.

Main Constraints on Market Development

Since the mid-1990s, the Danish market has been of significant size and been remarkably constant. It was expected that the market would slow down due to uncertainty regarding future purchasing prices and constraints due to spatial planning, but for 2002 the replacement program and offshore development have kept the market up.

In certain regions of Denmark, the deployment of wind energy has now reached a point of saturation with respect to spatial planning. Future land-based market development will therefore mainly be tied to replacement of smaller wind turbines with new, higher-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 exploit energy from water and wind within the 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 preinvestigation of such within the national territorial waters and within the economical 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 EIA for each project.

Electricity Surplus

A possible constraint to the future deployment of wind energy into the Danish energy system is maintaining the power balance or dealing with the electricity surplus. Due to the high share (~50%) of electricity from combined heat and power (CHP) and the high share (~14%) from renewable electricity

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 6.4 Annual operational and maintenance costs in % of the investment in the wind turbine. Source: Danish Energy Authority, E&M-Data and Risø National Laboratory.

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

(mainly wind power), a substantial part of Danish electricity production is derived mainly from weather conditions (outdoor temperature and wind speed), thus limiting the system's ability to adapt to quickly changing electricity prices on the market. On cold, windy nights, an "electricity surplus" may arise. On one hand, this is a successful demonstration of how far CHP and electricity from renewable energy can be developed. On the other hand, it poses a new challenge to the electricity system in general and the system operators in particular to handle fluctuating electricity production.

In 2001, the Danish Energy Authority set up a commission with the task of illustrating the challenges from the increasing share of electricity from wind turbines and CHP. The report was submitted for hearing by the end of 2001. The commission looked in particular at the electricity surplus. Electricity surplus is generally exported. If it is not physically possible to export the entire surplus, a critical situation arises.

The commission concluded regarding the critical surplus that it happens already today in the western part of Denmark with increasing frequency, while in the eastern part it may be seen in the future.

The economical 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 exported from Denmark. In general, more flexibility in power production and demand will be appropriate to enable response to market conditions. The economical best means are to move the power demand, move production with heat storages, replace CHP with heat pumps, and replace CHP with heat boilers fired with natural gas or biomass. Also, stopping the wind turbines for a few hours can be a solution.

6.6 ECONOMICS

Trends in Investment

The ex-works cost of wind turbines decreased significantly with the introduction of 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, DKK 3.1 million to DKK 3.5 million, and for 750-kW in 1998 it was DKK

3.4 million to DKK 4.1 million depending on rotor diameter and tower height.

For the recent MW machines the ex-works cost might be slightly higher per kilowatt of capacity. But as the wind resource at rotor height is greater and the harvest of wind energy therefore better, the total economy of the MW projects will be better.

Availability of capital for wind power projects is not a problem. Financial institutions compete efficiently on this market, and different financial packages have been developed. Typical projects are financed over 10 years.

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

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 Energy and Buy-Back Prices

The production cost per kilowatt-hour for wind-generated electricity has decreased rapidly over the past 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 estimated cost is shown in Figure 6.4. Average consumer (4,000 kWh/year) net electricity price from power distribution utilities is around 0.56 DKK/kWh. This figure comprises subscription, grid and PSO tariff, and commercial and prioritized power cost. For private consumers (connected to the 400/230-volt distribution grid) several taxes are added to this price. On the top a 25% Value Added Tax (VAT) is added. 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 regulation from year 2000, the whole payment for wind-generated power comes from the 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 among several European countries on the practical arrangements.

Table 6.2 gives an overview of the price subsidies.

6.7 INDUSTRY

Manufacturing

Danish-based manufacturers of large commercial wind turbines in the 150-kW to 3-MW range are Bonus Energy A/S, NEG Micon A/S, Vestas Wind Systems A/S, Norwin A/S, and Wincon West Wind A/S. The originally Danish company Nordex Borsig has the main part of its manufacturing in Germany and is therefore not included in

	Realistic capacity	Realistic production	Percent of annual electricity consumption
Offshore	**12,000 MW**	**30 - 40 TWh**	**~ 100 %**

Table 6.6 Estimated wind turbine capacity and production in Denmark

the statistics for sale from Danish manufacturers.

Gaia Wind Energy A/S makes 11-kW machines for electricity to households. Calorius-Westrup A/S makes a 5-kW heat-producing turbine.

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

Industry Development and Structure

Industrial development in 2002 focused on refining the MW 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 diameter. The wind turbine types from Danish manufacturers are shown in Table 6.7. For most of the types, several versions with different tower heights can be supplied.

Estimated sales by Danish wind turbine manufacturers (excluding Nordex Borsig) were almost 3,150 MW in 2002, which is only slightly higher than the figure for 2001 (3,115 MW). The global increase of wind power capacity in 2002 is estimated to have been around 7,000 MW, corresponding to 28% increase of capacity, bringing the world's

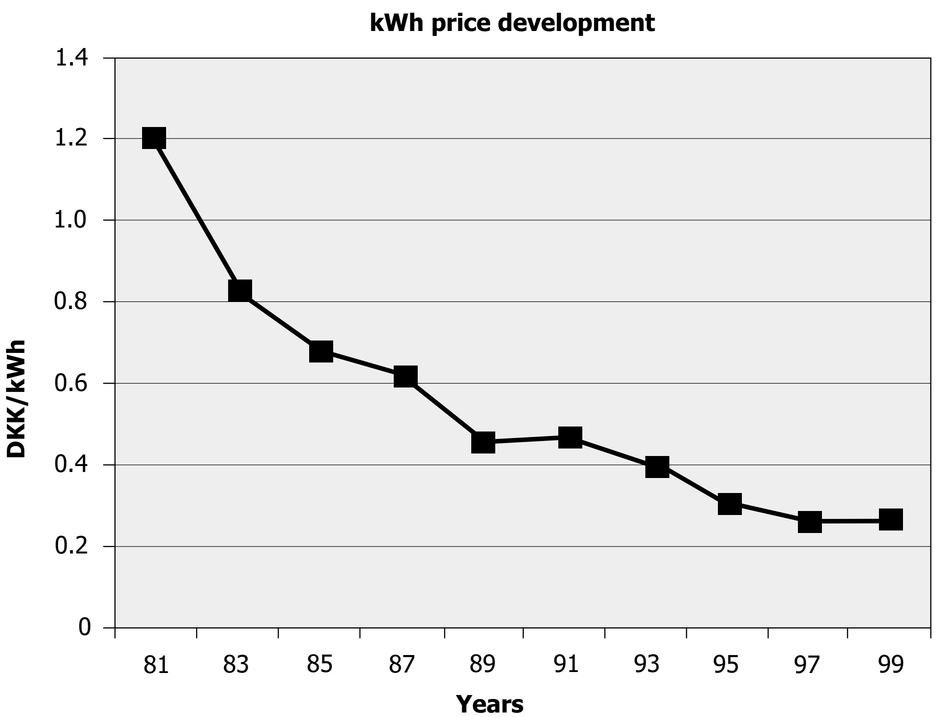

Figure 6.4 Estimated costs of wind generated electricity in Denmark. Based on 20 years' depreciation, 5% interest rates and siting in roughness class 1.

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 6.7 Cost of a 1000 kW wind turbine project. Source: E&M-Data, Nov 2001)

total up to about 32,000 MW by the end of 2002. The rate of growth was apart from the unusually high rate in 2001 (47%) on level with previous years development rate of the world market. The Danish wind turbine manufacturers' share of the total world market in 2002 was thus about 45%. The Danish home market has amounted to about 490 MW, which is remarkably higher than the 117 MW in 2001. It is worth noting that a significant part of Danish wind turbines and components are produced abroad by sub-suppliers and/or by subsidiaries.

Service and maintenance of wind turbines in Denmark is carried out by the manufacturers' own service departments. 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 companies are specialized in providing cranes for installations of wind turbines; providing transport of turbines, towers, and blades domestically and for export; insurance, etc. Companies with expertise in offshore construction and operations in the field of oil and gas activities are now offering their assistance to the wind energy business in connection with the offshore wind farms. The major Danish consultancies in wind energy utilization are BTM Consult ApS, E&M Data, Tech-wise A/S, WEA ApS, and Tripod ApS. Several experienced engineering consulting companies such as Carl Bro, Rambøll, Cowi, and others have shown increasing interest and are taking active part in wind energy development. There is one major independent developer of wind farms in Denmark, Jysk Vindkraft A/S, that sells turnkey projects to farmers and co-operatives.

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

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. Practically all projects are initiated through the annual calls for proposals issued for each area of energy, where wind energy is one of the issues. Projects are normally run over two or three years, and funding will be given by the end of each year. In almost all projects several partners participate, and industrial participation and co-financing are encouraged. The Danish Energy Authority finances 50% to 85% of the total costs. The budget for the EFP in 2002 has been 40 million DKK – almost one third of previous years. Out of that budget for 2002, two wind energy projects were supported with a total amount of 4 million DKK.

According to an agreement reached in 2002 between the government and the opposition, a total 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.

Until 2002 the Danish Energy Authority also managed a program for development and demonstration of renewable and information about it (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 the related activities was reduced to 3.7 million DKK.

In addition to the government R&D programs, the system operators (ELTRA and Elkraft System) have PSO-subsidized R&D programs for non-commercial projects concerning new and environmentally friendly energy technologies. Prioritized issues are efficiency, costs and reliability of the wind turbines, regulation and forecasting of production, environmental impact, and maintenance. Calls for proposals have been issued with 15 September 2003 as the deadline, and several wind projects have been chosen for support. The programs include development of renewable energy technologies including wind power. Final approval rests with the Danish Energy Authority. For 2002, a total amount of 12.8 million DKK was PSO-subsidized to R&D wind energy projects. For 2001 the total PSO funding for wind energy was 16.2 million DKK.

International co-operation on wind energy R&D is emphasized by the Danish Energy Authority. Denmark has participated in the international co-operation in IEA R&D Wind since its establishment 25 years ago.

Danish universities, research centers, power utilities, and the manufacturing industry participate in the European Union's RTD programs. No quantitative data are available for 2002.

Active Danish participation in international standardization in IEC and CEN/CENELEC has a high priority, and R&D efforts supporting international standardization are encouraged.

New R,D&D Developments

In recent years the Danish energy research program has emphasized the uncertainties and challenges associated with wind development offshore. In 1999, new R&D projects included wind resources and forecasting offshore, integration of the large offshore wind farms into the electricity system, and development of large wind turbines. For 2000 and 2001, new projects were initiated about components (e.g., gears), design conditions, integration with the electricity system, and environmental impact. For 2002 the calls for proposals have been limited to wind turbine technology and wind resources and climate.

Descriptions (in Danish) of the projects are available on the Danish Energy Authority's Internet site (refer to www.ens.dk).

These activities comprised 2002 activities for the test station for wind turbines.

- General support to the Danish Energy Agency
- Secretariat for the Danish certification and type-approval scheme
- Spot-check of type-approved turbines
- Inspections of major breakdown of turbines

- Danish and international standardization
- Development of framework for a new approval scheme
- Preparatory tests for new test station at Høvsøre

In May 2000 the Minister of Environment and Energy issued a directive allowing Risø to acquire and develop a test site for wind turbines in Høvsøre at the windy northwest coast of Jutland. The test site was inaugurated in December 2002. In the first phase it

Figure 6.5 The new test station for MW wind turbines at Hoevsoere in Jutland

is equipped with five test sites for measurements on multi-megawatt wind turbines with heights up to 165 m. Four of the test sites were put into operation at the end of 2002. (See the photo, Figure 6.5.)

Offshore Siting and Wind Energy Development

The two small demonstration farms at Vindeby (4.95 MW) and Tunø Knob (5 MW) owned by the utilities have been in operation since 1999.

The 40-MW project at Middelgrunden 2 km outside the Copenhagen harbor in shallow water (3 to 5 m) was put into operation at the beginning of 2001. The farm comprises 20 Bonus wind turbines, each of 2 MW. The total projected power production per year is 89 million kWh, with a net production cost of 0.32 DKK/kWh. After a run-in period, the wind farm was set on full power from the end of March 2001, and owners report that production has been slightly higher than anticipated for 2001.

The wind farm is owned 50-50 by a wind energy cooperative, Middelgrundens Vindmøllelaug, and the utility, Copenhagen Energy. At its inauguration, the project was the largest offshore wind farm worldwide. About 8,500 people and companies are members of the cooperative. The objective was to combine pollution-free electricity production with involvement of local people in Copenhagen.

Prior to the development of wind farms offshore, a governmental committee has been looking at the regulatory conditions for offshore wind power installations. Beyond selecting the sites for the small demonstration farms and the new larger farms, all interests in Danish waters were mapped. Also, a set of recommendations for future installations was given based on input from authorities and on surveys carried out over the years.

Studies financed by power utilities Danish Energy Agency and EU/JOULE indicated a substantial cost reduction for new 100-MW to 200-MW offshore projects: a 56% reduction compared with Vindeby. More accurate assessment of the offshore wind climate and prediction of wind loads are important research issues that have been supported by government funding.

A Plan of Action for Offshore Wind Farms was submitted to the Minister of Environment and Energy in 1997. The plan includes eight areas with water depths of up to 15 m. The total theoretical installed capacity of these areas is 28,000 MW, and it was estimated that about 12,000 MW realistically could be utilized in four major areas. These are west of Horns Rev in the North Sea, south of the island of Læsø in Kattegat, south of the island of Omø in Smålands Havet, and south of Lolland Falster (Rødsand and Gedser) in Østersøen (the Baltic Sea). Wind speeds in the areas allow 3,530 "net-full load hours" in the North Sea (Horns Rev) and between 3,000 and 3,300 hours in interior Danish waters. This corresponds to an annual electricity production of 36 TWh to 40 TWh. For comparison, the total Danish electricity consumption in 2000 was 35 TWh.

The Danish Energy Authority has continued the implementation of the first phase of the Plan of Action for Offshore Wind Farms in Danish Waters, which started in 1998. According to the agreement, 750 MW in five large offshore farms should be erected between 2001 and 2008.

In 2001, Elsam/Eltra was granted permission to develop a wind farm at Horns Rev at the west coast of Jutland, while SEAS on behalf of E2 was granted permission for a project at

Rødsand, south of Seeland. Environmental impact assessments have been carried out for the projects.

Both wind farms consist of 80 wind turbines and a capacity of approximately 160 MW. The Horns Rev farm was completed and connected to the grid in 2002. The farm is located 14 km from the coast at Blåvandshuk. The turbines are 2-MW Vestas turbines with a total height of 110 m, and the farm occupies an area of 20 square kilometers. The wind turbines for the farm at Rødsand will be 2.3-MW Bonus turbines. Rødsand was under construction in 2002 and was expected to be put into operation in 2003. The other Danish offshore wind farms mentioned previously were put on hold by the government in 2002.

Estimates of the total realistic offshore power capacity and the electricity production are shown in Table 6.8.

According to Danish electricity supply law, the establishment of offshore wind farms has up to now required a permit as well as a license for operation. The twofold approval process includes permission for preliminary surveys and later a final approval of projects (a building permit). Both depend on a process of public hearing to take the different interests into account. In relation to the latter, the applicant is called on to do an EIA. The topics cover a wide range of environmental matters: sea bed conditions, raw materials, hydrography, water quality and benthic fauna and vegetation, fish, birds, marine mammals, landscape and visual impact, marine archaeology, emissions, noise, matters of recreation and planning, and the impact on sailing and fishing in the area. The EIA will also contain suggestions for limiting or neutralizing potential negative effects on the environment.

Due to the special status of the demonstration program, an environmental measurement and monitoring program more comprehensive than the EIAs 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 to conduct the demonstration program has been established. Further the appointment of an international panel of experts with the objective of evaluating the demonstration program mirrors 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.

The environmental committee has prioritized activities in the demonstration program to clarify the following issues.

- The risk of having essential negative effects on the environment
- The ecological fragility of the specific areas
- The usefulness of the areas to investigate specific effects
- The relevance of the effects to decision-making regarding further development within the specific areas and the overall development of future offshore wind farms
- The importance of the different effects in relation to the demand for action and the economic framework for the program

Baseline studies are presupposed to be undertaken in all the projected areas to be able to compare the existing environmental condition 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.

To concentrate the investigations further it has been decided to conduct a monitoring program for prioritized subjects and to study

Manufacturer	Type	Nominal power (kW)	Extra generator (kW)	Rotor diameter (m)	Power regulation
BONUS	600 MK IV	600	120	44.0	Stall
BONUS	1 MW	1,000	200	54.0	Ac stall
BONUS	1.3 MW	1,300	250	62.0	Ac stall
BONUS	2 MW	2,000	400	76.0	Ac stall
BONUS	2.3 MW	2,300	400	82.4	Ac stall
NEG MICON	NM600/43	600	150	43.0	Stall
NEG MICON	NM600/48	600	150	48.0	Stall
NEG MICON	NM750/44	750	200	44.0	Stall
NEG MICON	NM750/48	750	200	48.0	Stall
NEG MICON	NM900/52	900	200	52.0	Stall
NEG MICON	NM1500C/64	1,500	400	64.0	Stall
NEG MICON	NM2000/72	2,000	500	72.0	Ac stall
NEG MICON	NM 2750/80	2,750	-	80.0	Ac stall
NORDEX	N27/150	150	30	27.0	Stall
NORDEX	N43/600	600	125	43.0	Stall
NORDEX	N50/800	800	125	50.0	Stall
NORDEX	N60/1300	1,300	250	60.0	Stall
VESTAS	V27	225	50	27.0	Pitch
VESTAS	V39	500	-	41.8	Pitch
VESTAS	V47	660	200	47.0	Pitch
VESTAS	V52	850	0	52.0	Pitch
VESTAS	V66	1,750	0	66.0	Pitch
VESTAS	V80	2,000	0	80.0	Pitch
WINCON	W250/29	250	0	29.0	Stall
GAIA WIND	GW 11	11	0	13.0	Stall

Table 6.8 Wind turbines approved to the Danish market. Dec. 2002

effects in areas where the presence of species to investigate can be expected to be high. In addition, selected thematic effects studies are undertaken, such as the visual aspects, introduction of hard-bottom habitat (artificial reefs), and impact from electric or magnetic fields.

Also, the economic and technical aspects are to be evaluated as part of the demonstration program. If the experiences are positive, the areas will then become open for commercial projects.

An important concern for the Danish government is to ensure that future offshore development is based on market conditions in an economically efficient way. The government therefore in 2002 decided to set up a committee to study the possibilities and conditions of tendering future offshore wind farms. The main objective of the committee was to establish a framework of conditions for a tendering procedure for establishing offshore wind farms in Danish waters. By applying such a procedure, competition among the bidders will be ensured and the most cost-effective offshore turbine developments will be undertaken. The committee finished its work at the end of 2002 by publishing a report that will be discussed in the government in connection with a climate policy to be published in the beginning of 2003.

The committee recommends that the first future offshore development take place at Horns Rev and points out that offshore wind farms are more stable power producers than turbines on land. Furthermore, the committee presents two scenarios for the economy of future offshore wind farms: with 3-MW wind turbines resulting in a production cost of 0.28 DKK/kWh to 0.34 DKK/kWh, and with 5-MW turbines for which the production cost is estimated to be 0.26 DKK/kWh to 0.31 DKK/kWh. Finally, the committee estimates that if the government decides to start the tendering in 2003, the next offshore wind farm in Denmark will be in place and grid-connected by 2007 at the earliest.

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Chapter 7
Finland

7.1 INTRODUCTION

In 2002, deployment of wind energy in Finland showed a new start after low growth years of 2000 and 2001. The production of wind energy was lower than in 2001 due to a very low wind year, according to wind indices. Series manufacturing of 1-megawatt (MW) wind turbines was started in Finland.

7.2 NATIONAL POLICY

Strategy

The Action Plan for Renewable Energy Sources was updated. The plan recognizes the Kyoto Protocol on the reduction of emissions of greenhouse gases of 1997 and the European Union (EU) White Paper endorsed by the Commission in 1997 and the Council in 1998, into targets for renewable energy deployment.

The target is to increase the use of renewable energy sources at least by 50% (3 Mtoe/a) by 2010 from the level in 1995. Ninety percent of this increase is expected to originate from bio-energy, 3% from wind power, 3% from hydro-power, 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 terawatt-hours (TWh) (2,010 megawatts [MW]) from the level in 1995. The major part, 75%, would be generated from bio-fuels. Achieving the targets would reduce greenhouse gas emissions by about 7.7 million tons of carbon dioxide equivalent. The vision for 2025 is an addition of 100% (6 Mtoe) of renewable energy from the level in 1995, with biomass still dominating but several percent 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 projected gross power consumption.

Progress Towards National Targets

During the review of the Action Plan for Renewable Energy, 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 an investment subsidy type of 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 on-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 be looked for. A working group established by the Ministry of Environment has set up a framework for planning and building permission procedures. The Åland islands between Finland and Sweden constitutes an autonomous region with its own legislation, budget, and energy policy. Wind energy deployment is steady and, related 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

Two 2-MW wind turbines were put into operation in 2002, bringing the total wind capacity to 41 MW by the end of the year. A further 7 MW, originally also due to be on line by the end of the year, were under construction. The gross wind energy production amounted to about 63 gigawatt-hours (GWh). This is about 10% less than production in 2001 and is due to a poorer-than-normal wind year. The development in capacity and gross production is presented in Figure 7.1.

Gross power consumption in 2002 is estimated to be about 81 terawatt-hours (TWh). Domestic production covered 90% of the electricity need. Wind stands thus for about 0.1% of the national consumption.

7.4 MARKET DEVELOPMENT AND STIMULATION

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 rate of 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 €/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

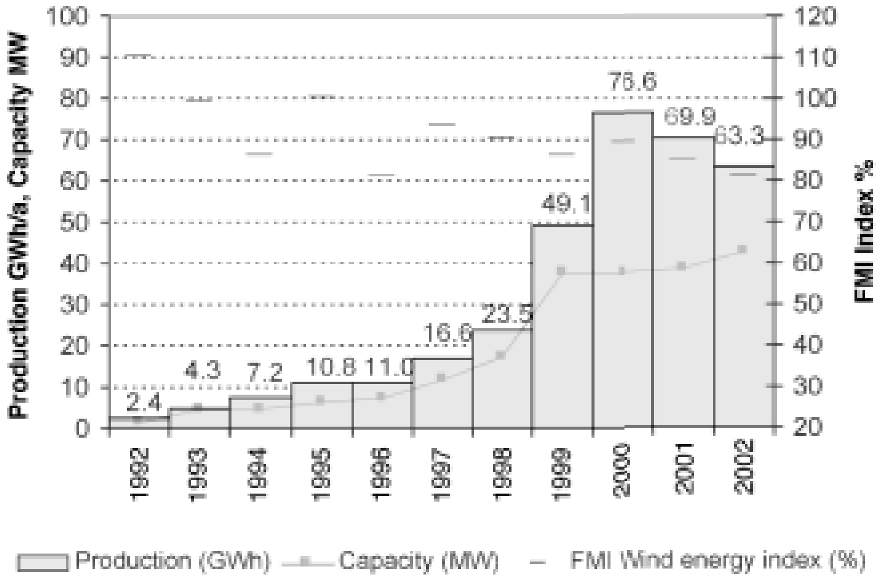

Figure 7.1 Development of wind energy production and installed capacity in Finland, 1992 to 2002

by publishing best-practice guides and handbooks. The Finnish Wind Energy Association is also actively promoting wind energy through seminars and political lobbying.

In the CLIMTECH-program, financed by the National Technology Agency (TEKES), the possibilities of various technologies for green-house gas emission reduction as well as new business opportunities were investigated in order to have guidelines for further support for the different technologies. Export prospects for the Finnish wind industry seem to be promising and can be supported by active support of both R&D and the domestic market. The contribution of wind energy to the reduction of greenhouse gas emissions depends on the rate deployment of wind energy, which is expected to take off in the latter part of this decade.

Unit Cost Reduction

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

An attempt was also made to analyze the development of operation and maintenance costs over the years. Trend lines could not be drawn because of the scarcity and large spread of the available data.

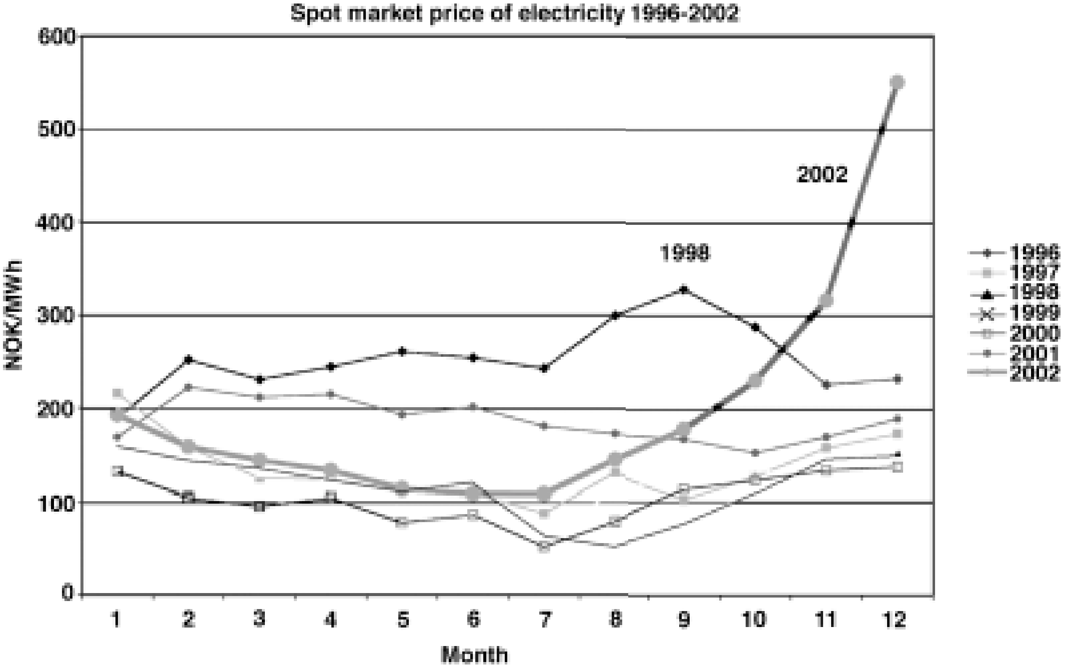

Figure 7.2 Export prospects of wind technology until 2010 for present product range and for a wider product range

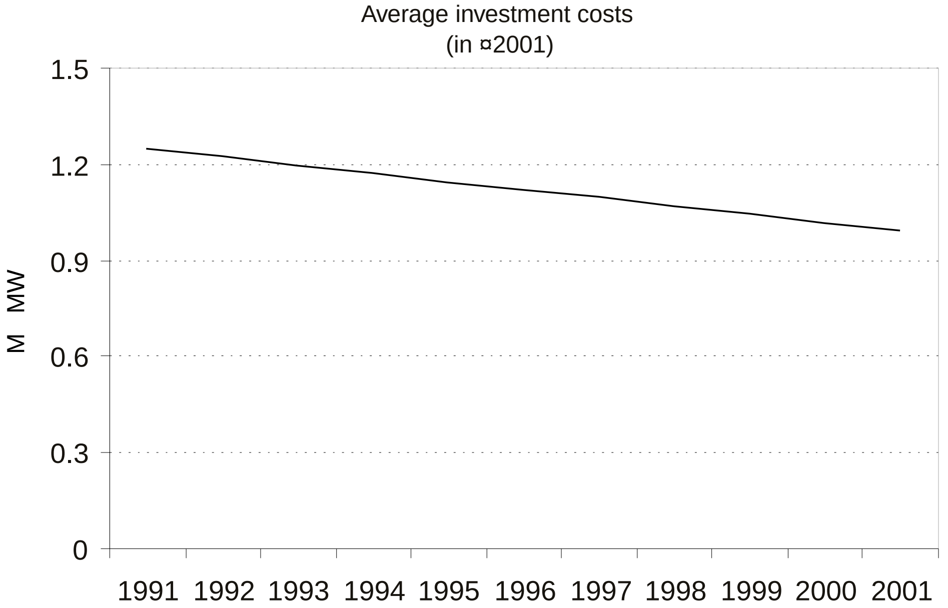

Figure 7.3 The development of average total installation costs of wind power plants in Finland, 1991 to 2001 (in 2001 Euros)

7.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Out of the 65 turbines now in operation in Finland one is from Finland, the rest are from Denmark and Germany. The most recent and largest wind turbines have for a long time been preferred, mainly due to difficult siting in the complex coastal landscape. The projects to be constructed in 2003 and 2003 use turbines with rated power from 1 MW to 2.5 MW.

Turbines installed in the harsh climate of northern Finland are protected with ice-preventive equipment. The same solution is tested at certain sites in southern Finland as a public safety concern due to occasional icing. Experience shows that the higher and the closer to sea the turbines are, the more prone they are to icing.

Operational Experience

In general the turbines operate satisfactorily. There are incidents of breakage in seals and bearings, but overall availability among the reporting turbines reaches about 95%. Gearbox failures accounted for about 50% of the down time during the past year. Turbines operating in extreme climates report higher down times.

Main Constraints on Market Development

The electricity market has been fully liberalized, down to the household consumers, since 1997. Thus all wind energy installations are "merchant" producers that have to find their customers on a competitive market. Current market prices are that low and, despite the quite substantial support, wind

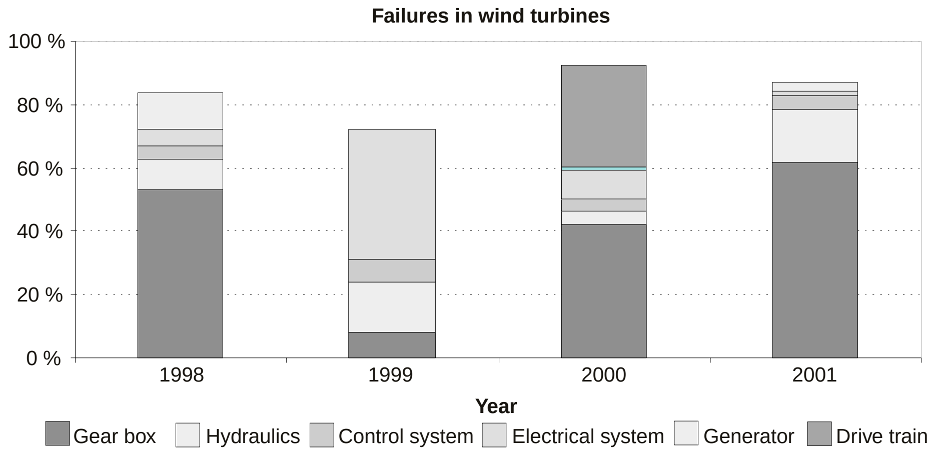

Figure 7.4 Development of down time due to failures in Finland, 1998 to 2001

energy can not yet compete with spot prices for electricity. Most turbines are owned by or operate in co-operation with a local utility to facilitate energy market access.

The transmission and distribution charges for distributed generation vary greatly 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, especially in relation to summer residents and vacation activities, might yet prove a significant obstacle to development.

7.6 ECONOMICS

At a good site on coastal Finland, the cost of wind energy production could be about 240.00 FIM/MWh to 250 FIM/MWh, including an investment subsidy.

As stated previously, 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 and at a price higher than the average household price. Market success for these initiatives has, however, been modest. Only a few percent of household consumers have changed electricity supplier 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. The aim is to develop the concept further into a 3.5-MW turbine for offshore applications. The next units of the 1-MW turbine are under construction and will be on line in spring 2003.

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 of this "sale of components" is estimated to be about 200 million € in 2002. The industry has been successful in supplying components for 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 been no national research program for wind energy. Individual projects can receive funding from the National Technology Development Agency (TEKES) according to the general priorities and requirements for technical R&D. Benefit to industry is stressed as is the industry's direct financial contribution to individual research projects. Priority is given to product development and the introduction of new products.

New development mainly comprises the new domestic turbine mentioned previously. The actual performance of the turbines installed has been followed both in terms of annual production and failure statistics and, in two cases, in more thorough measurement and follow-up 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 cooperative venture of research bodies and industry.

Some semi-offshore installations at "artificial" islands out of gravel in low waters 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 for new investments in fjell areas at the moment.

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Chapter 8
Germany

8.1 INTRODUCTION

The Deutsche Windenergie Institut (DEWI) collects most of the data presented in this report, which is based exclusively on manufacturers' information and therefore depends on their exactness and reliability.

8.2 NATIONAL POLICY

General national policy guidelines are fixed in the coalition agreement of the German government.

Strategy

One of the general goals in German energy policy is to double the share of renewable energy in the total electricity consumption until the year 2006, and wind energy is a major part of renewable energy. The federal government's goal for the erection of offshore wind turbines is to reach 500 MW by 2006 and 3,000 MW by 2010. The *Renewable Energy Sources Act*, or *Erneuerbare Energien Gesetz* (EEG) from 1 April 2000 will be adjusted to these goals.

8.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Support from the EEG and German wind turbine producers has grown for programs such as the 250-MW Program. By the end of December 2002, the number of installed wind turbines in Germany reached 13,759, with a total rated power of 12,001 MW. The number of turbines installed in 2002 was 2,328 with a total rated power of 3,247 MW (see Table 8.1).

The average rated power per wind turbine went up by 9% from 1,279 kW in 2001 to 1,395 kW in 2002. That means wind turbines

YEAR 2002	Total number of wind turbines	Total rated power [MW]
January	111	150
February	219	287
March	361	464
April	472	609
May	616	801
June	822	1,084
July	955	1,286
August	1,115	1,510
September	1,366	1,877
October	1,628	2,263
November	1,947	2,719
December	2,328	3,247

Table 8.1 Number of wind turbines and total rated power in Germany in 2002

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

Table 8.2 Total number of wind turbines and total installed rated power in Germany from 1989 to 2002

with a rated power of 1,500 kW or more reached a market share of 78% – these large turbines are therefore playing a dominating role in the German market. The trend towards larger wind turbines has continued in 2002.

The share of the calculated annual wind energy yield to the electric energy consumption of Germany was approximately 4.7% in 2002; in 2001, it was approximately 3%. This value reached approximately 29% in Schleswig-Holstein, 21% in Mecklenburg-Vorpommern, and 14% in Niedersachsen. Therefore, a considerable share of the electricity consumption is covered by wind power in the federal states in northern Germany.

8.4 MARKET DEVELOPMENT AND STIMULATION

Does not apply.

8.5 DEPLOYMENT AND CONSTRAINTS

With support from the German Ministry of Economics and Labour, ENERCON constructed the first 4.5-MW wind turbine in the world. It is named E-112 and was erected in August 2002 in a test site close to Magdeburg, with a 120-m high concrete tower. The generator cabin had to be mounted in several steps at the top of the tower due to its weight of 500 tons. Since October 2002, this wind turbine has been connected to the local grid.

Currently ENERCON investigates the behavior of the E-112 wind turbine, especially in comparison with existing computer simulations. A second wind turbine erection, close to Wilhelmshaven, is planned for 2003.

8.6 ECONOMICS

The German wind energy market annual turnover in 2002 is estimated to be more than 3.5 billion Euros.

8.7 INDUSTRY

Table 8.3 provides an overview of the market share of manufacturers in 2002.

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

Parameters such as hydrological, meteorological, oceanographic, physical, and environmental will be monitored at research platforms that are relevant for the construction of offshore wind plants and for the permission procedure of wind farms in the German Exclusive Economic Zone compatible with nature and the environment.

The first platform (information can be found at www.fino-offshore.de) will be located in the North Sea about 45 km north of the coast of the island Borkum, which has a water depth of 28 m, adjacent to the location of the first planned German pilot wind farm. Data will be collected before, during, and after wind farm installations.

A mast up to 101 m above sea level enables the measurement of wind profiles with anemometers and ultrasonic sensors. Four containers will house measuring equipment, living/working space and emergency accommodations, data storage, communication systems, batteries, radar equipment, and a diesel-generator set. A telescope-crane will be used to take seabed samples of the surroundings. The platform is equipped with a helicopter pad for maintenance operations. Measurements can be done fully by remote control.

The data collected will be transferred onshore by directional radio and are available publicly after validation by the contributing research institutes. In 2002, construction of

Manufacturer	Share of the total rated power [%]
ENERCON GmbH, Aurich	34.0
VESTAS Germany GmbH	17.8
GE Wind Energy GmbH, Salzbergen	13.1
NORDEX AG, Norderstedt	8.7
NEG Micon Germany GmbH, Ostenfeld	8.3
AN Windenergie GmbH, Bremen	7.0
Repower Systems AG, Hamburg	6.8
DeWind AG, Lübeck	2.4
Fuhrländer AG, Waigandshain	1.4
OTHERS	0.2

Table 8.3 Manufacturer shares of newly installed rated power

the platform started after a Europe-wide invitation of tenders for supplies. The platform is expected to begin operation in the summer of 2003.

Two offshore wind farms have been approved in Germany. In November 2001, the Federal Maritime and Hydrographic Agency (BSH) approved the pilot offshore wind farm, Borkum West. The Prokon West GmbH will erect 12 wind turbines approximately 45 km north of the island Borkum in a first step starting in 2004.

In December 2002, the BSH approved the Buergerwindpark Butendiek wind farm. Beginning in 2005, 80 3-MW wind turbines will be erected approximately 35 km west of the island Sylt.

Author: V. Monser, Forschungszentrum Jülich GmbH, Germany.

Chapter 9
Greece

9.1 NATIONAL POLICY

Strategy

Greece is one of the European countries possessing high wind energy potential. In spite of this, the deployment of wind energy technology has been slow. During the last two years, with enforcement of the Law 2773/99 (Liberalisation of the Electricity Market – Regulation of Energy Policy Issues and Other Provisions), the development of the wind energy technology has been speeded up.

Besides, it is among the aims of the government 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.

During 2002, the Regulatory Authority for Energy (RAE) approved an important number of applications for power production from wind energy, of 595 megawatts (MW) total installed capacity. More analytically, 407 MW have been approved for the interconnecting system of the mainland while 188 MW have been approved for the islands Evia, Andros, and Tinos, which are characterized by high wind potential. Especially for the area of Evia there is a great investment interest, although it is problematic, since the high wind power potential cannot be absorbed by the existing poor electrical infrastructure. Recently, with the approval of a study for the development of electrical energy transportation system and the involvement of a project for the development of high voltage electrical grid, 550 MW of installed wind capacity is planned to be accepted for installation in this region.

According to Law 2773/99, the Hellenic Transmission System Operator (HTSO) uses the wind energy produced in 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 as defined by the older Law 2244/94 in power until the 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 this price.

Progress Towards National Targets

A significant progress towards the development and growth of the wind energy sector has been achieved during past years in Greece. The installed capacity of wind turbines reached 355.4 MW at the end of 2002, fulfilling the target of 350 MW set by the Greek Ministry for Development. It is worthwhile to mention that in 1995 the total installed capacity was only 29 MW.
The Greek Ministry for Development set a new target for wind energy of more than 1,500 MW installed capacity for 2010, following European Union (EU) directions.

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

Figure 9.1 Nine-megawatt wind park at Skopies-Zarakes, Evia (Source: ROKAS AIOLIKI ZARAKES)

9.2 COMMERCIAL IMPLEMENTATION

Installed Capacity

In total, 70 WECS having an installed capacity of about 57.4 MW, concerning 10 separate projects, have been connected to the electricity supply network in 2002, bringing the total installed wind energy capacity to 355.4 MW (685 machines). The distribution of the installed wind energy capacity around Greece for the year 2002 is shown in Figure 9.2.

Rates and Trends in Deployment

Development of wind energy within the last 10 years is shown in Figure 9.3, where the total installed capacity per year is depicted.

Contribution to National Energy Demand

The energy produced from wind turbines during 2002 was approximately 650 GWh, while the energy produced in 2001, 2000, 1999, 1998 and 1997 was 756 GWh, 460 GWh, 160 GWh, 71 GWh, and 38 GWh, respectively. Total energy consumption in the country is on the order of 50 terawatt-hours (TWh), so the energy produced from wind turbines accounts for about 1.5% of the energy demand. For 2010 total energy consumption in the country is expected to reach 72 TWh. Figure 9.4 shows the electricity produced from wind turbines for the last ten years and the corresponding capacity factor.

9.3 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

Support for the development of wind energy projects was provided under the Operational Program Competitiveness (OPC). The Center for Renewable Energy Sources (CRES) acts as an intermediate agent in charge of the

Figure 9.2 Distribution of installed wind energy capacity around Greece in 2002

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 to be realized on the mainland and these with nominal capacity greater than 5 MW to be realized on the islands of Greece. The relevant budget is up to 650 million Euros (€).

According to the OPC, wind projects may be subsidized by 30% of the cost. An installation permit is necessary in order to finance a project. The eligible cost for financing a wind farm is up to 900 € per kilowatt (kW) without including the cost for the connection to the electrical grid. During 2002, 85 applications of 846.5 MW were submitted, of which 38 applications of 418.2 MW were approved. However, only four projects of 12.5 MW were finally contracted.

Unit Cost Reduction

No data are available.

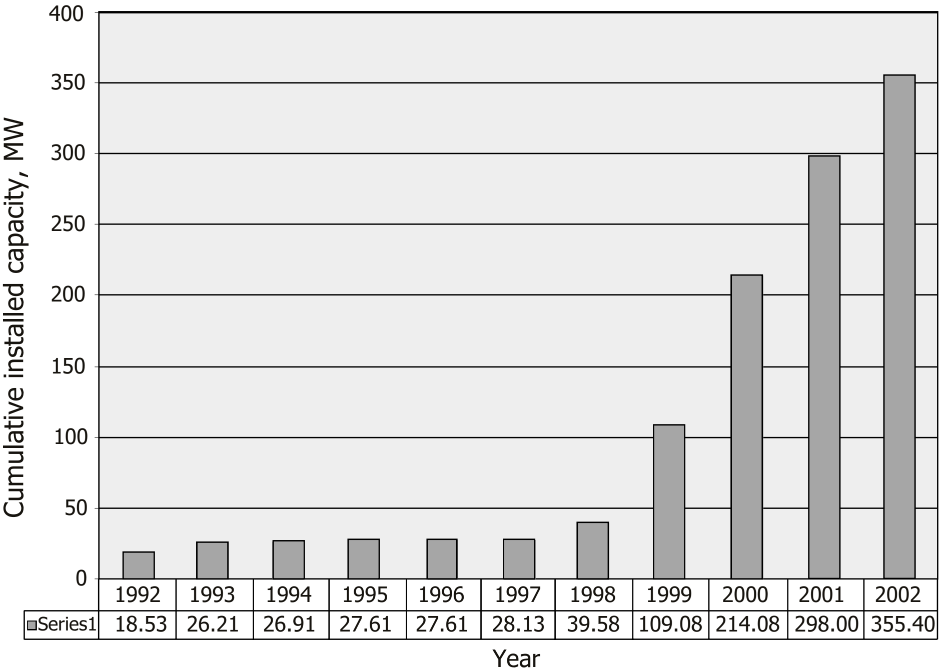


Figure 9.3 Cumulative installed wind capacity in Greece

9.4 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The average capacity of the wind turbines installed in 2002 was 814 kW, while the average capacity of all the wind turbines operating in the country is 518 kW. The market share per manufacturer is depicted in Figures 9.5 and 9.6.

Operational Experience

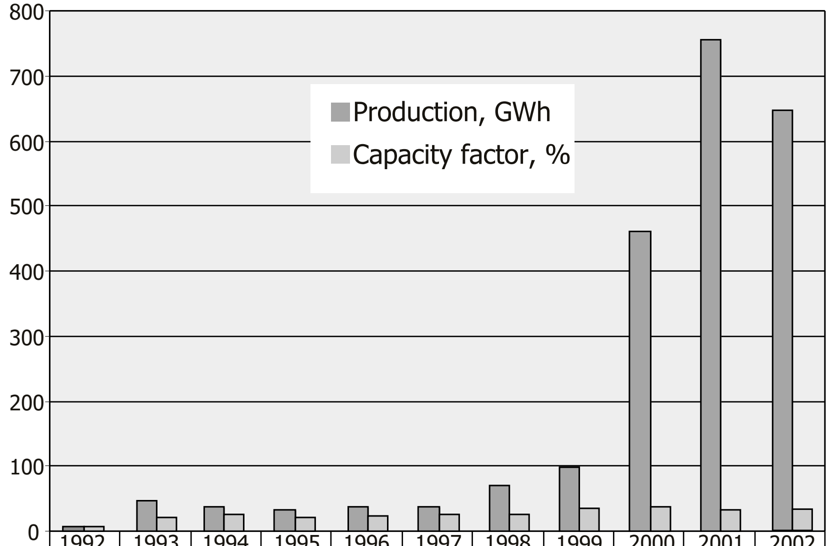
Due to the relative short period of operation of most of the wind energy projects, limited malfunctions have been reported since their commissioning. However, CRES has developed and continuously updates a database with related information for the operation and performance of all the wind parks around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

Main Constraints on Market Development

Complicated procedures for acquiring generation authorization and an electrical network that is inadequate to absorb the energy produced remain the two main constraints for the installation of new wind farms.

Trends in Investment

The total cost of wind power projects depends on the type of wind turbine, its size, and accessibility, and varies between 970 €/kW and 1,170 €/kW. Cost of generated wind power could be assumed to be between 0.026 €/kWh and 0.047 €/kWh, depending on the site and project cost. The typical interest rate for financing wind energy projects is on the order of 7% to 8%.



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Production	8.00	46.00	37.00	33.40	37.20	38.10	71.00	98.00	460.00	756.00	650.00
Capacity factor	7	21.4	24.8	21.8	24.3	24.3	26.8	34.9	37.1	33.5	31

Year

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

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 today's 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.

The following selling tariffs for low and medium voltage have been valid since July 2002.

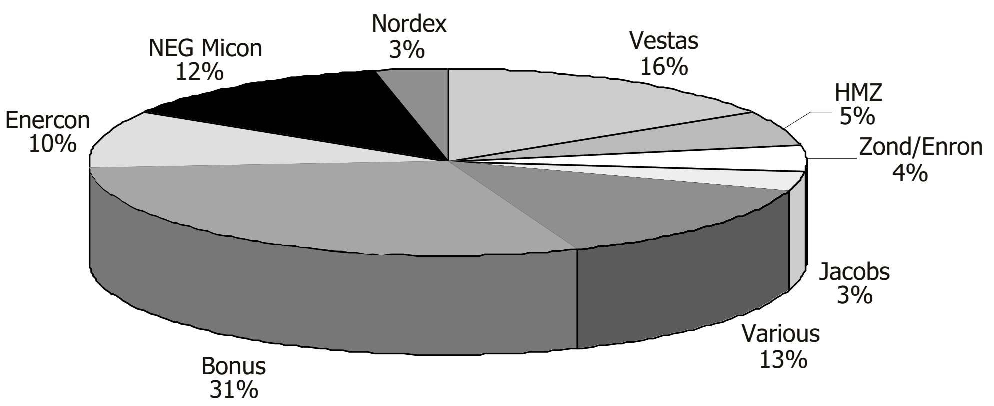


Figure 9.5 Market share of wind turbine manufacturers (as a percentage of number of wind turbines)

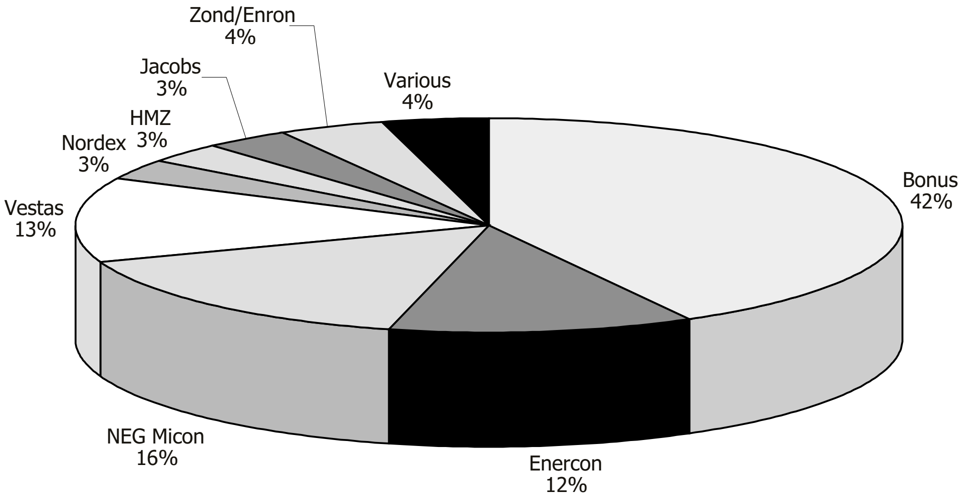


Figure 9.6 Market share of wind turbine manufacturers (as a percentage of installed capacity of wind turbines)

- Low voltage: 0.08643 €/kWh
- Medium voltage: 0.06991 €/kWh and 3.2305 €/kW (peak power value)

The purchase prices defined by HTSO for renewable energies are based on the actual selling price.

For the interconnected grid, the tariffs have two components: energy and power (capacity credit). The energy component is set at 90% of the medium-voltage tariffs, i.e., 0.06292 €/kWh, while the power component is set at 50% of the respective PPC's power charge, i.e., 1.61525 €/kW x P/2 where P is the maximum measured power production over the billing period. For the autonomous island grids, the tariff is set at 90% of the low-voltage tariffs, i.e., 0.07779 €/kWh. The Ministry of Development has the right to ask the producers for discount on these prices.

9.5 INDUSTRY

Manufacturing

Concerning the Greek wind industry, there is no significant development except for a couple of small wind turbine manufacturers in a typical range of 1.0 kW to 5.0 kW. However, an important involvement by the Greek steel industry, manufacturing the tubular towers of the wind turbines, has been considered. A Greek company that has been involved in blade manufacturing has not yet managed to commercialize its products.

Certification

In Greece, installation permission is required for the installation of a wind turbine of more than 20 kW installed capacity. With the new law entitled "Procedures for the Installation and Production Permits," a type approval certificate along with a power quality certificate for each wind park is needed.

The Center for Renewable Energy Sources is, by law, the certifying authority for wind turbines in Greece and is responsible for issuing the two certificates just mentioned.

Until now, CRES has been accepting type certificates and reports of the measurements of the power quality issued by authorized institutions (such as Germanischer Lloyds 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
- 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 2002, active involvement in the conduct of IEC TC-88, CLC/BTTF83-2 and its working groups was continued.

9.6 GOVERNMENT-SPONSORED R,D&D

Priorities and New R&D Developments

The Ministry for Development promotes all research and development (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 are wind assessment and characterization, standards and certification, development of wind turbines, aerodynamics, structural loads, blade testing, noise, power quality, wind desalination, and integration in autonomous power systems. There is limited activity in Greece concerning MW-size wind turbines or offshore deployment.

A project for the development of a 450-kW wind turbine was initiated within the framework of the EPET-II National Programme in 1995. The project was aiming at both the development of a 450-kW variable-speed, stall-regulated wind turbine and the development of blade manufacturing technology. The assembly of the prototype concluded in 2000. It was installed at the test site at the beginning of May 2001, and the connection to the electrical grid was completed at the end of 2002. The measurement equipment for the commissioning tests has been installed, and the tests are planned to take place during 2003.

CRES is the national organization for the promotion of renewable energies 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, and wind assessment and integration. CRES has developed and operates a laboratory with advanced blade testing facilities for static, dynamic, or fatigue testing of blades up to 25 meters (m) long. The blade testing laboratory has been accredited under the terms of ISO/IEC 17025:2000 standard.

CRES wind-diesel hybrid laboratory system, which simulates small autonomous grid operation common in the islands of the Aegean Sea, is effectively used in optimizing the integration of the renewable energies in such systems. Also, CRES in co-operation with the Greek market has designed and developed a pilot autonomous hybrid (W/T, PV) reverse osmosis system for seawater desalination, within the National Programme PAVET, of the Greek Ministry for Development, Third Framework Programme, for further research on technologies coupling. The system has been installed at CRES Wind Park at Lavrio, Attiki.

Several research projects were running or initiated at CRES during 2002, cofunded by DGXII and GSRT (the Greek Secretariat for Research and Technology) aiming at the following goals.

- 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 in such environments. In that direction, new techniques are under development for power-curve measurement of wind turbines operating in complex terrain and developing wind turbines for installation in hostile environments with poor infrastructure
- Improving the damping characteristics of wind turbine blades
- Developing new techniques for power quality measurement and assessment
- Contributing know-how to wind turbine standardization procedures
- Developing blade-testing techniques within the in-house experimental facility
- Understanding generic aerodynamic performance of wind turbine blades through computational fluid dynamics (CFD) techniques
- Developing cost-effective micro-siting techniques for complex terrain topographies

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, namely in rotor aerodynamics and wind energy integration in the electrical grid. The Fluids Section of the Mechanical Engineering Department of the NTUA is active in the fields of wind modeling, rotor aerodynamics, load calculation, fatigue analysis, noise, and wind farm design. Work conducted during 2002 concerned 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. In 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 allowing the simulation of complete 10-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 as regards roughness sensitivity and stall behavior. Application of this procedure was carried out for MW-scaled machines within a CEU-funded project. Extension of the optimization procedure to the case of pitch and variable-speed machines has been initiated, aiming at an improved design of the new very 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 2002 the Electric Power Division of NTUA continued its research on issues related to 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 in the integration of wind power into the 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 because of 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.

The work on MORE CARE, the advanced control system comprising load and wind power forecasting, unit commitment, and economic dispatch and on-line dynamic security assessment modules integrated within a friendly person-machine interface, has been continued. 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 for the simulation of the effect of most common wind turbine types on the steady-state and dynamic performance of weak grids has been developed. 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 the operation of the distribution grids, and the planning of distribution networks in areas with high potential for dispersed generation. Particular emphasis is placed on the development of MicroGrids comprising low-voltage grids with increased dispersed generation.

Work on the control of variable-speed wind turbines concentrated mostly on small machines in order to reduce mechanical stresses and achieve a more "grid-friendly" operation (improved power quality and 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.

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

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

The University of Patras has successfully completed structural designs for a series of GRP rotor blades ranging from 4.5 m to 20 m, verification of which was performed by full-scale static, fatigue, and modal tests at a CRES blade-testing laboratory.

In the framework of the JOULE-III program, UP as subcontractor to CRES has participated in and successfully completed several projects, such as "AEGIS-Acoustic Emission Proof Testing and Damage Assessment of W/T Blades" and "ADAPTURB: Adaptation of Existing Wind Turbines for Operation on High Wind Speed Complex Terrain Sites; kWh Cost Reduction." During 2002, UP contributed to the following three research projects funded by EC.

- "DAMPBLADE: Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites"
- "MEGAWIND: Development of a MW Scale Wind Turbine for High Wind Complex Terrain Sites"
- "OPTIMAT BLADES: Reliable Optimal Use of Materials for Wind Turbine Rotor Blades"

In DAMPBLADE, UP is contributing with experimental characterization of anisotropic damping properties, development of a dedicated FEM code for efficient damping modeling of composite structures, and, finally, 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 of a prototype under development by Geobiologiki SA. In the OPTIMAT BLADES project, UP is a task group leader in investigating blade material behavior under complex stress states in which the effect of multi-axial static and cyclic loading on strength and life of composite laminates is to be assessed. Results will be available in the form of design guidelines for rotor blade manufacturers.

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

9.7 DEMONSTRATION

The main demonstration programs in wind energy currently under way in Greece are financed within the framework of the Thermie program of the EU and the National Operational Program of Energy. The following demonstration projects were ongoing in 2002.

1. Large advanced autonomous wind/diesel/battery power supply system in Kythnos (THERMIE program).

The aim of this project is the demonstration of the technical feasibility of the integration of a very high penetration of wind energy in large supply systems. This large modular system for the island of Kythnos is designed for the combination of diesel generator sets, battery storage, rotating phase shifter, five small wind energy converters, and one additional large wind energy converter. This large wind energy converter with a power output of 500 kW will supply a great portion of the power demand. It will be the first time that such a high portion of more than 50% of the energy demand is realized by wind turbines, and due to this the diesel generators can be totally stopped when the power output of the wind turbines is sufficient.

The wind turbine was erected in mid-1998 and the commissioning was completed during 2000. High wind penetration reaching even 100% has been achieved, while the system is still in trial operation.

Furthermore the already existing PV system with a nominal power of 100 kW, as well as the existing five energy converters of type Aeroman (with 33-kW rated capacity each) will be integrated into the wind/diesel/battery system. The project is being carried out from PPC and SMA.

Following are the most important advantages achieved during the system's operation.

- Demand under specific conditions can be covered totally by RES
- Great reliability of the system
- Improvement of grid stability and consequently the quality of the power supply
- Decrease in the operational cost of the diesel gensets.

2. CRES 3.1-MW wind farm in complex terrain (National Operational Program of Energy).

CRES's demonstration wind farm is located just near the Wind Turbine Test Station in Lavrio. The purpose of the project is to study the effects of complex topography on the performance of the wind turbines as well as of the overall wind farm. It consists of five different medium-sized wind turbines with distinguished design aspects: a 500-kW gearless synchronous multipole wind turbine generator Enercon E40, a 750-kW stall-regulated induction wind turbine NEG Micon 750/48, a 660-kW pitch-regulated induction wind turbine Vestas V47, and two variable-speed-stall AC/DC/AC wind turbine generators of 500 kW and 600 kW each, both developed in Greece and manufactured by PYRKAL S/A.

The first three machines were erected in 2000 and the electrical infrastructure and commissioning were completed in January 2001. Since then the three machines have been in continuous operation. The two variable-speed-stall generators manufactured by PYRKAL S/A have been installed. Their electrical infrastructure and commissioning are under way.

Among the five HAWTs, three are commercially available machines and the other two are Greek prototypes. The last ones use an advanced variable-speed technique (OPSC®: Opti Power Speed Control) together with stall-designed blades. The electricity is fed to the grid via an active line inverter. The other three commercial turbines are a stall-controlled turbine with an asynchronous generator, a pitch-controlled turbine also with an asynchronous generator, and a pitch-controlled, variable-speed, direct-drive turbine with a synchronous generator. Finally, the wind farm comprises two meteorological masts (100 m and 40 m), which are used to measure the reference wind conditions.

To investigate how the different design concepts perform at this specific complex-terrain wind park, it was necessary to develop one single monitoring program that continuously stores, in a common way, the operation of each turbine. This was realized using a home-developed software, based on the communication protocol, which was provided by each turbine manufacturer. Similarly, the total produced power, fed to the 20-kilovolt (kV) grid, is monitored at the main circuit breaker of the wind park.

A feature of the monitoring software worth noting is its ability to periodically update the contents of an Internet site, presenting the latest operational data of the wind park. Figure 9.7 presents the typical contribution of each turbine to the total power. Finally, the monthly production of the year 2002 is shown in Figure 9.8.

No offshore wind farms were installed.

Authors: E. Tzen , K. Rossis, and P. Vionis, CRES, Greece.

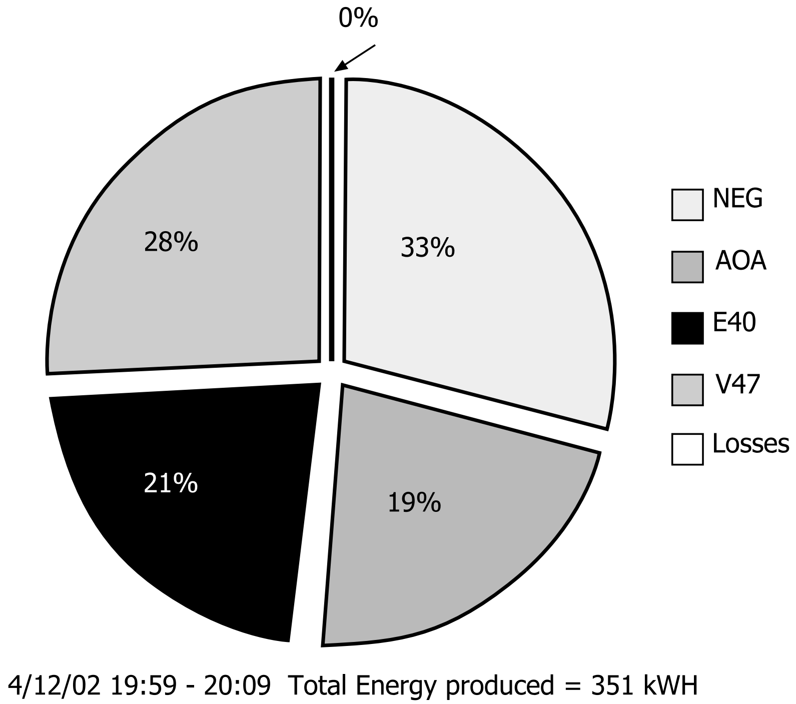


Figure 9.7 Typical contribution of each turbine to total power

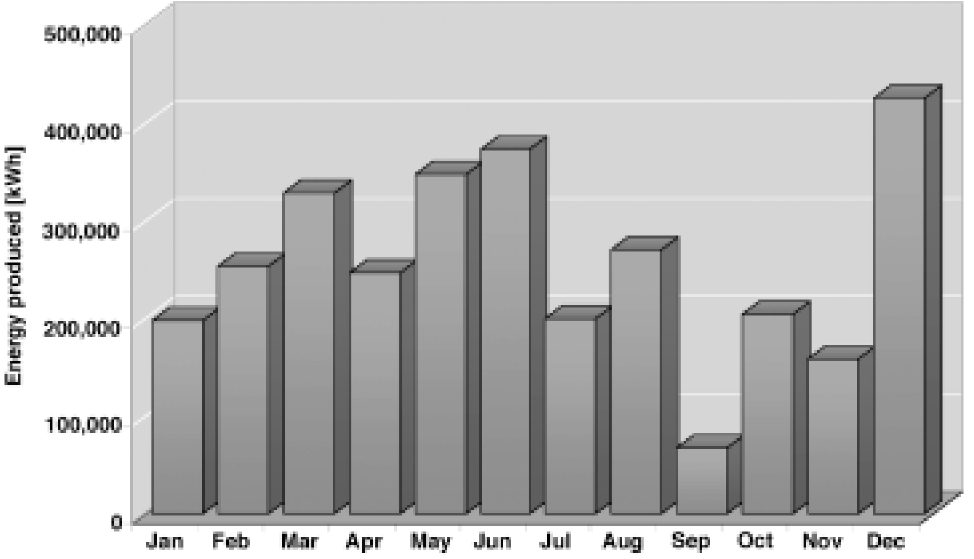


Figure 9.8 Monthly production of CRES wind park in 2002

Chapter 10
Ireland

10.1 INTRODUCTION

Ireland benefits from having one of the most favorable wind regimes in Europe for wind energy generation. Average wind speeds on many upland west coast onshore potential wind farm sites exceed 8.5 meters per second (m/s) at 50 meters. Several successful pilot-scale projects in the 1980s gave promising results but were not followed by larger-scale developments.

From the late 1980s an obligation was placed upon the then state monopoly vertically integrated electricity company, ESB, to purchase renewable electricity, which effectively amounted to a feed-in tariff. In 1995 the first government price support scheme for renewable electricity was introduced, replacing the earlier scheme. This was known as the Alternative Energy Requirement, or AER 1, and, through a competitive tendering process, 15-year fixed-price power purchase agreements were awarded. There have now been a total of three programs that offered contracts for wind power projects. AER 1 in 1996 authorized contracts for wind generation capacity totaling 30 megawatts (MW). AER 3 in 1999 authorized contracts totaling 90 MW for wind power projects and, in February 2002, AER 5 was announced, authorizing a total of 353 MW of generating capacity from wind power. A total of 137.7 MW of grid-connected wind energy generating capacity was installed as of the end of December 2002.

The Electricity Regulation Act of 1999 initiated the process of electricity market liberalization in Ireland, and the completion of the deregulation process is planned for 2005. Renewable electricity suppliers have been granted full access to all customers since market opening. The market for green electricity in Ireland is at an early stage of development, with a single major supplier marketing electricity from renewable sources. Virtually no wind farms other those developed by this supplier trade their electricity on the open market, opting instead for the security of the government price support schemes.

10.2 NATIONAL POLICY

Strategy

Government strategy on renewable energy in Ireland is laid out in the Green Paper on Renewable Energy of 1999 and the National Climate Change Strategy of 2000. In these, a target of an additional 500 MW of installed renewable electricity generating capacity in the period 2000 to 2005 was set. Ireland is also committed to an indicative target, within EU Directive 2001/77/EC, of increasing electricity consumption from renewable sources to 13.2% of total demand by 2010. It is recognized that wind energy will make the greatest contribution to achieving the 2005 target and will also represent a large portion of the 2010 target.

Progress Towards National Targets

The early rounds of competitive tenders had low success rates in actual deployments. Planning approval was identified as a key factor, and it was therefore made a pre-condition of the AER 5 competition of 2001 to 2002 that planning approval should be obtained prior to applying. However, as the industry grew, developers became accustomed to submitting more sophisticated proposals in line with planning requirements, and many planning authorities adapted the planning guidelines and local development plans to include wind energy project considerations. This is a continually evolving process as the size and nature of wind turbines and wind farms develops. The implementation of national planning guidelines at a local level is not necessarily uniform.

However, planning approval will not present a primary constraint to the achievement of 2005 targets. There is currently planning approval for wind farms with generating capacity totaling 850 MW that are awaiting development. Also, current planning applications being processed for wind farms total over 1,000 MW generating capacity, and the average success rate of wind farm applications to date has been 65%. Nevertheless, the treatment of wind energy within the planning system continues to be a focus of attention for the wind industry, and there is a continued effort to provide planning authorities with the information, training, and tools to allow an unbiased evaluation of wind project planning applications.

There was no significant progress in 2002 towards achieving the 2005 national target of 500 MW of renewable generation in addition to that installed in 1999. The installation rate has been reduced to about 10 MW per year, whereas ten times this amount is required to meet targets. An average of 170 MW will have to be installed in each of the years 2003, 2004, and 2005 to compensate for the low installation rate since 1999. A complete review of the renewable electricity price support mechanism will be carried out in 2003 as detailed below.

10.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

A total of 137.7 MW grid-connected wind generation capacity was operational as of the end of 2002. One large project scheduled for completion in 2002 was delayed due to difficulties with the provision of grid connection. The public service obligation (PSO) order, for the purchase of renewable electricity supported by AER 5, was issued by government to the single public electricity supply franchise holder in November 2002. This was required in order for construction to proceed on many of the projects that won contracts.

Rates and Trends in Deployment

In 2002, 11.9 MW of new grid-connected wind power was installed, and a single 0.67-MW off-grid installation for an island desalination plant was also commissioned in this year. This was a small increase on the 2001 figure of 9 MW of new capacity but is still lower than previous peak annual installation rates, which have exceeded 30 MW. Details of the upcoming AER 6 tender round were announced towards the end of 2002. In order to address the low uptake of AER 5 contracts, projects awarded contracts under that tendering round will be allowed to compete for new contracts in AER 6. The AER 6 tendering round will have more favorable price caps and contract terms.

Contribution to National Energy Demand

The estimated contribution from wind power to national electricity demand in the year 2002 was 426 gigawatt-hours (GWh). This represents a 27.5% increase on 2001 production. A preliminary estimate for the total electricity demand in Ireland in 2002 is 24,695 GWh, a decrease of 1% on 2001. The percentage contribution of grid-connected wind power to gross national electricity demand was therefore 1.7%.

10.4 MARKET DEVELOPMENT AND STIMULATION

Support Initiatives and Market Stimulation Incentives

As outlined in the introduction, the primary market support mechanism is the Alternative Energy Requirement (AER) scheme, through which price support contracts with a 15-year term are awarded to renewable electricity generators in regular competitive tender rounds. The scheme has been in place since 1996. The AER 6 tender round announced in November 2002 will be the last in this scheme, as it will allocate the remaining generating capacity for which EU state aids approval has been obtained. Consultation with the industry on the design of a new support scheme to succeed AER will be embarked upon in 2003.

In the liberalization of the electricity market in Ireland, 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 a "green" electricity supplier, rather than that for each half-hour metering and trading period. One renewable electricity supplier, Airtricity, has been successful in developing a renewable electricity market and is also involved with the development and operation of wind farms. However, few other wind farm owners have opted to sell generated electricity within the deregulated electricity market, as the guaranteed term of the government price support scheme is the best vehicle for attracting financing. Also, the base level price or "spill price," which non-dispatchable electricity generators can command, when selling their electricity within the electricity market without a supply contract, is currently considered too low to be viable. The independent electricity supply market is as yet in the early stages of development, with few relationships formed between renewable electricity generators and independent suppliers.

The main fiscal incentives, from which investors in wind farm projects can benefit, are (a) the Business Expansion Scheme (BES) and (b), tax relief under Section 486b of the 1998 Finance Act, on capital directly invested in wind farm assets. Under (a), 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 Euro and is thus of limited value to larger wind energy projects. Under (b), corporate investors in renewable energy projects can claim tax relief on equity investment in capital assets. As the corporate tax rate will be reduced to 12.5% in coming years, this fiscal incentive will hold limited attraction in the future. A 2002 amendment to the Finance Act also restricted eligibility for tax relief on capital assets, and this measure effectively eliminated a commonly used investment vehicle for private investment in wind farms.

10.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The number of operational grid-connected wind turbines in Ireland at the end of 2002 was 226. The size of operational wind turbines ranges from 225 kilowatts (kW) to 1.65 MW. The largest wind farm currently operational is 15 MW. The average size of grid-connected wind turbines deployed in Ireland in 2002 was 850 kW. A wind farm with 10 Nordex 2.5-MW wind turbines is currently under construction and to be commissioned early in 2003. When completed, this will be the largest wind farm and have the largest wind turbine deployed in Ireland to date.

Operational Experience

Due to competition for the award of supply contracts, developers consider operational data for wind farms to be commercially sensitive, and consequently no national statistics have been compiled on turbine availability or failure rates. There is currently no representative body of wind turbine users in Ireland, and the absence of a mechanism by which the market can ensure minimum standards of service from turbine manufacturers is seen as a weakness that could compromise long-term development of the wind industry. It is therefore a priority for Sustainable Energy Ireland to stimulate the formation of an Irish wind turbine users' group and monitoring program in 2003.

Main Constraint on Market Development
In past years, planning difficulties placed a major constraint on the development of the nascent wind power industry. However, education of both planners and project developers, particularly relating to planning requirements for wind farms, has removed planning permits for wind farm construction as a primary constraint upon development. There is now a substantial reserve of wind farm sites with planning permission awaiting development. There still remain some particular difficulties relating to stringent planning and environmental impact assessment requirements, local issues, and planning for electrical power lines for grid connection.

The availability of grid connections, in particular for larger wind farms, is likely to emerge as a further primary constraint upon the rate of development of the wind power generating industry in Ireland in coming years. High economic growth rates in the late 1990s and consequent high growth in electricity consumption outpaced electricity infrastructure development, and the national electricity grid is now operating outside of transmission planning standards in many areas (ESB National Grid [2001], *Forecast statement2001/2 –2007/8*, page 19). Studies by the Transmission Grid Operator have indicated that there are few areas where new generation can be connected without major reinforcement. The lead times associated with grid reinforcement work may preclude large wind farms being connected within a time scale that allows national renewable electricity targets to be met. A program to provide grid upgrades, specifically for the connection of clusters of renewable energy projects, has been initiated by government but has not yet been implemented.

Other constraints on development have been low "spill" prices available within the electricity market and the slow rate of development of a green electricity market sector. The competitive tendering market support system has also been argued to constrain development, as it assigns capacity in discrete blocks and has a long lag time in receiving feedback on its effectiveness. The market support system for renewable energy in Ireland will be subject to a complete review in 2003.

10.6 ECONOMICS

Trends in Investment

Due to the competitive nature of the price support scheme for wind power, construction costs are considered to be confidential and there is difficulty in obtaining accurate detailed breakdowns of these. However, indicative average total costs for onshore wind farm construction for 2002 are in the range of 900 to 1,100 Euro per kilowatt installed (Sustainable Energy Ireland [2002], *Renewable Energy Research, Development* *and Demonstration Strategy,* page 16). Wind turbine and tower costs average approximately 80% of total project costs. Costs for off-site grid connection assets generally fall within the range of 60 to 200 Euro per kilowatt connected, with the average at 100 Euro/kW. Annual operating and maintenance costs are estimated at 5.5% of project capital costs. As no offshore wind energy projects have yet been built, there are no confirmed costs for this sector of the industry. Estimated costs for developments in Irish coastal waters range from 1,270 to 2,050 Euro per kilowatt installed (Sustainable Energy Ireland [2002], *Cost Benefit Analysis of Government Support Options for Offshore Wind Energy,* page 41.) The costs for such developments are highly sensitive to project scale.

Trends in Cost of Energy and Buy-Back Prices

The 1995 bid price for AER contracts was 0.051 Euro/kWh; the 1998 weighted-average bid price for AER 3 contracts was 0.035 Euro/kWh. In 2000 the weighted-average bid price for large-scale wind energy projects in AER 5 was 0.048 Euro/kWh; for small-scale wind energy projects it was 0.0525 Euro/kWh. When consideration is given to the fully index-linked increases in buy-back prices for AER 1 and AER 3 projects, compared with 25% indexed prices for AER 5 and considering that grant assistance was available for project construction under the earlier schemes, a general trend downward in the buy-back price can be inferred. However, the low uptake rate of AER 3 and AER 5 contracts may indicate that the highly competitive nature of the scheme may be counterproductive and is hindering the growth of a wind power industry.

As the majority of wholesale electricity in Ireland is traded through bilateral contracts, average wholesale prices for comparison to wind power are unobtainable. 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 0.0441 Euro/kWh in 2002. Wind power, with generating costs in Ireland ranging from 0.003/kWh to 0.006Euro/kWh (Sustainable Energy Ireland [2002], *Renewable Energy Research, Development and Demonstration Strategy,* page 16), compares favorably with it. The other benchmark price, which can be used for comparison, is the 110-kilovolt (kV) maximum demand public electricity supply tariff, which, in 2002, was on average 0.0537 Euro/kWh.

In November 2002, a government announcement was made on the sixth and final round of the AER program. Price supports of 0.05742 Euro/kWh for projects smaller than 5 MW and 0.05216 Euro/kWh for those larger were announced. Also included was a category for offshore wind farms to a total capacity of 50 MW with an indicative price cap of 0.084 Euro/kWh. The price support scheme is to be redesigned in consultation with the industry after AER 6.

10.7 INDUSTRY

Manufacturing

There is no significant wind turbine manufacturing industry in Ireland. All of the grid-connected wind turbines currently deployed in Ireland have been imported. The late development of the wind sector of the electricity generating industry in Ireland left indigenous technology developers without a home market in which turbines might be piloted. Some industrial research and development work is currently being carried out on manufacturing technologies for specific wind turbine components. At this stage of industry development, the more likely manner for full-scale turbine manufacture to be initiated in Ireland is through one of the larger turbine manufacturers locating a subsidiary in Ireland to serve a local market.

Industry Development and Structure

Not applicable.

Export Potential

Not applicable.

10.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Prior to 2002 the majority of R,D&D effort in renewable energy in Ireland was sponsored through EU programs such as Joule, Thermie, and Energie. The 1999 Green Paper on Sustainable Energy 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 which 16 million Euro is specifically allocated to renewable energy research, while other parts of the program also contain renewable energy elements. Priorities identified within the Green Paper were techniques for assessing the wind regime on land-based sites and their adaptation to Irish conditions and site evaluation techniques for offshore wind farms.

New R,D&D Developments

In August 2002 Sustainable Energy Ireland launched the Renewable Energy R,D&D program outlined in Section 10.8.1. The focus of the program is to stimulate the application and further deployment of renewable energies, particularly those close to market viability. That could include measures to stimulate the development of the technologies and produce implementation plans for those with economic potential. The primary objectives are to remove barriers to the deployment of renewable energy technologies and help stimulate the development an Irish renewable energy industry.

The Renewable Energy Research, Development and Deployment program, with a budget of 16 million Euro, will give priority to supporting the following work.

- Research aimed at developing policy options for enhanced deployment
- Research to define the market structure for renewable energy technologies with high penetration potential
- Research aimed at cost reduction, improved reliability, and/or opening new markets
- Demonstration of non-technical innovation
- Feasibility studies for renewable energy projects
- Demonstration aimed at high-risk, high-reward projects
- Investigation into core areas, common to many renewable technologies, such as the electricity system, regulation, technical standards, fiscal and support measures, finance, markets, planning, and policy.

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

For offshore wind energy, key priorities are assessment of government support mechanisms, assessments of wind farm construction costs in Irish waters, assessment of the environmental impacts of offshore wind farms, resource prediction, and energy storage.

References:
ESB National Grid (2001), Forecast statement2001/2 –2007/8, Page 19.
Sustainable Energy Ireland (2002), Renewable Energy Research, Development and Demonstration Strategy, Page 16.
Sustainable Energy Ireland (2002) Cost Benefit Analysis of Government Support Options for Offshore Wind Energy, Page 41.
Sustainable Energy Ireland (2002), Renewable Energy Research, Development and Demonstration Strategy, Page 16.

Author: John McCann, Sustainable Energy Ireland, Ireland.

Chapter 11
Italy

11.1 INTRODUCTION

Although 2001 was a good year for wind plant deployment, this unfortunately was not the case for 2002. In fact, at the end of December 2002, cumulative wind capacity reached 788 MW, with only 106 MW of new plants installed since January 2002. Two main reasons could explain this result. The first reason is the difficulty that exists in dealing with a new incentive scheme based on green certificates. The second reason is in part composed of a strong battle by a minority of environmentalists against the installation of wind turbines on the mountains (due to visual impact) and in part due to uncertainty and aversion on behalf of regional authorities in at least two regions.

An agreement between the Ministries for Culture, Environment, and Productive Activities and the Conferenza delle Regioni for supporting wind energy deployment and its proper insertion into the landscape should improve and speed up the authorization process. However, so far only the Ministry of the Environment has approved the agreement, and the other approvals are expected soon.

11.2 NATIONAL POLICY

Strategy

The Italian parliament, through Law 120 of 1 June 2002, ratified the *Kyoto Protocol on Climate Changes*. The Ministry of the Environment implemented a *National Plan for Greenhouse Gas Reduction*, approved by the Interministerial Committee for Economic Planning (CIPE) in December 2002, aimed at complying with the planned objectives on gas emissions. In August 2002, CIPE approved another document issued by the Ministry of the Environment: *Environmental Action Strategy for Sustainable Development*. On the basis of these CIPE resolutions, the actions, tools, targets, and monitoring aspects of the *National Plan for Greenhouse Gas Reduction* and the *Environmental Action Strategy for Sustainable Development* will be updated. In this context, the role played by the regions is decisive, including implementation of the energy-environmental plans that should support renewable energy sources.

The Italian white paper for the exploitation of renewable energy sources (RES), approved by CIPE in August 1999, establishes that the annual amount of electricity produced by renewables should increase from 10.2 Mtep in 1997 to 16.7 Mtep from 2008 to 2010, corresponding to 75 TWh per year. An additional 11 TWh could be added to the reference value. In addition, the *European Directive 2001/77/CE*, which will be considered the reference document, sets as an indicative target that the electrical energy generated by RES should increase from 16% of the total internal gross electricity consumption in 1997 to 25% in 2010.

In accordance with *European Union Directive 96/92 EU* on the liberalization of the electricity market, the restructuring of the domestic energy sector is in progress.

In March 1999, *Legislative Decree 79/99* was issued, which fixed new rules in the national electricity sector. An important aspect of this decree is the obligation of a percentage of electrical energy produced or imported annually from conventional sources (beginning at 2%) to be generated from RES the subsequent year. This decree foresees a change in the system of stimulation and exploitation of renewable energy sources.

Pursuant to this provision in November 1999, a specific decree introduced a new support system based on the green certificate mechanism. This new system, actually in force from the beginning of 2002, should provide a satisfactory replacement to the previous system based on buy-back prices. Electricity produced by RES is labeled with green certificates issued by the Italian Independent System Operator (GRTN), which manages the electricity transmission grid; the green certificates are tradable.

In the summer of 2002, the government approved a draft law on restructuring and reform of the energy sector, prepared by the Ministry for Productive Activities and then passed it to the parliament, where it is now under discussion. Article 22 of the law is devoted to the increase of the mandatory quota of electrical energy from renewables. From 2005 through 2012, the electricity quota produced by renewables that must be put into the national electric grid is increased each year by 0.35%.

Beginning in 2003, subjects that have not fulfilled the quota obligation, now 2%, will be fined one-and-a-half times the money that would have been necessary for acquiring the amount of green certificates corresponding to the obligation for the previous year. The reference unit price for calculating the penalties is the maximum price of green certificates on the market the previous year, or, if more expensive, the price of green certificates issued by the GRTN. The revenues of such penalties will be credited to the account for new renewable and assimilated plants.

Progress Towards National Targets

According to Italy's national white paper, the Italian targets on wind energy are the following 700 MW by 2002, 1,500 MW by 2006, and 2,500 MW for 2008 to 2012.

The first objective was nearly reached at the end of 2001 under the old incentive system issued by the Interministerial Committee for Prices (CIP). This incentive system, *CIP Provision 6/92*, is based on feed-in tariffs, and in 2002, wind developers have installed wind farms with the new incentive mechanism based on green certificates. Due to difficulties faced by developers in tackling this new incentive scheme, growing environmentalist opposition, and bureaucratic and authorization barriers, the number of wind plants installed in 2002 (with a capacity of 106 MW) was less than that of 2001 (with a capacity of 263 MW). This was therefore not in accordance with the rate of 200 MW per year necessary to achieve the subsequent targets.

11.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

During 2002, wind power capacity in Italy increased by 106 MW, and the total wind capacity at the end of the year reached 788 MW. Figure 11.1 shows the installed capacity (annual and cumulative) and the annual energy production.

IVPC4, a company of the IVPC group, and Edison Energie Speciali (Edens) were also active this year, installing at the end of 2002 and at the beginning of 2002, respectively, several wind farms in the mountains of the Abruzzo, Basilicata, and Sardinia regions.

A trend towards larger machines was noticed in Italy in spite of the mountainous terrain of most sites. Particularly, IVPC4 added 34 Vestas V-52s of 850 kW, built in Taranto, to the previous wind installations in Sardinia. Also in Sardinia, a 12-MW wind farm of seven 1,750-kW Vestas V-66 units was set

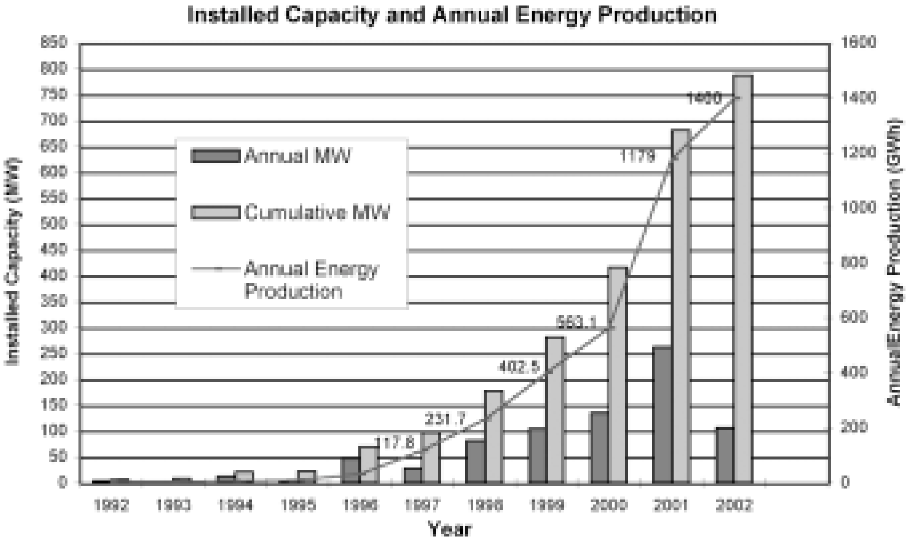


Figure 11.1 Installed capacity (annual and cumulative) and annual energy production

up at Enel GreenPower's Alta Nurra site in mid-2002 and has since been running well. This is the first production plant with turbines above 1 MW ever set up in Italy.

A new company that has recently entered the wind sector, Fin.so Energy, has completed its first wind farm at Ginestra degli Schiavoni (Campania), installing 21 Vestas V-52s of 850 kW each. Civil work on an additional 15-MW wind farm began in late September in the Campania region. The site is located on a hill 800 m above sea level (a.s.l.) and will host a total of 15 Fuhrländer FL1000 turbines. The operator is Harpen AG, which belongs to the RWE group.

Several new wind projects by IVPC, Edens, FRIEL, Lucky Wind, Eolo, and Enel GreenPower are ready to start at the beginning of 2003. An important contract was signed in August between Enel GreenPower and IWT, the Italian Vestas subsidiary, for supplying 134 V-52, 850-kW units with an option for 35 additional V-52 and V-47 turbines. The turbines will be delivered over the next two years and will be placed in nine new wind farms located in Sicily, Sardinia, Basilicata, and Molise, with an expected production of approximately 300 million kWh per year.

In the last year, Enel GreenPower has expanded its activities in wind energy significantly and aims to double its installed wind power capacity by June 2003 to reach a total wind capacity in Italy of 240 MW by the end of 2003. As a whole, the company plans to reach 900 MW installed capacity in Italy in five years. Enel GreenPower has also been working as a manufacturer of small-sized wind turbines – four MiniWind E20s of 20 kW each were in operation at the end of 2002, and there are plans to build an additional 20 units by March 2003. Jonica Impianti manufactures the blades of these small turbines. In this way, Enel GreenPower is confirming its commitment towards the development of wind energy in addition to its traditional renewable energy sources (geothermal plants and small hydro-power). Work has also been in progress abroad, in countries such as the United States and Costa Rica, Enel GreenPower has been acting for

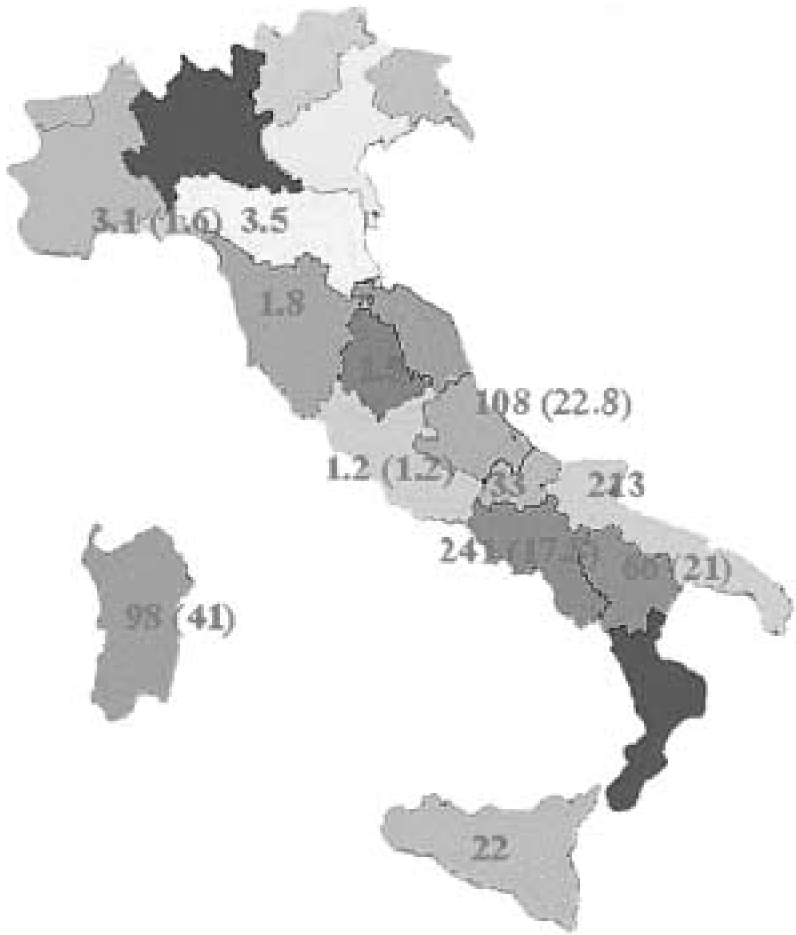


Figure 11.2 Wind capacity at the end of 2002 in Italian regions (new capacity for 2002 is in brackets)

some years through the acquisition of local renewable energy companies.

Rates and Trends in Deployment

The 106 MW of new wind power capacity installed this year are, as mentioned above, below the rate of deployment necessary to reach the next installation target. According to main developers, the decreasing rate of wind power in 2002 is likely to be temporary. In fact, some large wind projects are currently under evaluation by local authorities and, in the case of a positive response, the growth trend beginning in 2003 could be in line again with the national target.

Contribution to National Energy Demand

Due to the long time necessary to obtain definitive statistical data on electrical energy production, the 2002 figures presented here are provisional.

Domestic electrical energy demand was 310.4 TWh (including transmission and distribution losses) in 2002, increase of 1.8% from 2001. Of this amount, 50.6 TWh, 4.6% more than in 2001, were imported from foreign countries. In 2002, the gross electrical energy produced in Italy was 283.7 TWh, 1.7% more than the previous year.

Thermal plant production grew by 4.8% compared to 2001, with a total gross production of 229.8 TWh, while the gross contribution of renewable sources, including large and small hydro, was 53.8 TWh, with a slight drop from the previous year due to hydro-power (the total gross production of hydro-power plants was 48 TWh in 2002).

In 2001, the contribution of wind energy to electricity generation was 1,179 GWh, approximately 110% more than 2000. In 2002, the total wind energy production was estimated at 1,400 GWh. However, wind energy's share of the country's total energy demand remains small at less than 0.5%.

11.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

Finally, in 2002, all the wind plants entitled to obtain the premium tariff granted by *CIP6 Provision 6/92* were completed, and a new phase began with incentives for the building of renewable energy plants. Through the previous incentive system, more than 90% of Italian wind farms (corresponding to a total capacity of approximately 700 MW) were installed, particularly in southern regions.

Legislative Decree 79/99, in force since 1999, on the liberalization of the electricity market, states that the quota of energy produced by renewables should correspond to 2% of the annual conventional energy produced or imported annually until 2005. A subsequent specific decree regarding renewable energy sources defines the rules related to the emission of green certificates.

Electricity produced by renewable energy sources is labeled with green certificates issued by the GRTN. Green certificates are tradable, and one green certificate corresponds to 50 MWh of electricity generated by a renewable source. In order to stimulate the use of renewables by small energy producers, the value of one green certificate has recently been cut back from 100 MWh to 50 MWh.

This new mechanism for supporting clean energy sources is based on market competition, which began in January 2002. The green certificates can be sold or purchased on the basis of bilateral contracts or in an exchange organized by the Electricity Market Operator (GME). In practice, however, the exchange mechanism did not operate during 2002 – but it is likely to begin in 2003.

The following conclusions are based on the most recent information reported by the GRTN on green certificates related to renewable energy sources.

- The Green Certificate Demand value for 2002 was approximately 3.3 TWh, which corresponds to 33,000 green certificates. This involves 35 operators, producers, and importers of conventional energy who are subject to the obligation.
- Green Certificate Supply is composed of certificates relating to *CIP Provision 6/92* plants put into operation after 1 April 1999 issued by the GRTN (to avoid double benefit), and by those relating to private plants that have the qualification of Renewable Energy Sources Plant (IAFR) from the GRTN commission.
- On the basis of the production foreseen from plants qualified as IAFR and expected to be in operation during the year 2002, green certificate supply from private producers is evaluated at approximately 1.2 TWh (12,000 green certificates). Green certificates issued by the GRTN will cover the

remaining demand value (2.1 TWh).

- The GRTN has fixed the supply price per kWh of its green certificates for 2002. This price is equal to 8.418 Euro cents/kWh, which is the difference calculated between the average cost of the *CIP Provision 6/92* energy purchased by the GRTN in 2002 (generated from renewable source plants receiving incentives) and the revenue arising from the sale of the same energy in 2002.
- Green certificates can be sold or purchased on the basis of bilateral contracts or in an exchange organized by the GME.

With the aim of facilitating wind turbine installations, an agreement between the Ministries for Culture, Environment, and Productive Activities and the Conferenza delle Regioni has been approved by the Ministry for the Environment. The approval of the other subjects involved should happen soon. The main objectives of the agreement are as follows.

- Facilitating the pursuit of the national target.
- Favoring a proper insertion of wind plants into the landscape.
- Determining a framework to make authorization procedures easier, certain, and homogeneous.

Two additional main financing opportunities exist. The first is a tax credit for RES investments in favor of enterprises' corporate income tax declaration or on Value Added Tax (VAT) payments. Law 388 dated 23 December 2000 provides this opportunity. In fact, Article 8 of this law provides for the grant of a tax credit from 14 March 2001 to 31 December 2006 for the following. (However, the grant is not compatible with other types of financial support.)

- Interested subjects: Enterprises, particularly Small and Medium-sized Enterprises (SME), with new investments. Tax credit amounts are up to 50% for the SME and 35% for other enterprises.
- Territories concerned: Investments must be made in the South or in depressed areas of the Centre-North included in the list of "Objective 1 and 2" areas eligible for European Structural Funds.
- Investment categories: Purchasing of real estate, infrastructures, and durable equipment for new productive structures existing or to be developed in the areas mentioned, among which RES technology investments can be included.

The second financing opportunity is public aid from direct subsidies that assist RES investments, included in important laws such as the ones listed below.

- According to *Law 10/91* for the promotion of RES technology, the regions currently grant subsidies, mainly from revenues derived from carbon tax and excises on fossil fuels and in accordance with the provision of *Legislative Decree 112/98* for the decentralization of administration.
- *Law 488/92* has as its main national objective the increasing and improvement of production, the economy, and employment (particularly in the depressed areas included in "Objectives 1 and 2"). With this aim, the law provides for subsidies on investments to enterprises in various sectors, including electricity. The categories of eligible investments are: construction of new plants; enlargement, re-conversion, renovation, and updating of existing plants; rehabilitation of decommissioned productive plants; transfers of production plants; and restructuring of the organization of enterprises.

Like tax credits, subsidies are given in percentages of up to 50% for SMEs and 35% for other enterprises. Some categories of initiatives, such as those concerning the energy sector, can be co-financed with European Structural Funds.

The energy plans (Piani Operativi Regionali or PORs) of the Campania and Sicily regions have granted financial support to RES initiatives. This support is 235 million Euros and 125 million Euros, respectively, to RES initiatives including wind energy plants for the period of 2000 to 2006, according to the laws mentioned above. In regards to the wind sector, the Sicily region provides financial support to plant installations with power capacity more than 1 MW, constituted by wind turbines larger than 0.5 MW each.

Unit Cost Reduction

The ex-works cost of medium-sized wind turbines produced in Italy is approximately 640,000 Euros/MW, with a slight decrease compared to the previous year. Adding on-site assembly and transportation costs can increase total cost to 680,000 Euros/MW.

To these costs must be added the balance-of-system cost, which is approximately 25% to 30% of turbine cost, bringing the total cost per megawatt installed to approximately 900,000 Euros/MW. In particular, the contribution of the various balance-of-system items can be estimated as follows: civil engineering work, 15%; electro-mechanical engineering work, 7%; and grid connection usually ranging from 2% to 7%.

11.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

During 2002, the number of new wind turbines installed was 137, with an average capacity of 774 kW, bringing the total number of wind turbines in Italy to 1,346. The average turbine size rose to 585 kW (see Figure 11.3).

Three new wind farms in the Campania and Sardinia regions are composed of 850-kW V-52 turbines, which were manufactured in Denmark and Italy.

The first wind farm ever built with large-sized machines, namely a plant with seven Vestas V-66s of 1,750 kW each, was installed at Enel's Alta Nurra site in Sardinia (see Figure 11.6).

Approximately 40 additional wind turbines, totaling approximately 30 MW, were installed by IVPC4 in the Campania and Apulia regions but are not yet connected to the grid. Work is in progress, and the high-voltage line

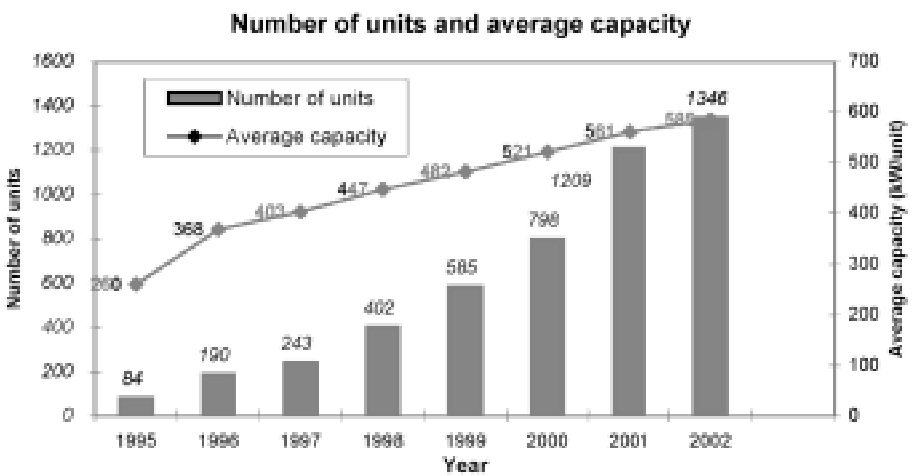


Figure 11.3 Number of turbine units and average capacity

necessary to transmit the energy produced will be completed at the beginning of the summer of 2003.

Figure 11.4 shows market shares for wind turbine manufacturers at the end of 2002, and Figure 11.5 shows the 2002 contribution by electricity producers from wind.

In Denmark and Italy, Vestas and IWT (an Italian Vestas subsidiary) have manufactured 65% of wind power capacity. Enercon, the other important manufacturer acting in Italy, has a 22% share.

The energy producers IVPC and Edison Energie Speciali confirmed their leading position in 2002. Two other new developers, FRIEL and Fin.so Energy have entered the Italian market, with approximately 18 MW and 9 MW, respectively.

Operational Experience

The wind regime in Italy during 2002 was not as good as the previous year. In fact, the load factor even in the most windy sites was equal to or less than 0.3. Wind turbines availability in 2002 was at the same level as 2001 with percentages of 98% and 99%. There were no particularly significant damages reported by developers.

Main Constraints on Market Development

In 2002, a minority of Italy's environmental associations, acting particularly at a local level, showed a growing opposition and increased the difficulties for new wind projects and installations. The main reason for this conflict with wind operators is the visual impact of wind turbines located on the top of hills and mountains.

Another main constraint on market development is represented by grid weakness and, sometimes, by the difficulties encountered in getting permission to build new electricity lines. The ongoing construction of a dedicated, 150-kV network for collecting power from wind farms in the most thickly developed area of Southern Italy has been suffering some delays, mainly for permitting reasons. More information can be found in the 2001 International Energy Agency (IEA) Wind Energy Annual Report.

In regard to authorization procedures, the agreement between ministries and regions

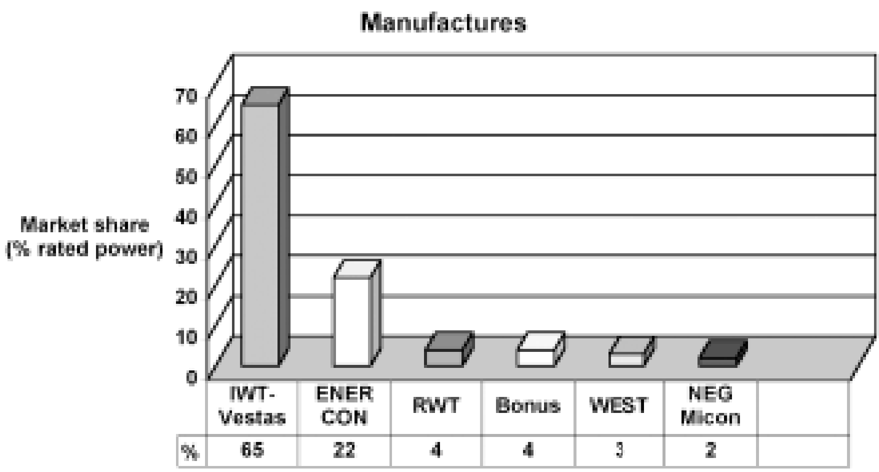


Figure 11.4 Market shares of wind turbine manufacturers at the end of 2002 (as a percentage of total online capacity)

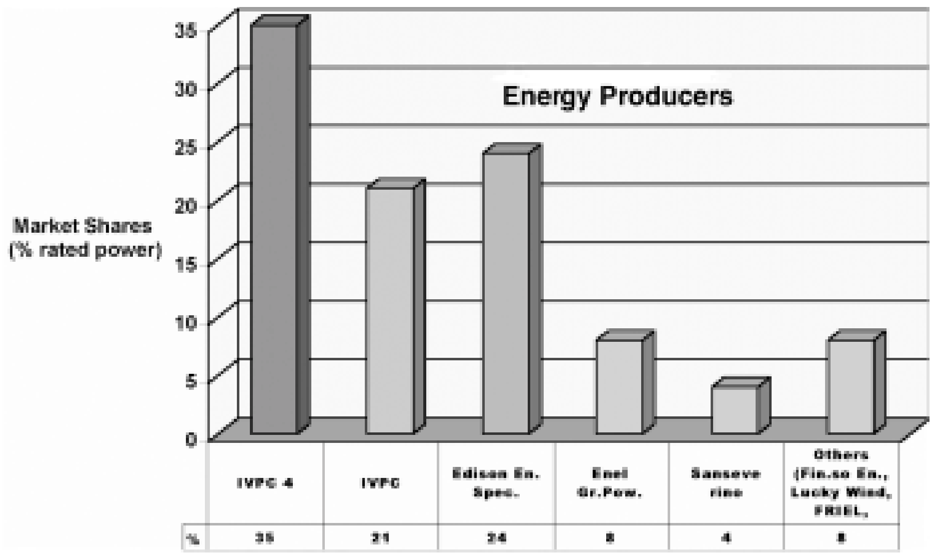


Figure 11.5 Contribution by electricity producers from wind at the end of 2002 (as a percentage of the total online capacity)

(as mentioned above) should reduce the barriers faced previously by developers.

11.6 ECONOMICS

Trends in Investment

Uncertainties due to the delay of the introduction of the green certificates exchange organized by the GME and growing difficulties encountered by wind investors in dealing with permit procedures have reduced the total capital invested in wind power in 2002 to approximately 100 million Euros.

Trends in Unit Costs of Energy and Buy-Back Prices

The wind plants installed in Italy under *CIP Provision 6/92* (about 90% of total wind power capacity) are entitled to obtain a premium tariff for the energy generated during the first eight years of operation. In 2002, the buy-back price for these plants was the same as the previous year, corresponding to 0.124 Euros/kWh.

GRTN has already fixed the selling price per kilowatt-hour of its own green certificates (ensuing from the energy produced by *CIP Provision 6/92* plants) for 2002. This value is equal to 8.418 Euro cents/kWh, calculated as the difference between the average cost of the *CIP Provision 6/92* energy purchased by GRTN in 2002 (only the share generated from renewable source plants receiving incentives) and the revenue from the sale of the same energy on the market in 2002.

When the green certificate exchange is fully operating, qualified wind producers that are not entitled to *CIP Provision 6/92* feed-in tariffs will obtain an overall income per kilowatt-hour corresponding to the sum of the electricity market price plus the green certificate value. As for the latter, in all likelihood it will have to be set equal or very close to the price of GRTN certificates at least in the next few years when the offer of certificates from *CIP Provision 6/92* plants will be prevailing.

Figure 11.6 Enel GreenPower's 12.25-MW wind farm, with seven Vestas V-66 units of 1,750 kW, at Alta Nurra site, in Sardinia

11.7 INDUSTRY

Manufacturing

IWT is the only wind turbine manufacturer in Italy involved in the production of blades and assembly of components. The factory is located in Taranto. In 2002, as a consequence of the fall in the internal market, it proved necessary to reduce IWT personnel significantly from 349 in 2001 to 250 in 2002.

In 2002, IWT began production of 850-kW turbines, and the first units made in Taranto were installed in Sardinia in November. The factory is able to produce about 400 medium-sized turbines (660 kW to 850 kW) per year, while bigger installations (1,750 kW to 2,000 kW) will be built by Vestas, for the time being, until the Italian large-sized turbine market grows enough to justify the construction of a new factory. Some components, such as steel towers and hubs, are built in Italy for IWT and Vestas according to Vestas specifications.

Through the acquisition of a new facility in Foggia, Wind Power Service (WPS) is enlarging its activity in the service and maintenance of Enercon and Riva Calzoni turbines installed in Italy.

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

In addition to IWT launching a new, 850-kW, V-52 production line, other developments were also made by the component industry. In particular, Monsud is very active in building tubular and lattice towers. A new Monsud factory devoted to the manufacture of wind towers is under construction in the province of Avellino. Colombo is a firm involved in the construction of hubs for medium-sized and large-sized turbines.

11.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Although deployment trends have changed in Italy in the last year, the level of public and private involvement in research and development (R&D) is more or less the same as last year.

Apart from some universities – in particular Rome, Genoa, Bologna, and Perugia, which are engaged in aerodynamics, siting, offshore, and electrical systems – only the CESI company has carried research on wind energy. However, the Italian Agency for New Technology, Energy, and the Environment (ENEA) has some involvement under European Union (EU) contracts regarding offshore siting.

Perugia University has carried out a study on advanced aerodynamic methods for wind site selection. Wind potential in Italy has not yet been completely explored, and many investors are still looking into the most promising sites. The Perugia University study investigates and compares wind site characterization tools and methodologies based on aerodynamics. Simulations and tests were performed at sites in Central Italy, where the complex topography requires efficient methods for site characterization and selection, with the aim of speeding up wind turbine installations.

At a meeting held in Rome in February 2002 about the environmental compatibility of renewable sources, and in particular wind energy, some time was devoted to a new challenge for the design and architecture world, through the promotion of a competition on the subject of wind landscapes. The idea was to give a response to the growing opposition caused by the visual impact of wind turbines. This event was organized by Enel Green Power and Legambiente, the most important environmental association in Italy, and was supported by the Ministry of the Environment.

The main topic of the Rome meeting was the insertion in the landscape of wind energy production infrastructures in a manner that ensures that the relationship between man and the environment be the most correct, balanced and ethical. A particular subject discussed was the design of two wind farms at Cinisi, in Sicily, and at Pescopagano in the Basilicata region.

Qualified people from France, Germany, the Netherlands, and Switzerland carried out projects. This is a confirmation of the attention that the research and planning world is paying to renewable sources.

New R,D&D Developments

Researchers at three universities have investigated the possibility of using wind power for hydrogen production. This is due to an increasing interest in the application of hydrogen for remote autonomous power systems.

Elettronica Santerno, which has developed a hybrid solar generator integrated with fuel cells, has carried out another step towards the use of hydrogen generated from wind or photovoltaic (PV). The unit operates as a continuous source of energy capable of feeding either an isolated network or the existing electricity distribution network. The system, based on high-efficiency, solid-state switching converters, is capable of optimized and automatic exploitation of PV or wind energy. The energy storage function, compulsory to adapt the variable power level of the renewable sources to the power needed by loads, is performed by means of hydrogen.

CESI S.p.A.

The company CESI S.p.A. performs specialist services and research in all areas linked to electrical power. Its shareholders currently include companies of the Enel Group, GRTN, and several other utility and industrial companies.

The research work of CESI on wind energy has been supported by the fund appropriated for *Research on the Electrical System* as provided for by a decree of the Italian Minister of Industry, Trade, and Handicraft (now Ministry for Productive Activities) issued on 26 January 2000 and modified on 17 April 2001.

So far, the main activity has aimed at creating a general atlas of Italy's wind resources in order to provide local authorities and plant developers with a framework for singling out the best promising areas where search for wind exploitation sites can be focused. This activity was seen as the necessary follow-up from a number of wind surveys that had

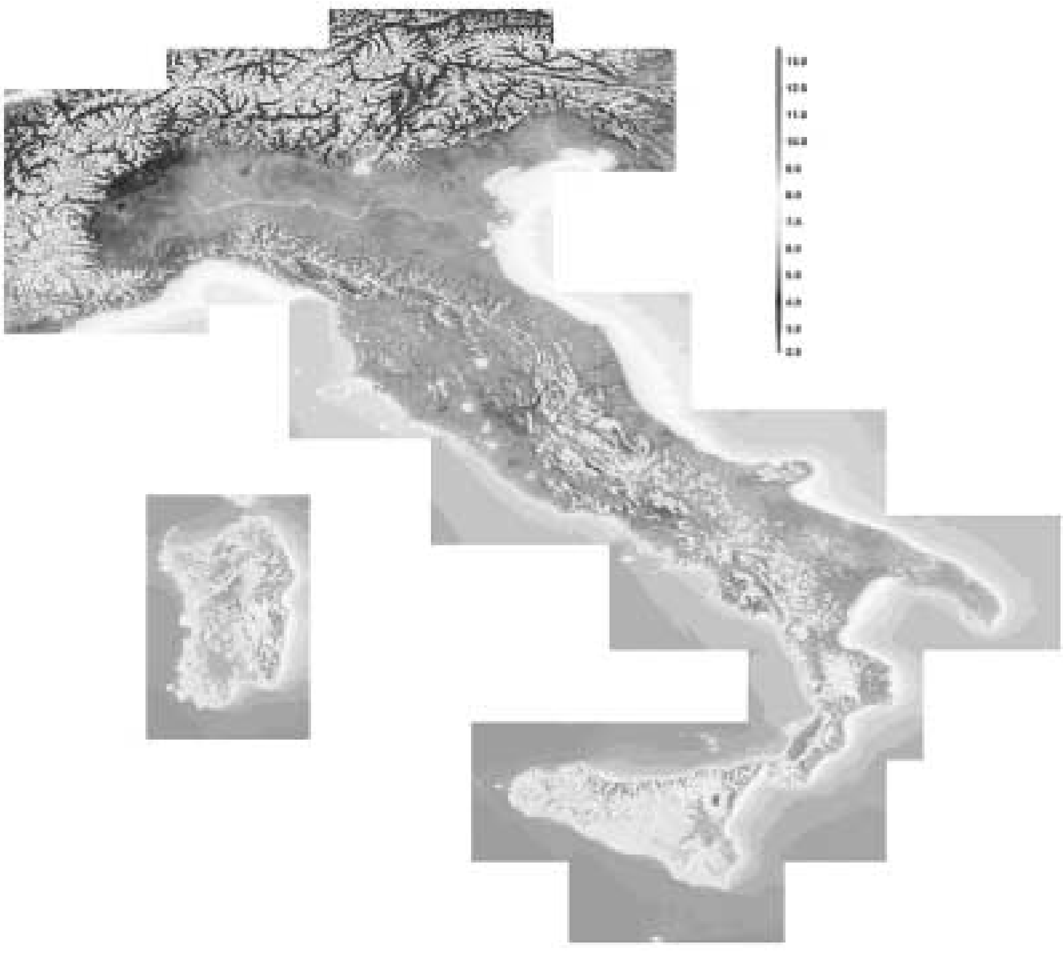


Figure 11.7 An overall wind map of Italy (annual average wind speeds at 25 m above ground) developed by CESI

been carried out by entities such as ENEA, the Enel Group, CNR, and other industrial companies over the past two decades.

The first phase of this work, conducted in 2000 and 2001, simulated the wind flow all over Italy, including Sicily and Sardinia, in co-operation with the University of Genoa. An up-to-date wind flow model (called WINDS) was used to obtain wind maps at various heights above ground from geotropic wind data provided by ECMWF of Reading (in the United Kingdom), taking into account topography and terrain roughness as worked out from data available from the U.S. Geological Survey.

A preliminary overall map of the annual average wind speeds at 25 m above ground is shown in Figure 11.7 as an example. Preliminary maps such as this, obtained by a simulation model, have been validated by comparison with measured data.

The second phase, conducted in 2002, aimed at fine-tuning these maps by comparing simulated wind speeds with data measured by current and historical stations throughout Italy. A method was developed to adjust maps in accordance with experimental data. A full atlas of validated maps will be made available at the end of 2002.

From 2000 to 2001, CESI also made a preliminary assessment on the feasibility of wind farms in mountain areas above 1,000 m. Since the results found this solution to be viable up to elevations of at least 1,800 m to 2,000 m, the methodology is now going to be developed further in 2003 to get an overall picture of Italy's usable high-altitude potential.

A 660-kW wind turbine was also bought with the intent of installing it at a 1,800-m site in the northern Apennines (Emilia-Romagna region) to check how well current technology can withstand in such an environment, especially in the winter. Unexpected delays that occurred during the permitting procedure for installing this machine in 2002 have caused the testing activity to be postponed until 2003.

In 2002, CESI also completed its general survey of the prospects for offshore wind farms by conducting a more in-depth analysis of some technical and economic aspects of wind plants in offshore situations typical of Italy. It was confirmed that some factors – such as deep waters, rocky sea bottoms, environmental constraints, and availability of erecting crafts – are likely to limit the extent of usable areas and bring about higher energy costs as compared to northern Europe. But this does not rule out the possibility to spot a number of sites where plants with 10 to 20 turbines could be feasible. Some additional information on offshore wind potential should be gathered next year.

CESI's average expenditure for wind energy research since 2000 has been approximately 700,000.00 Euros per year.

Offshore Siting

There has recently been some interest in offshore siting in Italy. In fact, after a feasibility study performed by the consultant group Garrad & Hassan on a site off the farthest Southern Sicily coast ordered by the province of Ragusa, the University of Bari prepared a feasibility study for an offshore wind farm in the Apulia region.

ENEA is involved jointly with the Nansen Institute (Norway) and the Risø National Laboratory (Denmark) in a European project (called WEMSAR). The Nansen Institute is coordinating the project, and so far the main results achieved are as follows.

- Wind retrieval algorithms for satellite data have been reviewed and presented in a report.

- SAR images have been obtained and analyzed to derive wind speeds at test sites in Norway, Denmark, and Italy.
- In-situ meteorological data have been acquired and analyzed for the three test sites for comparison with the SAR-derived wind speeds.
- Model simulations of the local wind fields at two test sites have been carried out.
- Validation has occurred of SAR data against in-situ data for all three test sites.

ENEA is also engaged in the organization of the fourth OWEMES seminar, which will be held in Naples in April 2003.

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Chapter 12
Japan

12.1 INTRODUCTION

After installation of a 20-MW wind farm in December 1999, Japan entered an age of commercial wind farms. At the end of 2002, the total wind-power capacity in Japan was estimated at 340 MW. The national wind target for the year 2010 is 3,000 MW, for which many efforts have been made. In April 2002, the Japanese government passed legislation for a Renewables Portfolio Standard (RPS).

12.2 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% from 2008 to 2012, compared to the 1990 level. To attain this target, the government has changed the 2010 wind power target 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 an RPS in order to realize the national target for renewables by 2010. The contribution of renewables to the

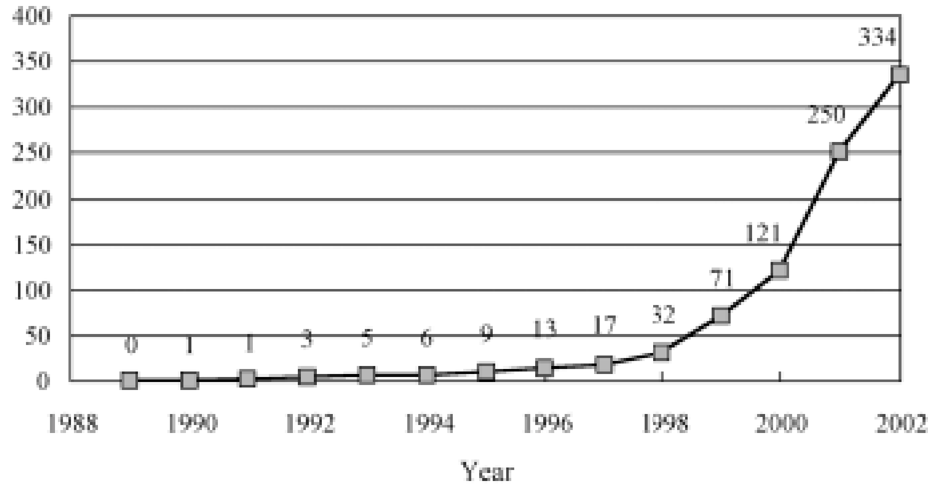


Figure 12.1 History of installed wind capacity in Japan

total primary energy resources will 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 estimated at 334 MW at the end of 2002, according to NEDO. Figure 12.1 shows the history of wind turbine development in Japan.

Rates and Trends in Deployment

During the last four years, the increase in cumulative wind-power capacity was recorded as ten times. With support from government promotional subsidy programs, many commercial wind farms have been developed. However, there are some limitations on wind capacity due to grid problems indicated by some regional utilities where the purchase price is decided by tender.

Contribution to National Energy Demand

Wind-power generation from April 2001 to March 2002 was 348.2 GWh. The national energy demand in the same period was 963.3 TWh, and the contribution of wind power therefore counts for 0.036%. If the national target of 3,000 MW is realized, wind-power contribution to national primary energy resources will be 0.22%, since wind-power generation is equivalently evaluated as 1,340 ML of oil in the government scenario. (Wind Energy/New Energy = 1,340 ML/ 19,100 ML and New Energy/Total Primary Energy = 3.1%.)

12.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

NEDO has been conducting the following three subsidy programs as a part of the Ministry of Economic, Trade, and Industry (METI) introduction and dissemination program. These programs are playing 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 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 since 1998. NEDO subsidizes up to one-half 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 private wind farm developers, and NEDO subsidizes up to one-third for each facility design and construction.

Unit Cost Reduction

More than 90% of the installed wind turbines in Japan are imported from Europe and the United States. Therefore, the unit cost 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 higher total plant cost.

12.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The number of commercial wind farms has been increasing recently. Locations for large wind farms are concentrated in the northern part of Japan, which has induced some grid problems. More than 90% of the wind turbines employed in Japan are European or U.S. turbines. There are 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.

Operational Experience

In Japan, the technical issues related to wind power to be solved are related to power quality, typhoon attack, high turbulent intensity at hilly sites, and lightning strikes. Now, because many wind plants are located in rather complex terrain, siting techniques have become more important. For example, the capacity factor for Tappi Wind Park (owned by Tohoku Electric Power Co.) varies from 15% to 33% among units.

Main Constraints on Market Development

Grid capacity, or power quality, has become one of the most important issues in Japan. In the Hokkaido area, the available capacity for wind generation is limited by the regional utility to a maximum of 250 MW.

NEDO conducted two demonstration programs on power stabilization techniques and battery-back-up systems. Through these programs, huge amounts of technical data were gathered; however, the practical measures required to solve the grid capacity problem have not been drawn. Without solving this issue, the national target by 2010 might not be attained.

The problem of complex terrain also affects mechanical strength and electrical quality due to gusty and turbulent wind. It increases the cost of transportation, erection, and grid-connection. Lightening has recently become a significant problem because many turbines have been damaged by it.

12.6 ECONOMICS

As large-scale, commercial wind-power plants ranging from 20 MW to 30 MW are developed, the economics is getting more and more competitive. The cost of energy (COE) is 9.00 Yen/kWh to 11.00 Yen/kWh for medium-scale wind turbines with a capacity from 500 kW to 1,000 kW. The COE is 7.00 Yen/kWh to 9.00 Yen/kWh for large-scale wind farms comprised of wind turbines above 1,000 kW.

Trends in Investment

After installation of a 20-MW wind plant in October 2000, a 30-MW wind plant and several large wind plants over 10 MW have been newly developed or planned within the next few years.

The current wind turbine cost is approximately 100,000.00 Yen. The installation cost is decreasing as large-scale wind power plants increase. Cost can vary depending on wind condition, grid condition, and plant size. The 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. The plant cost is 110,000.00 Yen/kW to 150,000.00 Yen/kW for large-scale wind farms comprised of large wind turbines with capacities higher than 1,000 kW.

	MWT-S2000
Rotor type	Horizontal axis, variable-pitch control, variable-speed control, gear-less type wind turbine
Rated power	2,000 kW
Rotor diameter	75 m
Hub height	60 m
Rotation	8 rpm to 24 rpm
Rated wind speed	13.0 m/s
Cut-in wind speed	2.5 m/s
Cut-out wind speed	25 m/s
Power control	Pitch control, AC/DC/AC
Generator type	Permanent magnet synchronous generator
Wind direction control	Yaw control

Table 12.1 Specifications for Mitsubishi's MWT-S2000 wind turbine

Trends in Unit Costs of Energy and Buy-Back Prices

The average electricity purchase price is about 18.00 Yen/kWh. The wind-generated electricity purchase price has been 11.50 Yen/kWh, according to the utilities' purchase menus. This is under the condition that the total capacity for wind generation at every regional network is limited by each regional utility, and the price is driven by tender. The purchase price is getting cheaper than 9.00 Yen/kWh.

12.7 INDUSTRY

Manufacturing

MHI is the only national manufacturer that supplies mid-sized to large-sized wind turbines. MHI recently developed variable-speed, synchronous wind turbines of 300 kW, 600 kW, and 2,000 kW. Recently, many MHI wind turbines have been constructed in the United States.

FHI is a new wind turbine manufacturer. Starting with 20-kW class rotor development in co-operation with the Mechanical Engineering Laboratory (MEL), FHI developed a 40-W Subaru wind turbine and a 100-kW wind turbine under a national project.

Industry Development and Structure

The major wind turbine manufacturers doing business in Japan are Neg-Micon, Vestas, Bonus, Enercon, MHI, and Lagerway. MHI developed a 2-MW machine and the first plant was erected in Okinawa in January 2003, as shown in Figure 12.2. The specifications for Mitsubishi's MWT-S2000 machine are shown in Table 12.1. It is a horizontal axis, variable-pitch control, variable-speed

Figure 12.2 Mitsubishi's MWT-S2000 wind turbine under construction at Gushikawa in Okinawa

control, gear-less type wind turbine with a permanent magnet synchronous generator.

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*. Nearly 100 companies in the wind industry started the Japan Wind Power Association in 2002 and started communication.

Japan's manufacturer MHI has high export potential and shows business results all over the world, including such countries as the United States, the United Kingdom, Portugal, India, Mexico, and Germany.

12.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Since 1978, the Japanese government – formerly the Ministry of International Trade and Industry (MITI), now METI – aims its wind energy Research and Development (R&D) program at energy security after the oil crises. This is one part of the general R&D program for renewable 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. In January 2001, the governmental ministries were reformed, and the NSS R&D activities were succeeded by METI in April 2001. In addition, MEL and the National Institute of Advanced Industrial Science and Technology (AIST) became independent research institutes. The national wind energy activities in Japan are shown in Table 12.2 and described in more detail below.

A. New Sunshine Project: Research, Development & Demonstration (R,D&D)
In 1999, Japan started new R,D&D programs on new wind technologies for remote islands as described in the section below, NSS-R,D&D Programs.

National Activities	Period	Organization/Institute
A. New Sunshine Project (R,D&D) (1) Wind Resources Measurement (2) R&D of LS Wind Turbines (500 kW) on Tappi Cape (3) Demonstration of a MW-class Wind Farm on Miyako Island (4) Generic, Innovative R&D (5) Advanced Wind Turbine Generating Systems for Remote Islands (6) Local Area Wind Energy Prediction Model	 1978- 1990-1994 1990-1997 1991-1998 1978- 1999-2003 1999-2003	 METI (NSS-HQ, MITI) NEDO NEDO, MHI, Tohoku EPC NEDO, Okinawa EPC AIST (MEL) NEDO NEDO
B. Demonstration Programs (1) Research on Stabilization of Output Power from Wind Turbine Generating Systems (2) Research on Stabilization of Output Power from Wind Turbine Generating Systems with Storage Batteries	2000-2001 2000-2001	NEDO NEDO
C. Promotion of Introduction (1) Field Test Program (2) New Energy Business Support	1992-	METI (MITI), NEDO
D. Standards (IEC, ISO, JIS)	1988-	METI, JEMA, AIST, Industries
E. IEA Wind R&D	1978-	METI, AIST, MU, JEMA

Table 12.2 National activities on wind energy

B. Demonstration Programs
In 2000 and 2001, two new demonstration programs were undertaken by NEDO to develop techniques to stabilize the output power from wind.

C. Promotion of Introduction
NEDO's Field Test Program, 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. Standards
The national programs include co-operation in International Electrotechnical Commission (IEC) standard activities in the wind energy category. METI is also promoting the policy in order to maintain international consistency. In 1999, two Japanese Industrial Standards (JIS) that keep conformity with IEC 61400 standards were published, and in 2001, JIS had three more standards introduced.

E. IEA Wind R&D
NEDO, AIST (MEL), Mie University (MU), and the Japan Electrical Manufacturers' Association (JEMA) have participated in International Energy Agency (IEA) international co-operations in Tasks XI, XV, XVII, and XVIII by presenting technical data.

Table 12.3 shows the history of METI's budget for various wind energy activities.

NSS-R,D&D Programs

Since 1999, METI has conducted 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. Three R&D projects are described below.

1. Advanced Wind Turbine Generating Systems for Remote Islands

Japan has plenty of wind resources, mostly on hundreds of islands where the electric power depends on expensive diesel power. NEDO has been conducting a national R&D project titled, Development of Advanced Wind Turbine Systems for Remote Islands, since 1999.

METI/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 targets of this project are as follows.

- Competitive COE less than 20.00 Yen/kWh: Among small islands, the COE of wind can be cheaper than that of diesel, amounting to 30.00 Yen/kWh to 100.00 YenkWh.
- High penetration up to 40%: Demonstrations are intended to show that design power quality is maintained at a maximum of 40%.
- Easy construction and maintenance: On islands where large cranes are not available, turbines can be easily constructed using a 16-ton crane and a gin pole unit (See Figure 12.4).
- Design extreme wind speed of 80 m/s: Turbines are designed safe for up to 80 m/s of extreme wind speed under typhoon attacks.

Figure 12.3 shows two units of the 100-kW prototypes, erected on Izena Island in 2002. Table 12.4 shows main design features. The annual wind speed at the site is approximately 6 m/s, which is typical; however, the island is located under the main pass of typhoons. The island is supplied with electric power from five diesel generators with a total capacity of 3,800 kW.

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
NSS Project (R,D&D)	540	981	978	744	634	606	554	477	414	516	739	722
NEDO Subsidies (Field Test)	-	-	-	-	80	320	460	1,529	1,739	1,620	1,390	460
NEDO Subsidies (Business Support, etc.)	-	-	-	-	-	-	430	1,670	3,320	11,010	18,850	11,810
NEDO Power Stabilization Demonstration	-	-	-	-	-	-	-	-	-	2,070	910	300
Total	540	981	978	744	714	926	1,444	3,676	5,473	1,5216	21,889	13,292
Ratio of R&D (%)	100	100	100	100	88.8	65.4	38.4	13.0	7.6	4.7	2.6	5.4
Ratio of Subsidy (%)	0	0	0		11.2	34.6	61.6	87.0	92.4	95.3	97.4	94.6

(Source: NEDO)

Table 12.3 Budget for national wind energy projects in millions (Yen)

Figure 12.3 100-kW prototypes on Izena Island in Okinawa Area

As outlined in Table 12.5, the program will close in March 2003 after the completion of grid-connected operations that demonstrate a maximum of 40% penetration.

2. Local Area Wind Energy Prediction Model

This computational fluid dynamics (CFD) model is applied to Japanese complex terrains with high accuracy in predicting local wind flows. Figure 12.5 shows the nesting structure employed in the CFD model. Flow models employed in each nesting domain are shown in Figure 12.6, and Figure 12.7 shows the performance of the developed CFD model.

3. CFD Aerodynamics of Airfoil Sections

Generic research conducted by AIST shows that the operational characteristics of a wind turbine are highly affected by varying wind conditions. These conditions bring direct effects on the airfoil performance of the rotor blade because the angle of attack and Reynolds number vary widely, and flow separation occurs often. CFD research has been focused on simulating the flow field around an airfoil section to study the structure of a stall or formation of a separation

Design Items	Specifications
Rated power	100 kW
Rotor type	Horizontal Axis Upwind
Rotor diameter	22 m
Hub height	24 m
Number of blades	3
Blade length	10.5 m
Cut-in wind speed	3.0 m/s (10-min average)
Rated wind speed	10.5 m/s
Cut-out wind speed	25.0 m/s (10-min average)
Extreme wind speed	80 m/s (instant)
Power control	Active pitch
Rotor speed	30 rpm to 72 rpm
Yaw control	Active yaw
Main brake	Blade feather
Main brake	Feather
Second brake	Feather (Fail safe)
Generator	PMG (60 pole)
Construction	Jim pole type
Lifetime	20 years
Manufacturer	Fuji Heavy Industries, Ltd.

Table 12.4 Main technical specifications of a 100-kW wind turbine for remote islands

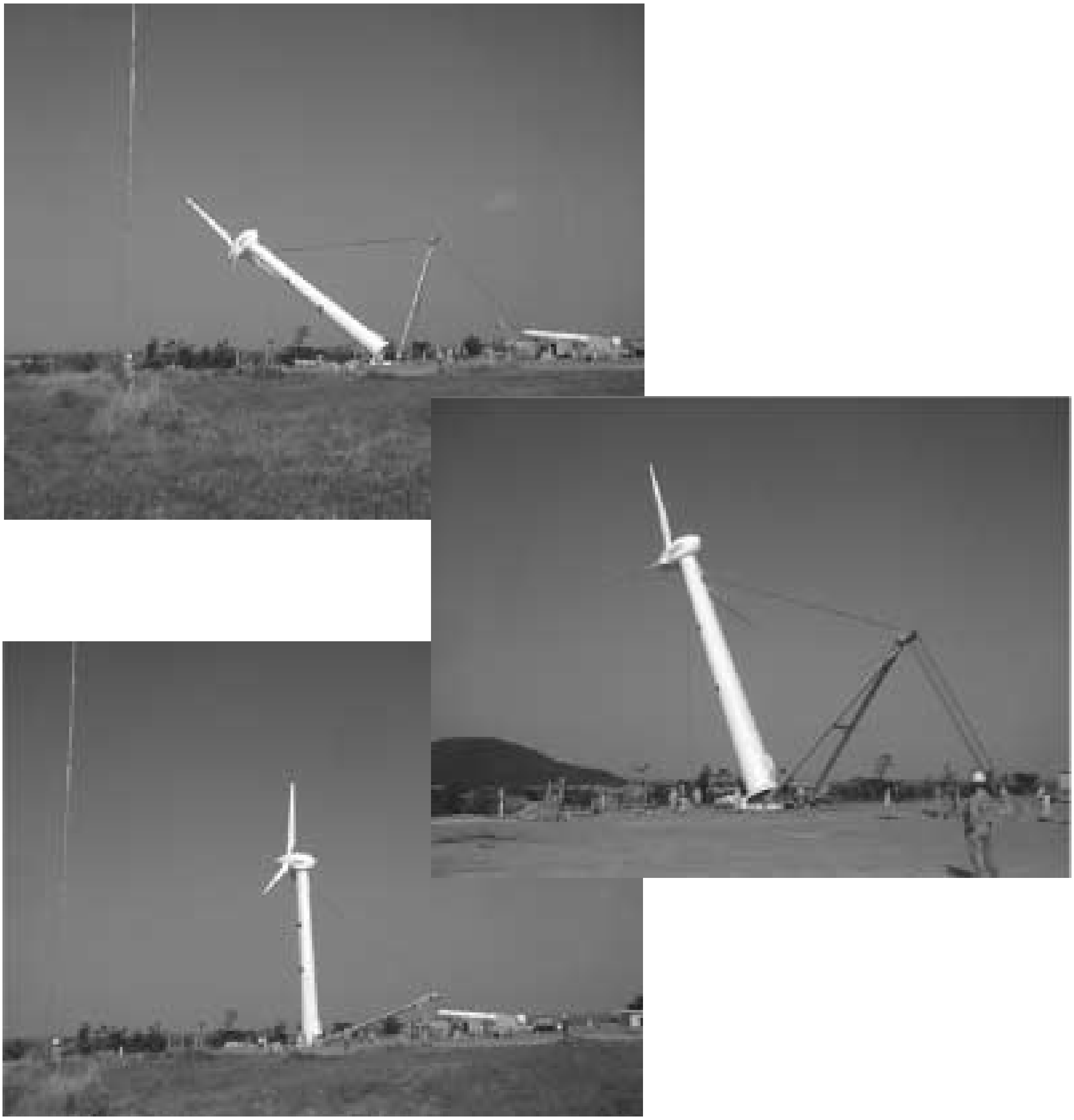


Figure 12.4 Construction with a gin pole unit

Financial Year	Main Items
1999	Conceptual Design
2000	Detail Design, Component Tests
2001	Manufacturing, Construction
2002	Demonstration, 40%-Penetration Tests, etc.

Table 12.5 Testing schedules for the R&D Project of Advanced Wind Turbine Generating Systems for Remote Islands

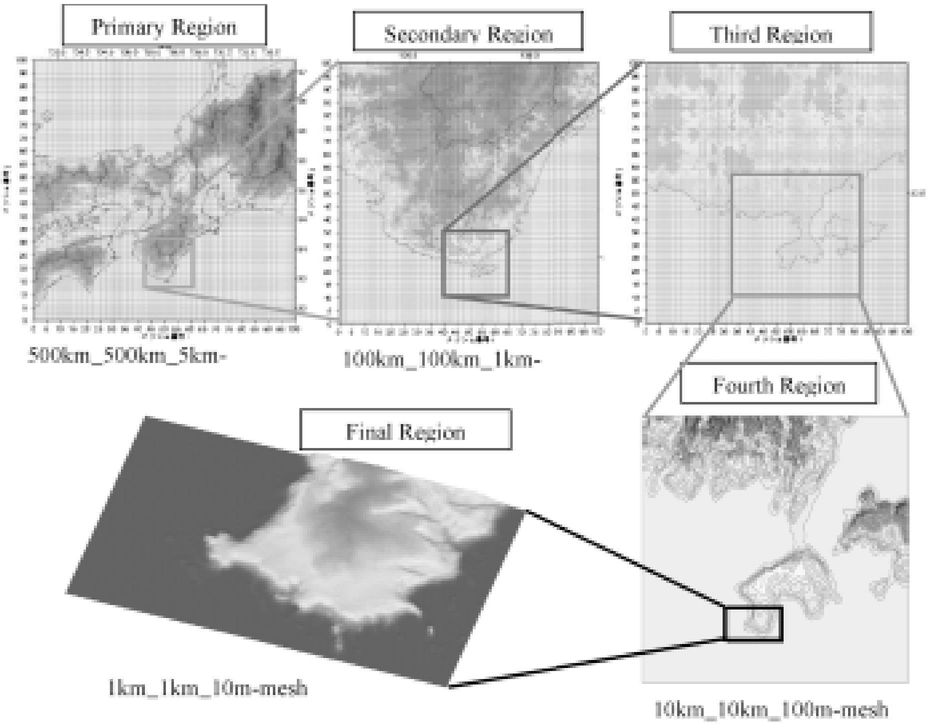
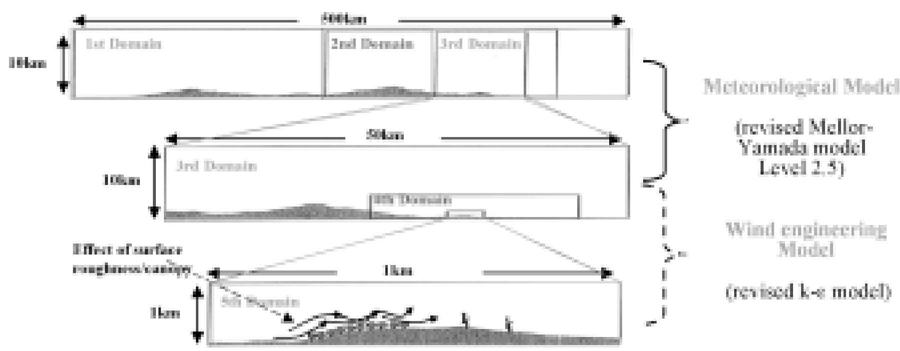


Figure 12.5 Nesting structure of the CFD model



(1st Domain) horizontal area: 500km, **horizontal resolution: 5km**, vertical area: 10km
(2nd Domain) horizontal area: 100km, **horizontal resolution: 1km**, vertical area: 10km
(3rd Domain) horizontal area: 50km, **horizontal resolution: 500m**, vertical area: 10km
(4th Domain) horizontal area: 10 km, **horizontal resolution: 100m**, vertical area: 4km
(5th Domain) horizontal area: 1km, **horizontal resolution: 10m**, vertical area: 1km

Figure 12.6 Flow models in each nesting domain

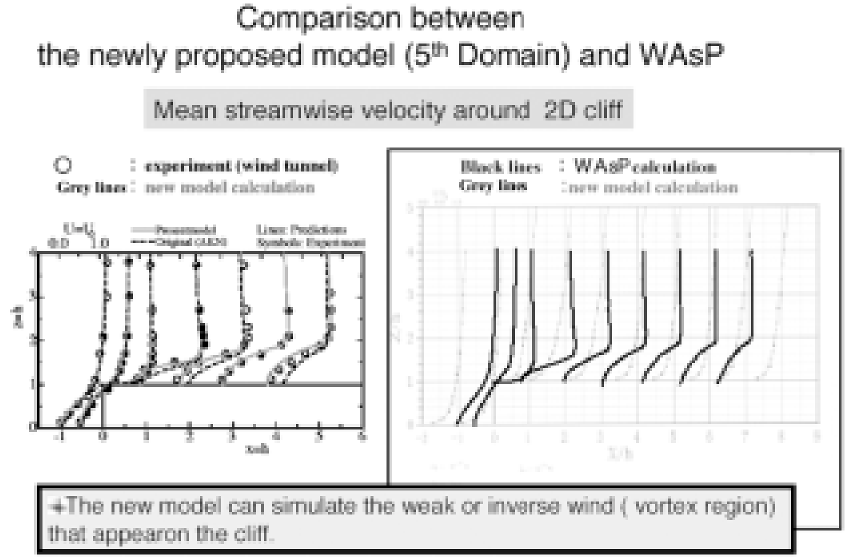


Figure 12.7 Performance of the developed CFD model

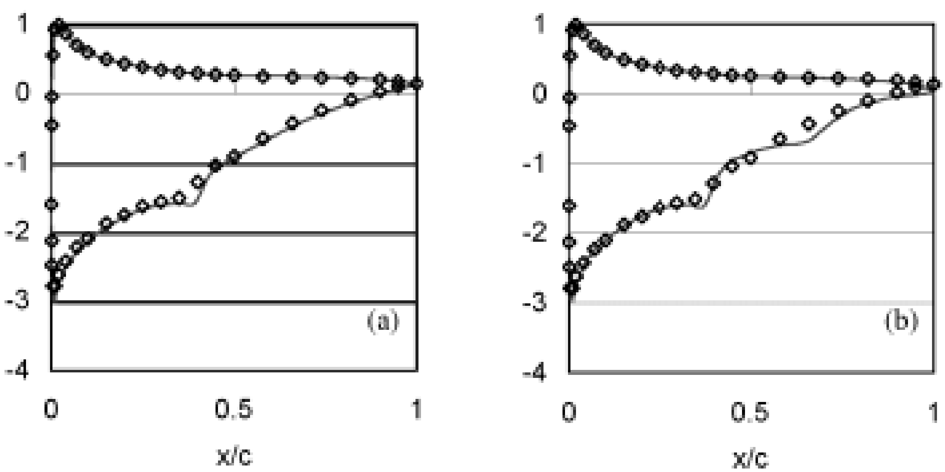


Figure 12.8 A sample of a separation bubble simulation using CFD

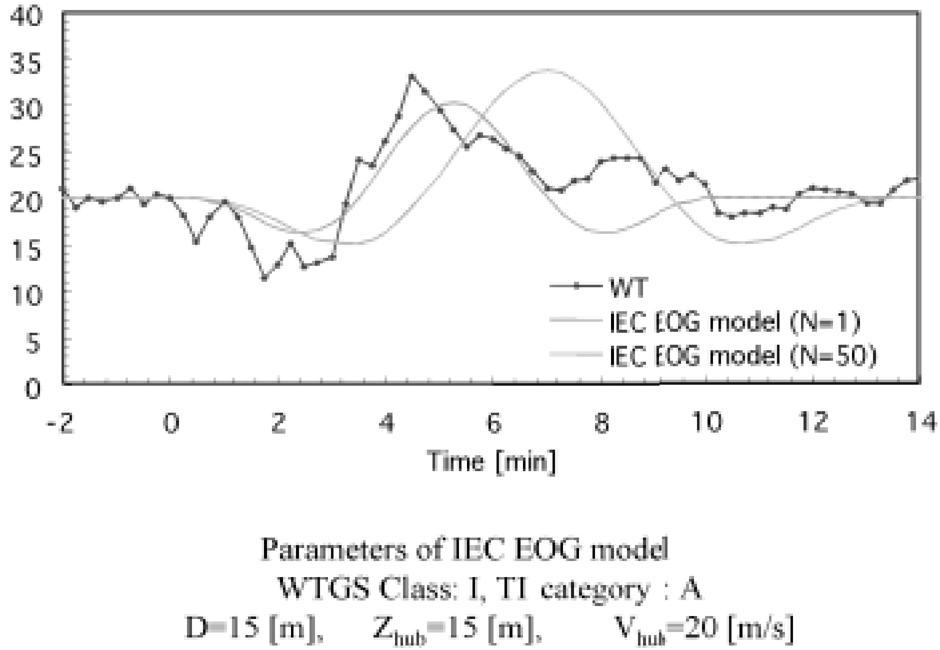


Figure 12.9 An observed high gust compared to IEC EOG models

bubble. Some fine flow simulations were successfully performed by means of solvers for the Navier-Stokes equation using the QUICK scheme and LES. The primary technical conclusions are that 3-D analysis is essential, and CFD may provide advanced tools as a numerical wind tunnel in the near future.

Field testing of a 15-kW, variable-speed research turbine with a diameter of 15m and a teetering rotor at Mt. Nonobo (a typical hilly and gusty site in Japan) has provided valuable technical data. Figure 12.9 shows an observed high gust compared to IEC EOG models.

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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 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 strongest wind energy resource is found in a sizeable region (about 3,000 km^2) known as La Ventosa, located on the Isthmus of Tehuantepec in the State of Oaxaca (see 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 the region, its topography in particular. In fact, a 1.6-MW pilot plant, located in one of the best windy sites in the region (La Venta), has operated at an average capacity of approximately 40% for six and a half years, which compares favorably to wind power plants located in the best windy inland sites in the world. However, until now, implementation of wind power in Mexico has been incipient and inconsequential in view of the fact that a number of barriers exist.

Jointly, a number of actors from the public and private sectors are carrying out some actions to remove the major barriers. Negotiations are still in progress by the Global Environment Facility (GEF), through the United Nations Development Programme (UNDP), to support an Action Plan for Removing Barriers to the Full Scale Implementation of Wind Power in Mexico, which will be lead by the Ministry of Energy.

13.2 NATIONAL POLICY

In 2001, the Ministers of Energy and Environment and their respective staff met to discuss issues to jointly develop a policy on sustainable development for the Mexican Energy Sector. The purpose of this first step is to coordinate common objectives and to establish a shared vision concerning common goals and challenges, with global climate change being among the main concerns. The meeting concluded that energy supply must be guaranteed in accordance with sustainable energy policy, which in turn must take into account social, economic, and environmental sustainability. National programs on energy and environment must be aligned and coordinated to ensure fulfillment of environmental goals on the basis of a shared vision and strategy.

Conclusions from the meeting also emphasize the need to foster the use of alternative energy sources by means of voluntary programs on renewable energy, long-term contracts, and incentives for the development of energy sources by private investment. Consequently, the National Programme for the Energy Sector (2001 to 2006) is aimed at securing energy supply to go with projected economic development on the basis of increasing actions to protect the environment and stimulate sustainable development.

National consumption of electricity is expected to increase at an average annual rate of 5.6% from 2002 to 2011. This growth translates into a projected requirement of 291 TWh in 2011 for total electricity generation, which represents an increase of 122 TWh and an estimated required new capacity of 30 GW. Of this, 14.4 GW is already under construction or planned, the majority of which uses combined-cycle, gas-turbine technology in addition to several new hydro and geothermal plants. The remaining 15.6 GW will be supplied through new projects, with an expected 1.4 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 15.6 GW of new capacity using Mexico's wind energy resource. Unfortunately, there are a number of barriers that have to be removed in order for wind power development in Mexico to become a reality.

Strategy

By the end of 2002, GEF's Council approved to include the Mexican Project Action Plan for Removing Barriers to the Commercial Implementation of Wind power in Mexico in its 2003 work plan. In order for the project to begin, paperwork is expected to be completed by the middle of 2003. Phase 1 of the project, scheduled to last two years, 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 so that a wind power market is established. Simultaneously, a number of scenarios will be evaluated and promoted in order to implement a voluntary wind power market within the industrial sector.

Additionally, special attention will be put on the implementation of the Clean Development Mechanism as an important element to complement domestic incentives. An educational campaign, geared towards raising awareness among government officials to the benefits of wind energy, will be carried out simultaneously. Technical information and human resource barriers will be addressed through the creation of a regional center for wind energy technology. At this center, local technicians and engineers will obtain hands-on experience in the operation of a diverse range of wind turbines, wind energy equipment will be assessed for operation under local conditions, and international standards and best practices will be applied and adapted for Mexico.

A preliminary assessment and mapping of wind energy resources at the most promising sites in the country will also be carried out in Phase 1 in order to obtain the wind resource data essential to the development of commercial projects. A set of comprehensive feasibility studies will be developed in Phase 1, in conjunction with any required preparatory activities, all geared towards the formulation of business-demonstration wind power plants.

Phase 2 of the project will begin by launching a competitive bidding process for three model projects that will 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 finally, lessons learned, best practices, and specialized human resources will be the basis for a national campaign aimed at consolidating a sound wind power market. This project will be a major first step that could be consolidated with a strategic partnership, which is currently under negotiation between the Ministry of Energy and the World Bank.

Progress Towards National Targets

Until now, the federal government has not stated any specific national target regarding wind power capacity to be installed. Nevertheless, important officials are talking about a strategic goal of 1,000 MW to be completed within the next five years. The Oaxaca state government is active in promoting the development of wind power in La Ventosa on the basis of economic and social development.

In November 2002, a meeting called the Third Colloquium on Opportunities for Wind-Power Development in La Ventosa, Oaxaca, was held under the auspices of the state government. Approximately 100 people attended the colloquium, including important policy makers from the Ministry of Energy, the National Commission for Energy Conservation, the Federal Electricity Commission, and the Energy Regulatory Commission, as well as local authorities and landowners and a number of wind project developers from Finland, France, Germany, Mexico, Spain, and the United States. This meeting is currently the country's most important wind energy event. This meeting recognized that one of the main challenges is to establish a suitable framework for negotiating and securing wind rights, since agrarian communities called *ejidos* are the owners of most of the land in Mexico.

13.3 COMMERCIAL IMPLEMENTATION

During 2002, additional wind power capacity was not installed. The total installed capacity of wind turbines in Mexico decreased to 2.2 MW because a privately owned 550-kW wind turbine in Ramos Arizpe caught fire (see Table 13.1 and Figure 13.1). As a result, the rate of wind power development declined, although the contribution to national electricity demand from wind power remains negligible. Trends are unpredictable – a number of wind project developers are trying to go forward, but several different kinds of barriers hold back the initiatives. Despite these barriers, most project developers plan to start construction of their respective projects soon, although project dates tend to continually 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 existing legal and

Location	Manufacturer	Wind turbines (kW)	Capacity (MW)	Commissioning date	Owner
La Venta, Oax.	Vestas	7 x 225	1.57	1994	CFE
Ramos Arizpe, Coah.	Zond	1 x 550	0.55	1997 (2)	(1)
Guerrero Negro, B.C.S.	Gamesa Eolica	1 x 600	0.60	1998	CFE
TOTAL		9	2.2		

(1) Cementos Apasco (Cement factory).
(2) In mid 2002 this machine caught fire.

Table 13.1 Wind turbine installations in Mexico at the end of 2002

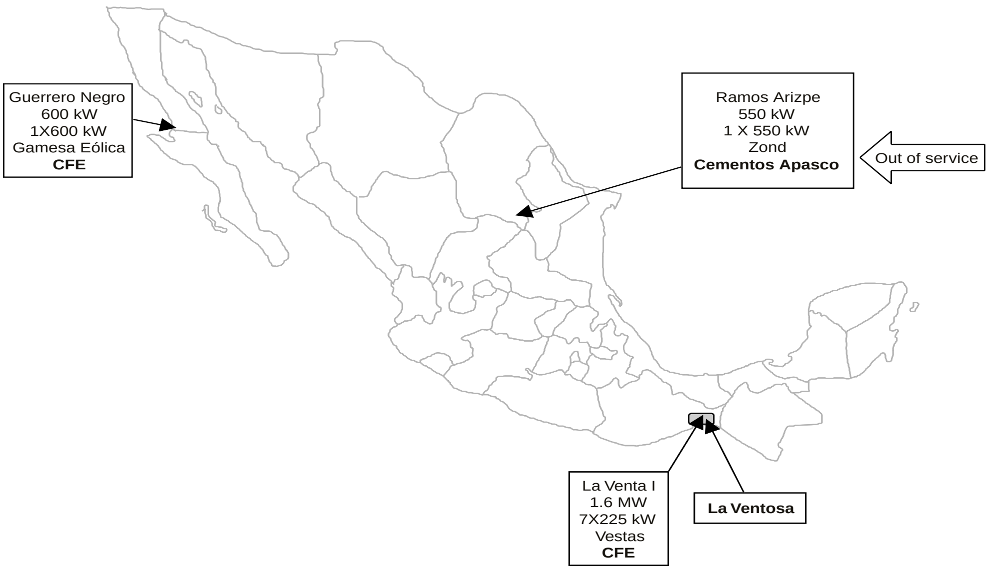

Figure 13.1 Locations of wind turbines installed in Mexico as of December 2002

regulatory frameworks, this new incentive consists of a model of agreement for the interconnection of renewable energy power plants to the national electrical system. 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 for energy extracted from the grid during different periods. 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 in order to match the 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 the new 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 agreement model is expected to facilitate some self-supply wind power projects that have been waiting for better regulatory conditions for years. Unfortunately, a year has 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 2002. The number of wind turbines installed in Mexico has decreased to eight (see Table 13.1).

Operational Experience

During 2002, electricity production from the La Venta wind power station was 6.0 GWh. The facility operated with an annual capacity factor of 43%, and its overall availability was 99%, according to Carlos García Aguilar, General Manager of the La Venta Wind Power Station.

Preliminary data reveal 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 approximately 8 m/s at 50 m above ground.

Detailed information was not released about the destruction of the 550-kW wind turbine installed in Ramos Arizpe. The nacelle of the wind turbine was reportedly in flames for hours after lighting presumably caught it on fire. At the end of 2002 the machine was still out of service. It has been said that Cementos Apasco is considering installing a new machine.

Main Constraints on Market Development

The following are the main constraints on wind power market development in Mexico.

- Current regulatory framework does not facilitate commercial development of wind power.
- Electricity for the industrial sector is subsidized.
- A critical need exists to cultivate a confident and stable business environment that can provide appropriate guarantees to international and national financial institutions on the viability and profitability of wind power projects.
- A national program on wind power implementation does not exist.
- Specialized human resources on the subject do not exist.
- Financial mechanisms do not fit.

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.

Sector	Average price (Mexican Pesos/ kWh)
Industrial	0.550
Agriculture	0.313
Residential	0.607
Commercial	1.303
Public services	1.133

Table 13.2 Electricity prices in Mexico as of January 2001

It is clear that a niche of economic opportunity for wind energy already exists in the commercial and public service scenarios. The challenge is to figure out and implement the appropriated 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. 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 2002, the Mexican government did not sponsor the construction of any additional wind power facilities for demonstration or local capacity building.

Under the auspices of the Ministry of Energy, the Electrical Research Institute is in charge of formulating 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 center for wind energy technology, which aims to offer the following provisions.

- Support to interested wind turbine manufacturers for the characterization of their products under local conditions of La Ventosa.
- A means to train local technicians for operation and maintenance of a diversified range of wind turbines.
- An easily accessible national technology display, facilitating the encounter between wind manufacturers and Mexican industries, thus promoting the identification of possible shared business ventures.
- A modern and flexible installation to obtain hard operational data on the interaction of specific types of wind turbines with the electrical system.
- A means to understand international standards and certifications (issued abroad) in order to detect additional requirements to fit local conditions.
- A way to increase the playing level of national research and technology development, including joint projects or specific collaboration activities with prestigious overseas research and development institutions.

Furthermore, major concerns exist because wind data currently available in Mexico is scarce, except for a 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 a primary requisite in order 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 local capacity building will be addressed comprehensively by the Electrical Research Institute and associated parties.

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Chapter 14
The Netherlands

14.1 INTRODUCTION

In 2002, 166 new turbines were installed in the Netherlands with a capacity of 217 megawatts (MW). NoordzeeWind was selected as the consortium to build and exploit the demonstration 100-MW Near Shore Wind Farm. A change was initiated in the various financial, planning, and research and development (R&D) instruments that are facilitating demand for renewables.

14.2 NATIONAL POLICY

The government policy and targets for renewable energy were revised in 2001. Wind and biomass energy are new priorities and are supposed to give the greatest contributions to the 2020 target. The realization of 6,000 MW of installed wind capacity offshore is seen as possible and necessary. The targets are summarized in Table 14.1.

Strategy

The government will create the conditions to reach these targets through various instruments that facilitate demand for renewables: amongst others, continuation of fiscal incentives and financial instruments, spatial planning; research programs, a competitive green market, administrative agreements, research and demonstration programs, carbon dioxide reduction subsidies, and joint implementation mechanisms.

Progress Towards National Targets

In 2001 about 1.3% of national energy consumption was provided by renewable energy. Numbers for 2002 are not yet available.

14.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 2002, 166 turbines were installed with a capacity of 217 MW, and 40 turbines with a capacity of 15 MW were removed. This brings the total installed capacity at the end of 2002 to 685 MW. The final numbers for 2001 show a total increase in operational capacity of 42 MW. See Figure 14.1.

Rates and Trends in Deployment

The net increase installed capacity in 2002 of 202 MW is twice as much as in the previous record year, 1995. The average installed

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 renewable energy in percentage of RE or electricity in italic. Avoided fossil fuel in PJ.

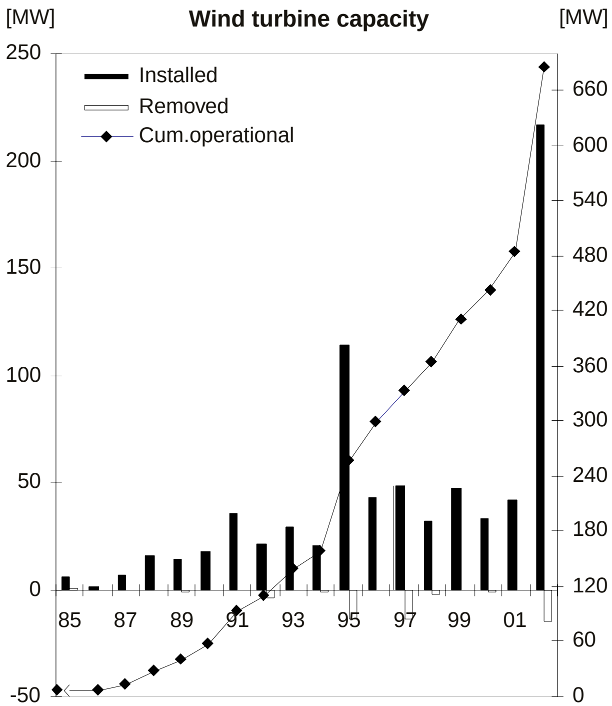

Figure 14.1 Installed, removed, and operational wind capacity

capacity per turbine doubled from 650 kilowatts (kW) in 2001 to 1,300 kW in 2002. The average hub height rose to 66 meters (m), and the installed swept area per unit of power continued to be stable at about 2.5 m^2/kW. See Figure 14.2.

Contribution to National Energy Demand

Total national electricity consumption in 2001 was 103.495 gigwatt-hours (GWh). Wind provided about 0.8% of it, which amounts to 825 GWh of electricity. In 2002 we expect the national consumption to be 106.815 GWh with wind providing 0.94% of that, which amounts to 1,006 GWh (see Table 14.2). In a normal wind year, the installed capacity of 685 MW can generate about 1,400 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 IEA Wind Energy annual reports for 1999, 2000, and 2001. Information about the competitiveness of prices can be found on the Internet at www.greenprices.com. At the end of 2001, about 800,000 households bought renewable electricity at the same price as grey electricity. In 2002 this almost doubled, to 1.4 million households.

After the elections in May, the new Netherlands government decided to change the financial framework for renewable energy stimulation for the following reasons.

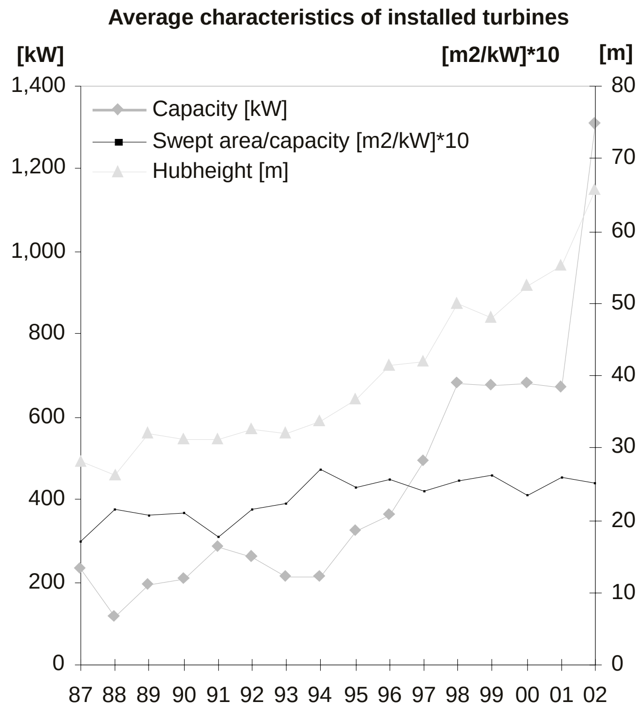

Figure 14.2 Average characteristics of installed turbines

- The market for green energy was liberalized from July 2001
- The market for grey energy will be fully liberalized from January 2004
- About 1.4 million households bought renewable energy at the same price as grey energy
- Large-scale import of electricity from existing production units (among others, biomass from Sweden and hydro from Norway and Switzerland) created a flow of about 140 million Euro of taxpayers' money out of the country in 2002 through the Feedback Eco tax for producers
- Due to lack of effective relevant European Union (EU) directives in Europe, there is no level playing field for renewable energy.

The state budget for 2003 (announced in September 2002) includes more details about the change of the financial framework. The budget initiated intense public discussions with the producers of renewable energy, the energy companies, parliamentarians, and the government, especially about the size of the reimbursement. It became clear that legislation could not be finished before the first quarter of 2003. This was also influenced by the fact that the government fell in October/November. New elections for Parliament were held in January 2003 and a new government will take over.

In the meantime, temporary legislation will be effective from the 1 January 2003. Main elements are that the Feedback Eco tax of 2 ect/kWh for imported green electricity is canceled; the Eco tax for consumers is 0.0639 Euro/kWh but the exemption for customers that buy green electricity is 0.0464 Euro/kWh; the yearly budget for Energy Investment Deduction (EIA) is decreased, but wind will still be eligible; and energy invest-

Year	Generated electricity	Primary energy savings	Electricity consumption
	[GWh]	[PJ]	[kWh]
1985	6	0.05	
1986	7	0.06	
1987	14	0.12	
1988	32	0.27	
1989	40	0.33	
1990	56	0.46	
1991	88	0.73	
1992	147	1.22	
1993	174	1.44	
1994	238	1.97	
1995	317	2.62	85,641
1996	437	3.62	88,665
1997	475	3.93	92,000
1998	640	5.30	95,421
1999	645	5.34	97,549
2000	829	6.86	100,604
2001	825	6.80	103,495
2002	1,006	8.29	106,815
*2002 numbers have been estimated			

Table 14.2 Electricity production, avoided fuel and electricity consumption. (Source 1 & 2)

ments will no longer be eligible for Free Depreciation (VAMIL).

Since the announcement of the change in fiscal instruments in June 2002, investors have put their investment decisions on hold. The market is waiting for final legislation, in which all the details will be clear. Especially crucial for their investment decisions is the size of the reimbursement on production of green electricity.

Unit Cost Reduction

There are no reliable statistical data for 2002, but the indications point to a slight increase in project costs. The best estimates are e1,100/kW for project costs with 900 e/kW for turbines, 125 Euro/kW for electrical infrastructure, and 75 Euro/kW for project development.

14.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Of the wind turbines installed in 2002, 59% are from Vestas. New turbine types were the Nordex N80/2500 and the Lagerwey LW70/2000 prototype. See Table 14.3.

Ten wind farms with an installed capacity higher than 10 MW were installed. The largest is 22.5 MW with 9 Nordex 2.5-MW, 80-m turbines at the refinery of Nerefco (daughter of BP and Texaco) at the Rotterdam harbor (see Figure 14.3). The second largest is with 12 Vestas 1.65-MW, 66-m turbines at Middenmeer. Table 14.4 gives the details. Further details can be found at http://home.wxs.nl/~windsh/nwturtab02.html.

Operational Experience

There were no major incidents or accidents in 2002.

Main Constraints on Market Development

Spatial planning.
The main challenge for wind on land is still securing enough sites for wind turbines.
In July 2001 the Administrative Agreement National Development Wind Energy (Dutch acronym BLOW) was signed by the ministers of Housing, Spatial Planning, and the Environment; the ministry of Economic Affairs; the sub secretaries of state of Agriculture, Nature Management, and Fishing; and the sub secretary of state of Traffic and Waterstate and of the Department of Defence. Co-signing were the provinces and the Association of Dutch Communities.

Manufacturer	Turbines	Installed		Rotorarea
	[-]	[MW]	[%]	[m²]
Vestas	**95**	**127.6**	**59%**	**287,073**
Nordex	**15**	**27.3**	**13%**	**57,020**
NEG-Micon	**29**	**25.8**	**12%**	**62,144**
Enercon	**7**	**12.6**	**6%**	**26,939**
GE Windenergy	**8**	**12.0**	**6%**	**31,229**
Bonus	**9**	**8.0**	**4%**	**19,182**
Lagerwey	**3**	**3.5**	**2%**	**8,756**

Table 14.3 Distribution of new wind turbines by manufacturer

The agreement is aimed at realizing 1,500 MW of wind capacity on land in 2010.

Each province has a target to designate locations for wind turbines specified in megawatts before 2005. The agreement required action plans before June 2002, and all but one have been submitted.

Supporting spatial planning
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 their 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.

Novem has published supporting instruments on two CD-ROMs. One is called 'Met de wind in de rug' and it contains the entire knowledge base of spatial planning for wind in step-by-step plans for realization of a wind project and an encyclopaedia with important information about financing, law texts, and regional spatial plans. The other is the 'Handboek Risicozonering.' It treats all risk aspects of wind turbine locations on dikes, roads, railway lines, industrial plants, waterways, industrial zones, residential buildings, underground cables and pipes, high-voltage lines, etc. Also treated are zoning near airport flight paths and radio-telecommunication links. It contains much scientific data and examples of calculations for individual risk, group risk, etc. The Handbook was made by ECN on the order of Novem and was pre-

Figure 14.3 2.5-MW wind turbines at Nerefco refinery

Wind farm > 5MW	Manufacturer	Turbines	Height	Diameter	Capacity	Swept area
		[-]	[m]	[m]	[MW]	[m²]
Rotterdam-Europoort,	Nordex	N80/2500	80	80	22.5	45,239
Middenmeer,	Vestas	V66/1650	78	66	19.8	41,054
Dronten, Eland - Wisentweg	Vestas	V80/2000	67	80	14.0	35,186
Dronten,	Enercon	E70/1800	70	70	12.6	26,939
Biddinghuizen,	Vestas	V66/1650	67	66	12.3	23,948
Rotterdam,	GE Windenergy	GE70.5/ 1500	67	71	12.0	31,229
Biddinghuizen,	Vestas	V80/2000	68	80	12.0	30,159
Zeewolde,	Vestas	V66/1650	67	66	10.5	20,527
Lelystad,	Vestas	V66/1650	67	66	10.5	20,527
Swifterbant,	Vestas	V66/1650	67	66	9.9	20,527
Kapelle,	NEG-Micon	NM52/900	70	52	9.0	21,237
Zeewolde, Wulpweg	Vestas	V52/850	70	52	7.7	19,113
Zeewolde,	Vestas	V52/850	55	52	7.7	19,113
Etten-Leur	Bonus	B62/1300	66	62	6.5	15,095
Zaewolde,	Vesta	V52/850	70	52	6.0	14,866
Various < 5MW	Danish, Dutch, German	-	-	-	44.0	107,581
TOTAL					216.8	492,343

Table 14.5 Size of wind plant installed in 2002

sented at the Global Wind Power Conference 2002 in Paris.

Streamlining procedures spatial planning
The government is also aiming to streamline and shorten the procedures for building permits. In 2002 the government carried out an investigation into the bottlenecks of wind projects. This will be followed in 2003 with an operation that aims to evaluate the entire complex chain of laws and rules that apply to wind projects. The ambition is to shorten the process to 2.5 to 3 years and to strive for one integrated permit.

14.6 ECONOMICS

Trends in Investment

Based on an average price of 1,100 Euro/ kW, the investment in wind turbines totalled 238 million Euro in 2001.

Trends in Unit Costs of Generation and Buy-Back Prices

The total pay-back rate offered by energy companies for 5- to 10-year contracts in 2001 was between 0.068 and 0.080 Euro/kWh. No numbers are known for 2002, mainly due to the commercially sensitive nature of the contracts. After the government announcement of the change in the financial framework for renewable energy stimulation contracts, the energy companies put negotiations on hold.

14.7 INDUSTRY

Manufacturing

In December, NEG-Micon Holland announced that it would stop production of wind turbines in the Netherlands.

Lagerwey erected the prototype of its 1.5-2 MW prototype Zephyros turbine in May (see Figure 14.4) on the Maasvlakte facing the North Sea. The advanced turbine features a 3-kilovolt (kV), permanent magnet direct-drive generator, developed in close co-operation with ABB Finland. It has a rotor diameter of 70 m , rotor speed of 18 to 24 revs/min, individually pitched blades, and full ac/dc/ac conversion based on IGCT technology from ABB.

Industry Development and Structure

Offshore heavy lift specialist Mammoet; dredging, offshore, and marine construction works contractor Van Oord ACZ; and other shareholders including Hovago Cranes and Marine Construct have joined forces in the field of offshore wind farm installation. The new venture will operate under the name Mammoet Van Oord. To this end, a Jackup Installation Barge has been developed and built. Apart from Mammoet and Van Oord ACZ, other shareholders are Hovago Cranes (a member of the Baris group) and Marine Construct. Mammoet Van Oord's activities will also comprise all onshore transport and the installation of scour protection around the wind turbines and the shore.

Measuring 33 m wide and 7 m high, the Jackup Barge, dubbed "Jumping Jack," features four 40-m-high legs that will lift the barge out of the water to keep the vessel secure on the seabed, creating a stable working platform for the installation work. See Figure 14.5. A specially developed hydraulic winching system will allow the barge to raise and lower its legs while bearing a load on deck so that it can quickly move from one turbine to another. The pontoon on the barge has been designed to carry heavy loads (up to 4,000 tons) to and from port without the need for auxiliary pontoons. It is equipped with a 1,200-ton crane, which is sufficient for the lifting of current and future large offshore wind turbines. It can be fitted with various other cranes if necessary.

14.8 GOVERNMENT-SPONSORED R,D&D

Novem's wind program ended in the year 2000. In 2001 and 2002, Novem carried out the Renewable Energy program, in which all

Figure 14.4 Erection of Lagerwey 1.5 to 2 MW prototype

Figure 14.5 Jumping Jack offshore installation barge

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 2002. Priority subjects are listed here.

- New developments: Offshore, innovative materials, and recycling
- Testing and measuring: Condition-monitoring systems and wind turbine test facilities
- Databases: Failing of wind turbines and components
- Design tools: Reliability, wind turbines, control, and aerodynamics.

Awarded Contracts Under Novem Renewable Energy Program

From the 18.2-million-Euro subsidy in 2001 available for renewable energy, about 2.4 million Euro was allocated to these wind energy research projects:
1. Optimat BLADE, reliable optimal use of materials for wind turbine rotor blades;
2. Implementation of a computer code to analyse offshore wind turbines the frequency domain;
3. Design tool for integrated design of wind turbine control mechanisms;
4. Design of a prototype Smart Tower (tubular pre-stressed concrete);
5. Analyse, characterize, interpret, and quantify flow phenomena in aerodynamic field measurements on wind turbines;
6. Sound detection capabilities of porpoises in noisy environments;
7. Development of a detection system for

collision of birds against wind turbines (WT-Bird);
8. Farm effects of large offshore wind farms;
9. Electric and control aspects of offshore wind farms, phase 2.

From the 2002 budget, only the projects of the first tender have as yet been allocated. From a total of 9.1 million Euro for renewables, 2.5 million Euro was awarded to these wind research projects:
1. STABCON, aëroelastic stability control of large wind turbines;
2. Demonstration of an offshore access system;
3. CONMOW, condition monitoring of offshore wind turbines;
4. IEA Annex XX, analysis of NASA Ames wind tunnel measurements;
5. FYNDFARM, computer code for design and optimization of wind farms for maximum energy yield, in relation to fatigue loads from wakes and noise emission;
6. IEA Annex XVII, Netherlands contribution to Database Wind Characteristics;
7. Development of offshore wind energy standards;
8. Extrapolation of extreme external loads.

Summaries in Dutch of the project proposals can be found on the Internet at www.den.novem.nl under Gehonoreerde BSE-projecten Windenergie.

New R,D&D Developments; Revision of R&D Policy

Energy research financed by the Department of Economic Affairs through institutions (about 100 million Euro/yr) is fragmented and covers too many subjects. The Department started a review in the so-called Energy Research Strategy (EOS) project in 2001. The Department wants to make clear choices in thrust areas and in other areas to work through international co-operation. Thrust areas are subjects where the Netherlands has strength and that contribute to the transition to a sustainable society. Import of knowledge is preferred in areas where the Netherlands has less strength. A preliminary chosen thrust area is offshore wind.

In 2002, interest groups and stakeholders were consulted and the strategy was further detailed. The final report defined five priority areas. In the area of electricity grids and generation, offshore wind is one of the thrust areas. The new strategy will be further detailed in 2003 with the choice of instruments of implementation and organization of platforms of stakeholders. It will be operational in 2004.

Offshore Siting

In the coming years, further information on the following subjects will be available from the web site www.windopzee.nl.

Offshore siting
In October 2001, the government issued the final draft of the Spatial Core Decision (Vijfde Nota Ruimtelijke Ordening), which designated a preferred area on the Dutch continental shelf for 6,000 MW of wind capacity. In 2002, the discussion about the final draft by the government, Parliament, and prospective offshore wind developers started to reconsider these preferred areas. The Departments of the Environment, Traffic and Water, State and Economic Affairs are thinking in the direction of either designating larger preferred areas or opening up the entire Exclusive Economic Zone for wind power development except for hard exclusions due to, for example, ship traffic and military practice zones.

A study "Multiple Use of Space on the North Sea," concentrating on the combination of wind energy and other activities, was carried out by a working group from all concerned departments. It concluded that the opportunities are relatively limited for gaining more sites for offshore wind energy by combining this activity with other activities. A simultaneous combination of wind energy and ship traffic, oil and gas exploration, fishing, mining, dredging, military use, cables, recreation and tourism, nature, and other constructions is often blocked by several safety problems. Furthermore, in most cases there aren't any advantages from the combination for the "owners" of these activities. Successive combinations of wind energy and these activities (first one activity, then wind energy, or vice versa) offer more opportunities. Depending on the type of combination, this can take considerable time.

Offshore concessions
In 2001, the government announced that before the end of 2003 a concession regime shall be in place to allocate areas where wind developers can build offshore wind farms. During 2002, a draft concession regime was discussed with prospective offshore wind developers. The discussion will continue in 2003.

Offshore grid integration
To be able to integrate wind power offshore in the grid, Novem, on the order of the Ministry of Economic Affairs, carried out the "Survey of Integration of 6,000 MW Offshore Wind Power in Netherlands Electricity Grid in 2020." This inventory to tried to answer the following questions.

- What are the technical, organizational, financial, and administrative/legal consequences of the future integration of 6,000 MW of offshore wind power in the Netherlands' electricity grid?
- What measures do the involved parties have to take, including their responsibilities to realize the integration of this capacity in the period 2002 to 2020?
- What are the (financial) consequences for the involved parties?

Representatives of the Netherlands grid managers were involved to select scenarios and criteria for the inventory. Novem contracted a study to KEMA, which carried it out together with the Delft Technical University. It involved (1) system studies, to look into the necessary technical adaptations and investments in the grid; (2) technical studies of short- (seconds to minutes) and long-term (15 minutes to days) balance of the electricity system; (3) economics of the present electricity market; and (4) administrative/legal study of offshore wind energy.

The study showed that the extra investment costs for the necessary grid reinforcements of the 380-kV grid for wind capacity varies between 275 million Euro and 570 million Euro. This constitutes about 3% to 5% of the estimated investment in 6,000 MW offshore wind capacity. It gives a qualitative description of maintaining the short-term energy balance during disruptions and conditions of high wind and low load and the influence on available regulating power. Also, it gives a qualitative description of how to maintain the long-term power balance, its effect on partial loads of conventional units and their operation and maintenance, and the needs for wind forecasts. It describes the responsibilities of the government and grid manager for in-depth investments of grid reinforcements and possible changes in regulations for planning and cost recuperation. Finally, it details applicable law for grids and building offshore wind farms within and outside the territorial zone and gives recommendations on how to investigate and overcome uncertainties in this regard.

Offshore demonstration
Near Shore Wind Farm and Measuring and Evaluation Program

NoordZeeWind, a consortium consisting of Shell Renewables and NUON, was announced the winning consortium according to selection rules for the 100-MW demonstration Near Shore Wind Farm (NSW) to be built offshore near Egmond aan Zee. The consortium will be entitled to apply for the building permit.

The wind farm will be built 12 kilometers (km) from the coast in water 15 m to 20 m deep. The turbine will be 36 NEG-Micon 2.75-MW, 92-m-diameter, built on a monopile.

The Near Shore Wind Farm is meant to gather knowledge and experience to enable construction and exploitation of large wind farms far in the North Sea at water depths up to 40 m and distances over 40 km. That is why an extensive Measuring and Evaluation Program (NSW-MEP) is connected to the demonstration. The document Measuring and Evaluation Programme (NSW-MEP) describes the mandatory and desired measurements to be carried out in the area of technology and economy and the area of nature, environment, and other use functions. It is based on an inventory of the learning objectives of all directly involved parties – government, lobbyists, and commercial companies. Novem elaborated the learning objectives in this NSW-MEP. The aim of this NSW-MEP is to collate knowledge and make it generally available. Account must be taken of the other monitoring programs conducted in the Netherlands and beyond. Double work must be avoided and the results of others should be used wherever possible, while others, in turn, are free to use the results of the NSW-MEP.

The government is responsible for a limited number of the necessary learning objectives for the nature and environment component. These are indicated in the NSW-MEP by the term "quantitative detailed approach by central government."

The NSW operator is responsible for collecting and supplying data of the NSW-MEP. The collection of data comprises the design and installation of the measuring infrastructure needed and conducting studies by itself or by third parties. The complete text of the NSW-MEP can be downloaded from the web site, www.nsw-mep.nl.

Project organization NSW-MEP

On the order of the government, Novem takes care of the project organization NSW-MEP. The Project Organization promotes the learning objectives and assures that they can be reached. It reports results to the Department of Economic Affairs.

For the collection of data on nature and environment, Novem is collaborating with the State Institute for Coast and Sea (RIKZ). This is a part of the Directorate North Sea of the Department of Traffic and Waterstate.

First, measurements of the undisturbed conditions of nature and the environment will be taken at the end of 2003. Then assessment of technology and economy will be made in either late 2004 or 2005.

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Author: Jaap L. 't Hooft, Novem, the Netherlands.

Chapter 15
New Zealand

15.1 INTRODUCTION

Energy Resources

New Zealand has a wealth of renewable energy resources. The availability of hydro, geothermal, wind, bio-energy, and solar resources is more than sufficient to supply New Zealand's four million residents with an entirely renewable energy supply. Renewable sources provide 29% of total consumer energy and about 70% of the electricity supply.

Current electricity production is approximately 39,000 gigawatt-hours (GWh) per year from 8,600 megawatts (MW) of capacity. In a normal hydrology year, hydro provides about 63% of electricity generation, with the balance comprising gas (22%), geothermal (7%), coal (4%), and other (3%). In a 1-in-20 dry year, loss of hydro capacity can be over 15% (about 4,000 GWh out of 24,000 GWh mean year capacity). In recent "dry years" such as 2001, this shortfall has been made up by increased thermal generation (gas and coal) and by demand reductions.

Wind Energy

New Zealand's position in the "roaring forties" latitudes provides the country with an exceptional wind energy resource. Several sites in the lower North Island offer annual mean wind speeds of 9 to 10 meters per second (m/s), several even higher. Technical availability of wind energy is estimated at 100 TWh/yr, over 2.5 times the present electricity demand. Commercial availability, considering sites that could deliver wind power for less than 0.10 New Zealand Dollars (NZD) per kilowatt-hour (kWh), is estimated at 8 terawatt-hours per year (TWh/yr), requiring some 2,500 MW of wind energy plant.

Over the last decade there has been an increasing commercial interest in harnessing wind energy. The first demonstration wind generator was installed in Wellington in 1993. Two commercial wind farms have since been installed, both in the lower North Island, and comprise the 3.5-MW Hau Nui wind farm near Martinborough, and the 32-MW Tararua wind farm near Palmerston North. Wind energy supplies about 145 GWh/yr to the New Zealand electricity grid annually.

Sector Reform

The New Zealand electricity industry has undergone major structural reform in the past five years. In 1999, state-owned generator ECNZ was split into three competing state-owned enterprises (Meridian Energy, Genesis Power, and Mighty River Power). This followed the 1996 split from ECNZ of Contact Energy, which was then privatized in 1999.

The Electricity Reform Act 1998 forced separation of electricity distribution companies into network and energy retail businesses with separate ownership of each. Restrictions imposed by the network companies on ownership of generation assets were relaxed in the Electricity Industry Reform Amendment Act 2001 to allow network companies to own embedded renewable generation.

Competition for retail customers began in April 1999 with the introduction of profiling, a system of estimating a consumer's consumption by half-hourly periods. The sale and purchase of wholesale electricity is now organized by the participants in a private-sector wholesale market operated by the MarketPlace Company (M-Co), with spot prices set half-hourly, two hours in advance.

These reforms kept the promotion of renewable energy at bay until July 2000, when the Energy Efficiency and Conservation Act came into force. The main purpose of the act is to promote energy efficiency, energy conservation, and the use of renewable sources of energy. It mandates three areas of activity, as listed below.

- Responsibilities of the Minister of Energy
- Development and implementation of a National Energy Efficiency and Conservation Strategy
- Responsibilities of the Energy Efficiency and Conservation Authority (EECA)

Demand Growth

A major determinant of future supply security is demand growth rates. Over the past 10 years, demand growth has averaged 1.8% per annum. Higher economic growth rates, rising population, and the prospect of more energy intensive projects, such as wood processing, will put upward pressure on demand. This demand will be partially offset by increasing power prices as the Maui gas reserves are depleted, climate change policies are instituted including negotiated greenhouse agreements (NGAs) and a carbon tax, and energy efficiency. However, demand growth would be expected to continue well above 1% despite these measures.

New Generation Capacity

Gas is currently a critical fuel for electricity generation. At present it fuels 22% of New Zealand electricity in a normal hydrology year, rising significantly in a dry year (for example in 2001, it rose to about 30%). The Energy Modelling and Statistics Unit of the Ministry for Economic Development has prepared a cost comparison of the new generation technologies (Figure 15.1), assuming a demand growth of 700 GWh/yr.

Aside from the proposed "Project Aqua" hydro scheme, gas (CCGT) is likely to be the preferred fuel for new generating capacity if it is available on a long-term basis. However, there are uncertainties over the volume of gas likely to be available in the future.

Market Model

The current market model applied to the electricity industry relies essentially on market participants responding to price signals to balance supply and demand over time. As supply tightens (and the probability of dry-year shortages increases), average spot prices (and therefore hedge prices) will rise, signaling the need for and incentivizing construction of new capacity and investment in demand-side management. Commercial pressures are expected to ensure that capital is invested wisely and costs are minimized.

Climate Change

In October 2002, the government announced its policy package for reducing greenhouse gas emissions in response to climate change and the Kyoto Protocol. On 10 December 2002, the Prime Minister, Rt. Hon. Helen Clark, signed the instrument of ratification for the Kyoto Protocol to the United Nations Framework Convention on Climate Change.

15.2 NATIONAL POLICY

Strategy

The core government policy for energy is to ensure its delivery in an efficient, fair, reliable, and environmentally sustainable manner to all consumers. EECA is funded by the government for the purpose of promoting

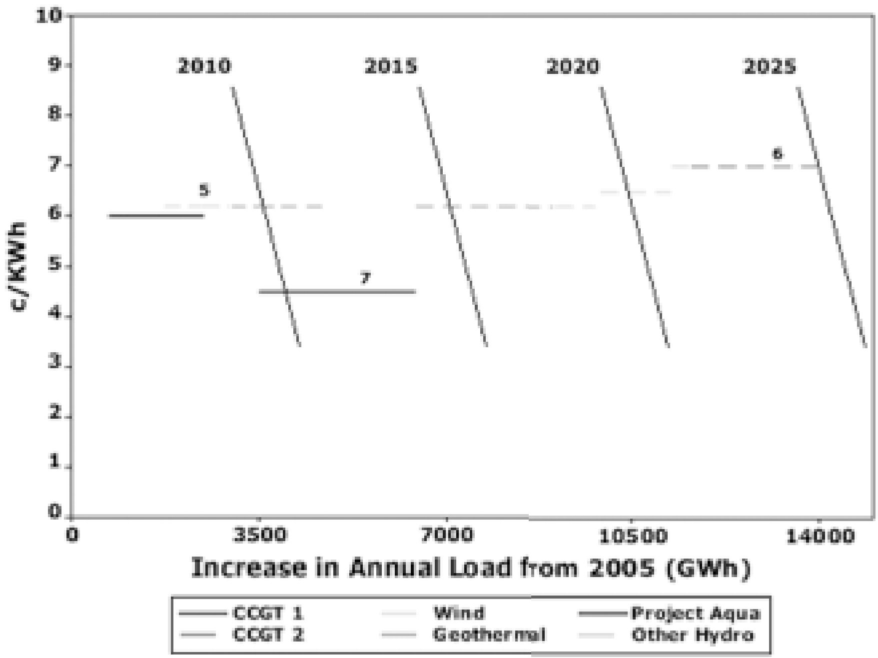

Figure 15.1 Cost of New Generation 2005-2025 (excluding Cogeneration) – note the CCGT2 price is higher due to a carbon tax.

the uptake of energy efficiency, energy conservation, and renewable energy.

The Energy Efficiency and Conservation Act 2000 required the Minister to draft and implement a National Energy Efficiency and Conservation Strategy (NEECS). The purpose of this strategy is to give effect to the government's policy on a continuing improvement in energy efficiency and a progressive transition to renewable sources of energy. The strategy is intended to create a sustainable energy future that will provide all New Zealanders with economic, social, and environmental benefits, and also assist New Zealand to meet its international climate-change commitments.

In September 2001 the government released the National Energy Efficiency and Conservation Strategy (NEECS) -Towards a Sustainable Energy Future. The NEECS contained two high-level targets for 2012.

- Economy-wide energy-efficiency improvement of at least 20%
- Aiming for a growth of 25 PJ to 55 PJ for additional consumer energy from renewable energy sources, with further work required to refine this range

In April 2002, the government released its proposed target for renewable energy and the preferred mechanisms to achieve it. This was subject to a period of public consultation, submission, and further analysis. The 30-PJ (8,333 GWh/yr) target is additional to the supply of consumer renewable energy in 2000. In 2000, renewable energy supplied 133.5 PJ, or 29%, of consumer energy. This means that by 2012 a minimum of 163.5 PJ of consumer energy should be supplied by renewable sources. Included in this target are new renewable energy developments that are likely to occur regardless of the additional incentivization provided through the government's policies.

Although this target is a welcome move, no quantifiable targets have been set for the electricity sector, nor specifically for the wind energy sector.

Progress Towards National Targets

Because the National Energy Efficiency and Conservation Strategy and the Climate Change Programme are newly implemented, no progress towards the target has been made.

15.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Installed wind farm capacity has remained static since June 1999, when the Tararua wind farm was commissioned. New Zealand's installed wind plant comprises three projects:

1. The Brooklyn demonstration wind turbine in Wellington city

This turbine is a sole Vestas V27 of 225-kW rating. The machine, owned by Meridian Energy, has operated well since 1993, setting performance records for its type at the outset. (It still holds the five-year record for its type and size.) Annual output continues to be in the range of 0.85 GWh to 1.05 GWh. Meanwhile, Meridian has announced its intention to develop 200 MW of wind plant in the next three years.

2. The Hau Nui wind farm near Martinborough

This wind farm was built in 1997 and is owned by Genesis Power. The seven Enercon E-40s of 500-kW rating, employ a high (30-m/s) cut-out to take advantage of the high average wind speed (10 m/s). ("Hau Nui" translates from the indigenous Maori language as "strong wind.") A retrofit program was completed in early 2000 to version four of the Enercon E-40. Hau Nui is claimed to be the world's first wind farm built without any form of subsidy or market support. Genesis intends to expand this wind farm by up to 16 more turbines in 2003.

3. The Tararua wind farm near Palmerston North

This wind farm was commissioned in 1999 and is owned by TrustPower Ltd. The 48 Vestas V47 wind turbines of 660-kW rating deliver about 130 GWh annually, making this wind farm the largest in the southern hemisphere. TrustPower proposes to expand this wind farm by an additional 52 to 55 turbines within two years.

Rates and Trends in Deployment

Pre-feasibility studies and site monitoring for a number of further projects have taken place over the last decade. Although no new projects have been built since 1999, there were several preparation activities and announcements throughout 2002, listed below.

- WindCorp request for tenders in April 2002 to develop a wind site north of Wellington
- Genesis announcement in July 2002 that up to a further 16 turbines would be installed at Hau Nui
- Meridian press release in October 2002 stating intention to build 200 MW of wind plant in next three years, comprising two or three large projects
- Wind Farm Developments proposal for 32-unit wind farm at Wainuiomata
- Windflow Technology design and manufacture of demonstration 500-kW wind turbine

Windfarm	Location	No.	Type	Capacity (MW)	Commissioned	Annual Output (GWh/ yr)	Owner
Brooklyn	Wellington	1	Vestas V27	0.225	1993	1	Meridian Energy
Hau Nui	Martinborough	7	Enercon E40	3.5	1997	14	Genesis Power
Tararua	Palmerston North	48	Vestas V47	31.7	1999	130	TrustPower Ltd

Table 15.1 Summary of utility-scale New Zealand wind plant installations as at 31st Dec 2002

The proposed expansion of Tararua wind farm by TrustPower is on hold.

Contribution to National Energy Demand

Wind-generated electricity contributes about 145 GWh annually to New Zealand's grid. This represents approximately 0.37% of the total annual generation of about 39 TWh each year.

15.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The mechanisms listed below have developed within the Climate Change Programme to help implement the NEECS targets.

- Negotiated gas agreements (NGAs)
- Emissions charge from 2007 (capped at 25NZD/ton Carbon monoxide)
- Projects mechanism

The Projects mechanism will be a competitive bid-in fund designed to support a range of Carbon dioxide mitigation projects, including renewable energy. The following criteria are proposed

- Projects will need to show "investment additionality"; i.e., these projects would not otherwise proceed
- Projects will need to show "environmental additionality"; i.e., benefits must be real
- Emissions from the electricity generation sector are considered
- Projects will need to meet minimum size criteria

Further design of the projects mechanism will be carried out until early 2003, with the intention of inviting first-round bids in mid-2003.

Meanwhile, EECA will run the Renewable Energy Programme to implement the remaining NEECS goals. This program is designed to support renewable energy development by engaging with stakeholders and working to minimize the barriers, including those listed here, that inhibit the realization of the full potential of renewable energy.

- Lack of knowledge and information among key parties and decision-makers
- Lack of economies of scale for some technologies.
- Institutional regulatory/planning approaches that might discriminate against some renewable energy opportunities

Unit Cost Reduction

The unit cost of wind energy at the most cost-effective sites in New Zealand lies between 0.05 and 0.08 NZD/kWh, representing some of the cheapest unsubsidized wind power in the world. However, a low exchange rate in recent years has led to a stalling effect on new projects.

New Zealand does not have a competitive wind turbine manufacturing industry. The sole prospective wind turbine supplier, Windflow Technology Ltd., will erect a demonstration turbine in early 2003 at Gebbies Pass near Christchurch.

15.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

A total of 56 grid- connected utility-scale wind turbines are deployed in New Zealand, comprising three separate projects. A summary of these is provided in Section 15.3.

Operational Experience

A total of 220 turbine-years of operation has been gained, involving three turbine types. New Zealand-trained wind energy consultants, engineers, and fitters are currently deployed in several countries.

Main Constraints on Market Development

Following are several market barriers to the development of wind power in New Zealand.

- Low electricity prices and price volatility
- Cost of imported turbines with a low exchange rate in recent years
- Transmission grid pricing system that tends to discourage distributed generation
- Compliance costs for planning approval for those applications requiring public notification under the Resource Management Act (RMA)
- Attentions of the utilities in recent years to electricity industry reform and significant restructuring
- Favorable “take or pay” gas supply contracts available to generators, which tend to undervalue this fuel
- Uncertainty over proposals for new CCGT plants, with the potential to defer need for other new generation, including renewables
- Higher funding within EECA for energy-efficiency programs over new renewables
- Low R&D funding of wind power
- Lack of green-pricing schemes to provide consumer choice for wind power
- Government promises to support a transition to renewables have yet to be delivered; practical details of the national renewable energy target mechanisms have yet to be implemented; there are no market support incentives to date
- Evident bias throughout the energy sector toward further deployment of incumbent technologies, particularly gas generation, to meet future demand growth

15.6 ECONOMICS

Trends in Investment

The wind farm projects to date have been “balance-sheet” funded by the generator owners. To date, no international wind farm developers have projects in New Zealand, although two overseas companies are among the wind site prospectors.

Trends in Unit Costs of Energy and Buy-Back Prices

There is no premium or fixed price offered for wind power in New Zealand, and projects are subject to standard market conditions. The wholesale selling prices for electricity are tabulated in Table 15.2 for the previous six years.

In recent years the cost of generation has averaged 0.047NZD/kWh for electricity, but significant variation is seen according to seasonal parameters such as lake level inflows.

15.7 INDUSTRY

Manufacturing

New Zealand has a good manufacturing infrastructure to support any wind turbine assembly needs. Towers for the existing wind farms were made locally. The northern cities of Auckland and Whangarei have successful boat-building industries that would be able to support rotor blade manufacture. The low New Zealand dollar and a competitive local industry could offer economic manufacturing opportunities to wind turbine suppliers. In addition, the high wind speed sites available in New Zealand could offer cost-competitive and accelerated R&D programs.

Industry Development and Structure

The New Zealand wind energy industry evolved over the last decade to support the construction of the first wind farms. Two companies, Garrad Hassan Pacific and PB Power Ltd., emerged to offer consultancy services to the fledgling industry. It is notable that these companies are now active in several countries. Meanwhile, other existing service companies were engaged to provide financial, legal, engineering, planning, and acoustic expertise. Tower construction, civil engineering, and electrical suppliers were involved in the projects to date. Currently, crane capacity is readily available for installing sub-megawatt-class turbines, and this is likely to be up-rated in the near term for the larger-megawatt-class turbines.

Yearly Average Reference Point Prices (NZD/MWh)			
Node	**Benmore (South Island)**	**Haywards (Wellington)**	**Otahuhu (Auckland)**
Year			
1997	**42.02**	**45.02**	**48.92**
1998	**29.75**	**34.79**	**41.55**
1999	**31.23**	**33.39**	**39.95**
2000	**29.52**	**32.49**	**41.32**
2001*	**80.14**	**79.85**	**77.78**
2002	**35.78**	**40.16**	**43.28**

(*Year 2001 was a "dry-year" for hydro)

Table 15.2 Wholesale electricity prices

In 2001, Windflow Technology Ltd. secured shareholder funding for its launch as a potential wind turbine manufacturer. The company has developed a two-bladed teetered-rotor wind turbine employing a torque-limiting gearbox, first tested in the United Kingdom by the Wind Energy Group Ltd. over a decade ago. Windflow intends to have a 500-kW demonstrator unit erected near Christchurch early in 2003. Local content is being maximized, including rotor blade manufacture in Auckland by Wind Blades Ltd.

15.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The Foundation for Research, Science and Technology (FRST) is the key government agency for the sponsorship of R,D&D. Funding is streamed through several portfolios. Although there is notional support within the energy portfolio for renewable energy technologies, it is notable that wind power has received only a small amount of funding in recent years.

New R,D&D Developments

Windflow Technology Ltd. is developing a wind turbine design for commercialization. The Windflow blades are the first utility-scale rotor blades made in the southern hemisphere. A test blade was subject to proof load and destructive load testing at the University of Canterbury in 2002.

Several academic institutes continue to support post-graduate research in wind energy. These include the Energy Studies Unit at Massey University, the Mechanical Engineering Department at Auckland University, Otago and Canterbury Universities, and several polytechnics.

New Zealand organizations such as Industrial Research Ltd. (IRL) are actively engaged in wind energy research through programs with the Australian Cooperative Research Centre for Renewable Energy (ACRE). The Electrotec unit at IRL runs a 300,000NZD annual program to develop and demonstrate economically viable combinations of renewable small-scale (up to ~10-MW unit size) energy systems and to help develop an infrastructure to build and sell advanced-technology distributed energy products and services in New Zealand and overseas.

Offshore Siting

Potential offshore wind farm sites are available around the New Zealand coastline; however, these are not being pursued at the present time.

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Author: Trevor Nash, Prowind Energy Limited, New Zealand.

Chapter 16
Norway

16.1 INTRODUCTION

In 2002, two wind farms totaling 80 MW were erected, and the interest in wind power as a commercial source of electricity remains high. However, wind turbine installation still faces substantial hurdles such as financing and public acceptance. A recent price hike on electricity in the Nordic electricity market in the late fall of 2002 has increased the general energy interest dramatically and has had somewhat of an impact on wind energy as well. However, since the outlook for long-term electricity prices is still low, this situation in itself is not a strong enough incentive to spur new investments in wind energy.

16.2 NATIONAL POLICY

Strategy

Most electricity production in Norway is based on hydro-power, but because new hydro-power projects are limited in size and quantity, wind energy has become more focused.

The ambition of the Norwegian government is to have an annual electricity production based on wind energy of 3 TWh/year by 2010. This represents approximately 1,000 MW to 1,100 MW of installed capacity, at the average availability of the most favorable sites.

Progress Towards National Targets

Two wind farms of 40 MW each were finalized during 2002. No other wind farms received public funding in 2002. However, a technology implementation grant to a 3-MW, prototype, Scanwind turbine was given in 2002 and will be finalized in 2003. In 2002, wind energy production was approximately 75 GWh, with an estimated full-year production of approximately 292 GWh.

Further developments depend mainly on the long-term electricity market price, public grants in the coming years, and other incentives such as green certificates and tax credits linked to wind energy.

16.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Two wind farms were commissioned during September and October 2002, thus increasing the total installed capacity from 17 MW to 97 MW. The first wind farm consists of 20 turbines, each rated at 2 MW. It is located on the western coast of Norway on the island Smøla, and has an estimated energy production of 118 GWh/year.

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 19 GWh/year (see Figure 16.1).

An overview of the Norwegian wind turbines and the energy production in 2002 is shown in Table 16.1.

Rates and Trends in Deployment

Norway's deployment trend has been rather slow for many years. However, the two wind farms being finalized in 2002 (each rated

40 MW) represent an initial step towards reaching the national target of 3 TWh/year by 2010. However, no other commercial wind farm received financial support in 2002, and therefore the next possible wind farm will at the earliest be constructed in late 2003 or during 2004.

Contribution to National Energy Demand

The total Norwegian electricity generating capacity is approximately 28 GW, of which approximately 99% is hydro-power. The mean energy production from hydro-power is 118.2 TWh/year. Therefore, the contribution from wind power, at estimated full year production, is still only 0.25% of the total production capacity.

16.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

Enova, a government enterprise established in 2002, is in charge of the Norwegian investment program for wind power and a technology implementation program that includes wind technology.

Enova offers investment grants with a maximum of 10% for new wind farms based on a maximum investment cost of 6,000.00 NOK/kW (826,000.00 Euros/MW). Wind farm owners also received a production subsidy of 0.0465 NOK/kWh (6.40 Euros/MWh) in 2002. The Norwegian Parliament decides this premium price annually.

16.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

See Section 16.3, Installed Capacity, and Table 16.1.

Operational Experience

One serious incident occurred in 2002. During the construction period for a wind farm, a nacelle from a megawatt-sized machine fell 80 m – but no one was injured. The incident is reported to be due to a human fault in use of the control system.

Some cases of wind turbine failures due to lightning strikes have been reported, and some cases of fatigue (e.g., in gearboxes) have been reported.

Main Constraints on Market Development

In recent years, interest in wind energy has been high, and several projects have been considered, all of which are along the coastline from Lindesnes in the south and northwards. However, the main constraint has been the low energy price, both for the long term and the short term. Visual and environmental concerns are also major factors, which limit the possible deployment of wind energy in Norway.

16.6 ECONOMICS

Trends in Investment

The unit cost of the Norwegian wind turbines erected in 2002, including infrastructure and grid connection, was approximately 8,300.00 NOK/kW.

Trends in Unit Costs of Generation and Buy-Back Prices

The Norwegian spot-market price of electricity from 1996 to 2002 at the main grid level is shown in Figure 16.1. This price represents the typical buy-back price for wind-generated electricity delivered to the grid transmission system. The average price on a yearly basis did, mainly due to ample supply of hydro-power, steadily decrease

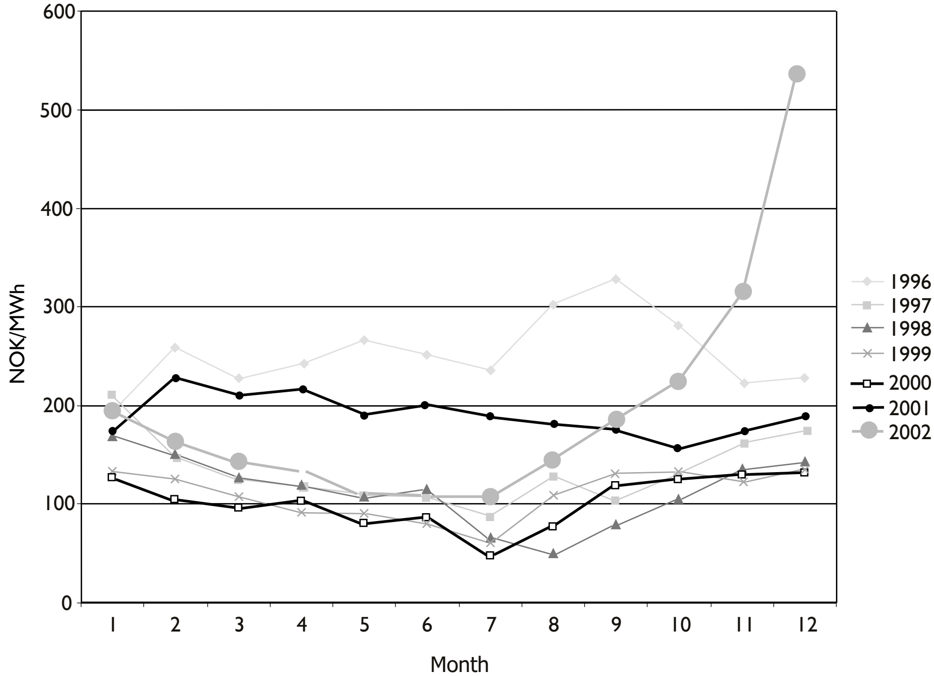

Figure 16.1 Norwegian spot-market price of electricity from 1996 to 2002 at the main grid level

from 1996 to 2000, but it showed a slightly higher level in 2001. The year 2002 began like recent years, but at the end of 2002, the average price in December was as high as 550.00 NOK/MWh. However, because long-term electricity prices are still low, this situation in itself is not a strong enough incentive to spur new investments in wind energy.

During 2001 and 2002, several interesting commercial agreements were made based on export of wind energy produced in Norway to the European market, with a premium price on wind energy. It is anticipated that the focus on international renewable energy trade will keep investment focus high in Norway in the years to come.

In order to estimate the final wind energy price, the energy consumer must include costs to cover transmission and taxes, in addition to the spot-market price.

Estimations on production costs from sites with favorable wind conditions suggest a production cost as low as 250.00 NOK/MWh to 300.00 NOK/MWh, including capital costs, operation, and maintenance. Thus, compared to the spot-market electricity price, wind energy, on average, cannot yet compete on current commercial terms. However, compared to the price of new hydro-power projects, some wind energy projects are almost competitive.

16.7 INDUSTRY

Manufacturing

Currently, there are no manufacturers of complete wind turbines in Norway.

Wind Turbine Projects	Year	No. Units	Total Power (KW)	Production 2002 (GWh)
Frøya	1986	1	55	0.02
Frøya	1989	1	400	0.79
Vallersund	1987	2	75	0.14
Kleppe	1988	1	55	0.04
Smøla	1989	1	300	0.43
Andøya	1991	1	400	0.77
Vesterålen	1991	1	400	0.58
Vikna I & II	1991/ 1993	5	2,200	5.98
Hundhammarfjellet	1998	1	1,650	2.77
Lindesnes	1998	5	3,750	8.93
Sandøy	1999	5	3,750	8.15
Kvalheim	2001	5	4,000	10.20
Smøla	2002	20	40,000	23.54
Havøygavlen	2002	16	40,000	13.18
TOTAL		65	97,035	75.52

Table 16.1 Norwegian 2002 wind turbine projects and energy production

However, the Norwegian/Swedish company Scanwind Group AS (SWG) is developing 3-MW wind turbines for directly driven generators with low maintenance in parks with difficult access. The turbines will be fully controlled (pitch/variable rpm) and linked to a main shaft system developed by SWG. The first prototype installations are expected to be ready during 2003.

The Umoe-group, a Norwegian-based investment company, recently decided to produce large wind turbine blades. It will be an independent blade sub-supplier to wind turbine manufacturers and deliver blades to megawatt-sized pitch turbines. The objective is to be competitive on the world market.
In order to be fully competitive, Umoe also focuses on cost-saving technologies of the product and production process. Composite laminates used today are typically made of glass polyester or carbon epoxy, but Umoe has a project that will evaluate the application of low-cost, vinyl ester materials for wind turbine blades. In addition, new weaving techniques allow the direct application of thick reinforcements without building up many layers. The project will be finalized during the end of 2004.

16.8 GOVERNMENT-SPONSORED R,D&D

Priorities

Enova SF coordinates public support to projects in close collaboration with the Norwegian Research Council. Current priorities include projects close to market introduction, and researchers should have an industrial partner in the project, where appropriate.

New R,D&D Developments

The following 2002 wind energy projects were partly financed by the Norwegian Research Council and/or Enova SF.

- Pitch-control sensor to be applied on wind turbine blades: The company SensIT AS launched a project to develop a pitch-control system for wind turbines. This will be based on the continuous collection of stress and torsion measurement values, correlated to wind speed and generating capacity.
- Test station for wind turbines: In order to assist the development of wind energy in Norway, SINTEF Energy Research, the Institute for Energy Technology (IFE), and the University in Trondheim (NTNU) took a joint initiative in 2001 to develop a test station for wind turbines on the western coast of mid-Norway. However, the actual construction of the test station has been delayed due to difficulties in obtaining the required private financing to balance the public grant. It is expected that the installation work will take place during 2003.
- Strategic Institute Program (SIP) at IFE: Activities are focused on the further development of the micro-scale flow solver 3Dwind (i.e., improvement of pre and post processing and solver algorithms). Numerical investigations were carried out with a focus on wind development in complex terrain, which is typical for Norwegian wind parks. Numerical results have been verified with measured data, and these results provide a quantitative good prediction for occurring wind-flow patterns.

Author: Harald Birkeland, Norwegian Water Resources and Energy Directorate, NVE, Norway.

Chapter 17
Spain

17.1 INTRODUCTION

The year 2002 showed continued solid growth of installation of wind energy plants in Spain, providing 1,440 megawatts (MW) of new capacity to the Spanish energy system structure.

Spain maintains a position as wind energy leader in the world, together with Germany and the United States. At the end of 2002, wind power in operation in Spain totaled 4,635 MW. Electricity generation by wind energy represents more than 3.8% of total electricity, and the goal is to have 13,000 MW grid-connected at the end of 2011.

The main reason for this growth is the existence of a stable legal framework for electricity producers that use renewable energy sources. The regulations contained in the Special Regime of the Electrical Sector Act state that electricity producers using wind have guaranteed access to the grid. The price per kilowatt-hour (kWh) generated has a bonus over the sale price of electricity.

New manufacturers, investors, producers, and researchers have been incorporated into the wind energy business in the past year.

17.2 NATIONAL POLICY

Spain is greatly dependent on external sources of energy. Table 17.1 shows the energy balance in the mainland electricity system (no data are included for the islands) during the past three years (2000 to 2002). During 2002, electricity demand was 2.3% higher than in 2001, with an amount of 210 terawatt-hours (TWh).

The Program for Promotion of Renewable Energies (PPER) was prepared by the national Diversification and Energy Saving Agency (IDAE) and is the response to the undertaking law 54/19976 on the Electricity Sector, which

Figure 17.1 Sierra del Trigo wind farm

Energy balance in the electricity system	2000	2001	2002
Source	GWh	GWh	GWh
Hydro	27,842	39,538	21,654
Nuclear	62,206	63,718	63,095
Coal	76,374	68,029	80,082
Oil/Gas	10,249	11,658	21,840
Special Regime (including renewables)	26,613	30,411	18,492
Import			5,603
Electricity Demand	194,992	205,414	21,0135

Table 17.1 Energy balance in mainland electricity system (2000 to 2002)

defines the target of achieving at least a 12% contribution to electricity demand in Spain from renewable energies by 2010.

Strategy

The strategy of the Spanish government is summarized in the PPER. The wind energy target for 2010 was to reach 8,974 MW installed, with an average production of 21.5 TWh/year (equivalent to 1,852 ktep). This target has been modified ("Electricity and Natural Gas Plant: Transmission Grid Development: 2002-2011"), and the new figure is 13,000 MW for the year 2011, contributing 28.6 TWh to the electricity demand. The new target represents an increase of 45% over the previous goal set in 1999.

The Electrical Special Regime for Renewable Energy Plants connected to the grid fixed the price and the bonus of the electricity produced by renewable energy plants. The price will be updated every year.

A complement to the PPER is the National Plan for Scientific Research, Development and Technological Innovation (2000-2003).

Progress Towards National Targets

The new target, 13,000 MW for the year 2011, looks to be realistic. On the other hand, the majority of the autonomous communities have regional wind energy programs that give a total figure of more than 30,000 MW to be installed in the next decade (exceeding the governmental target).

17.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

In 2002 another 1,440 MW was installed, and the total power at 31 December 2002 was 4,635 MW.

Rates and Trends in Deployment

Annual power installed continues to grow. Figure 17.2 shows the annual power installed in Spain, and the accumulated power, in past years. The increased rate of power installed in 2002 versus 2001 was 67.2%, which is a record.

The new wind farms are of large and medium sizes and are located on the mainland. They are owned primarily by consortiums formed by utilities, regional institutions involved in

AUTONOMOUS COMMUNITY	Potential Wind Capacity in 2011 (MW)
ANDALUCIA	4,000
ARAGÓN	3,200
ASTURIAS	500
ISLAS BALEARES	49
ISLAS CANARIAS	250
CANTABRIA	300
CASTILLA Y LEÓN	6,579
CASTILLA-LA MANCHA	4,452
CATALUÑA	1,073
EXTREMADURA	-
GALICIA	4,000
MADRID	50
MURCIA	600
NAVARRA	1,536
LA RIOJA	665
VALENCIA	2,820
PAÍS VASCO	250
TOTAL	30,325

Table 17.2 Wind potential identified in the programs of the Autonomous Communities

local development, private investors (national and foreign), and, in some cases, the manufacturers. Private individuals are not taking an important role in the development of wind energy in Spain.

At the present time, almost all the Spanish autonomous communities are incorporating wind energy into their energy structures. Galicia, Castilla-La Mancha, Castilla-Leon, and Aragón are the autonomous communities that had more activity during 2002.

Contribution to National Energy Demand

The production of wind-power plants for 2002 was about 8 TWh. The increase in energy production was 40% above 2001, when the energy produced by wind-power plants was 5.69 TWh (National Energy Commission). The total electricity demand in Spain in 2002 was 210 TWh.

Wind-powered electricity reached about 3.8% of the total electricity demand in the country.

17.4 MARKET DEVELOPMENT AND STIMULATION

The main action for market stimulation is the price paid for electricity generated by RES. The price is regulated through two royal decrees (the latter approved in December 1998) obliging utilities to pay a guaranteed price to RES generators for a five-year period. These prices and the related bonus are revised and fixed every year, taking into ac-

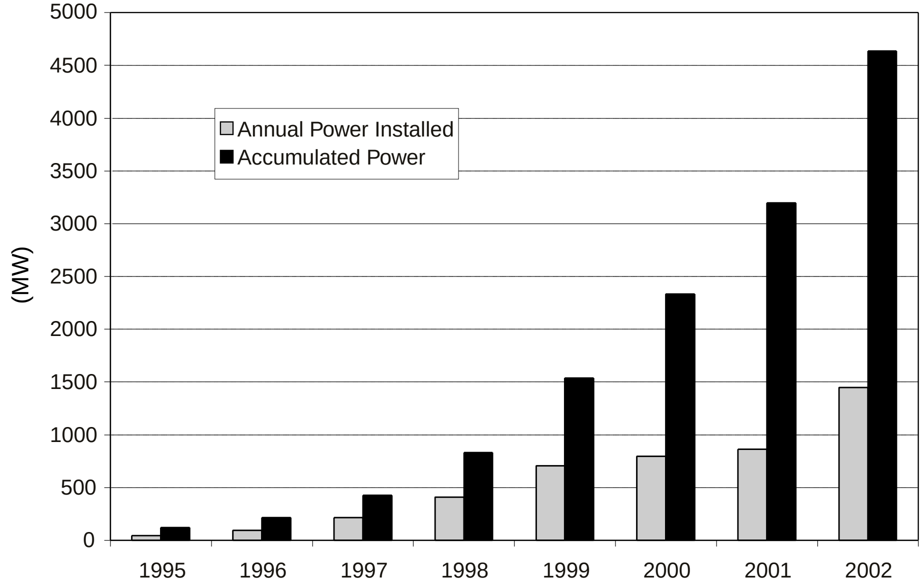

Figure 17.2 Wind power in Spain

count variation in the electricity market price and other factors.

17.5 DEPLOYMENT AND CONSTRAINTS

The strong growth of installed power is welcomed by a society that appreciates not only the contribution to environmental conservation but also industrial development and associated job creation. Job creation is the most important benefit of wind energy for the Spanish populace. Also, benefits obtained at the local level (landowners and municipalities) favor the development of new installations.

Conditions for developing wind projects in Spain are regulated under the law of the Special Regime for Electricity Production (December 1998). The grid operator (REDESA, a national public company) and the utilities are obligated to allow the connection of wind turbines to the grid. Developers must fulfill the technical require-

Year	Power Installed (MW)	Accumulated Power (MW)	Annual Growth Rate (%)
1995	46	119	-
1996	95	214	106.5
1997	213	427	124.2
1998	407	834	91.1
1999	705	1539	73.2
2000	795	2334	12.8
2001	861	3195	8.3
2002	1440	4635	67.2

Table 17.3 Accumulated wind power (1995 to 2002)

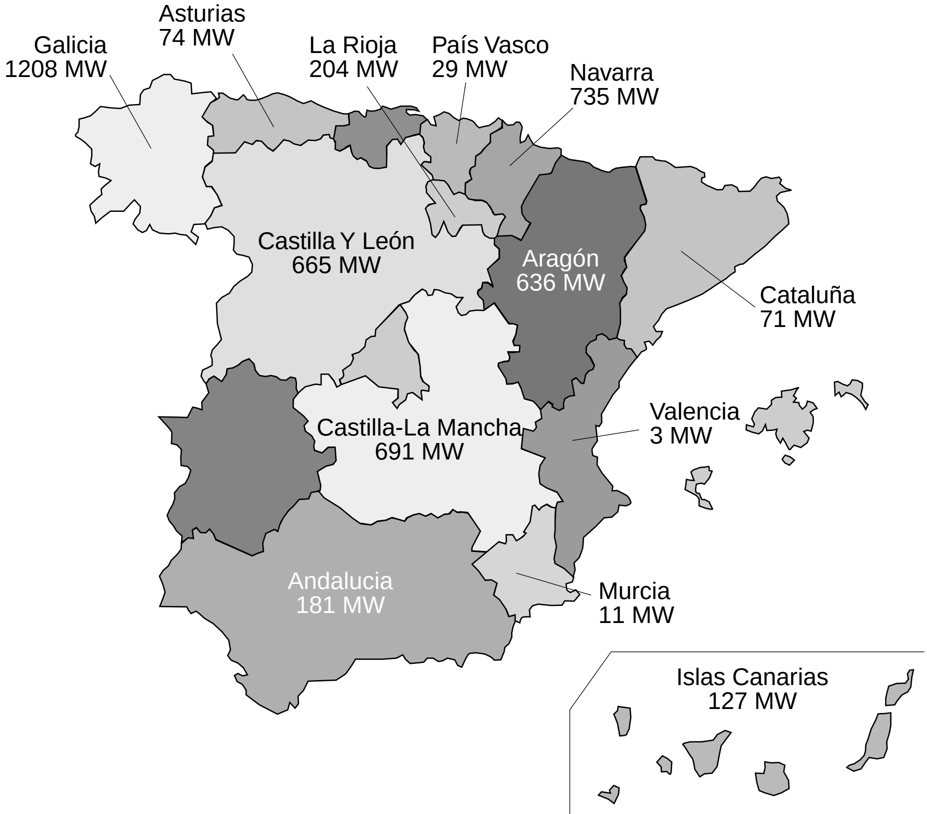

Figure 17.3 Regional distribution of wind installations (31 December 2002)

ments defined in the electrical law. The costs associated with connection are the responsibility of the plant developer. There are no widespread complaints about the process of obtaining permission to connect to the grid.

Wind Turbines Deployed

Figure 17.4 shows the share by manufacturers of the wind turbines in the Spanish market for 2002. The average size of the wind turbines installed has risen from 721 kW in 2001 to the present size of 808 kW. Table 17.4 provides a list of the wind turbines installed in the new wind farms.

Operational Experience

At the time this report was being written, information was not available about the yearly operational results of Spanish wind farms in 2002 (capacity factors, equivalent hours at rated power, cost of operation and maintenance, etc.). However, information about the instantaneous production of Spanish wind farms (and historical data of previous periods) is available on the Internet at www.ree.es.

Autonomous Communities	Total Power 31/12/2001 (MW)	Power Installed in 2002 (MW)	Total Power 31/12/2002 (MW)
Andalucía	156	25	181
Aragón	400.6	235	635.6
Canarias	117	10	127
Castilla La Mancha	421	270	691
Castilla y León	361	304	665
Cataluña	71	0	71
Galicia	888	320	1,208
Murcia	11	0	11
Navarra	639	96	735
La Rioja	74	130	204
C. Valencia	3	0	3
País Vasco	29	0	29
Principado de Asturias	24.4	50	74.4
TOTAL	3,195	1,440	4,635

Table 17.4 Wind turbines installed in the new wind farms

Main Constraints on Market Development

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 population density, and the grids are weak grids that require reinforcement and improvement. Concerted actions to solve the problem are ongoing between utilities and developers.

Last year, some opposition emerged against the installation of new wind farms in areas with strong development. This was launched by local ecology groups concerned about impact on the landscape and the possible impact on bird life. The opposition causes delays in the permitting of wind farms.

17.6 ECONOMICS

Trends in Investment

No information available.

Trends in Unit Cost of Energy and Buy-Back Prices

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 energies as the primary source, with installed power equal to or lower than 50 MW, could be included in that regime. The regime gives two choices to the producers. One is a fixed priced for the kilowatt-hours generated, and a second option is a variable price calculated from

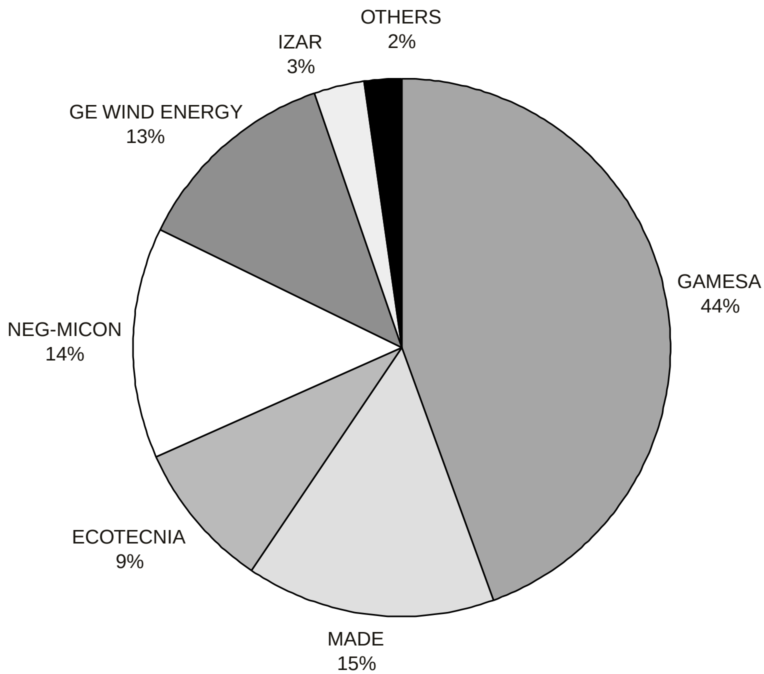

Figure 17.4 Share by manufacturers of the Spanish market in 2002

the average price of the market pool, plus a bonus per kilowatt-hour produced. The fixed price and the bonus will be updated every year by the Spanish Ministry of Economy in accordance with the annual variation of the market price.

The updated values for 2002 and 2003 are presented in Table 17.5.

To date, the fixed price has given lower returns than the premium and has not been popular. The bonus is paid on top of the market price based on the Spanish pool price. The government policy for the buy-back of the electricity produced for the wind plants is to lie between 80% and 90% of the pre-tax consumer price. Since pool prices

	2002		2003	
RENEWABLE SOURCE	**Bonus added to the base price (Euro/MWh)**	**Fixed price (Euro/MWh)**	**Bonus added to the base price (Euro/MWh)**	**Fixed price (Euro/MWh)**
Small Hydro	**30.051**	**63.827**	**29.450**	**64.849**
Wind Plants	**28.969**	**62.806**	**26.625**	**62.145**
Primary Biomass *	**27.887**	**61.724**	**33.236**	**68.515**
Secondary Biomass *:	**25.781**	**59.620**	**25.122**	**60.522**

(*)Primary Biomass: Agricultural crops
Secondary Biomass: Agricultural and Forest residues

Table 17.5 Buy-back electricity prices for RES in 2002 and 2003

have been rising, wind prices during 2002 have followed that tendency, and the buy-back price has exceeded the limit by three points (93%). As a consequence, for 2003 there is a reduction in the bonus added of 8.1% versus 2002, and a reduction of 1.1% in the fixed price.

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: blades, generators, gear-boxes, towers, wind sensors, etc. Also, the service sector (installation, maintenance, engineering) has grown in the past year.

New factories for components manufacturing began operation during 2002 (blades, towers, and gearboxes), and a large number of jobs were created, with special emphasis in the region of Castilla-Leon.

Manufacturing

The companies that are leading the national Spanish industry are Gamesa Eólica, Ecotécnia, Made, Izar, GE Wind Energy, and Neg-Micon. Other manufacturers are initiating their activities in Spain as DeWind or Nordex. Table 17.6 shows the list of wind turbines larger than 100 kW on the Spanish market:

Gamesa Eólica is the leading company in the Spanish market, with a share in the past year of about 44% of the market. The company

MANUFACTURER	MODEL	RATED POWER (kW)
ECOTECNIA	ECOTECNIA 44	640
ECOTECNIA	ECOTECNIA 48	750
ECOTECNIA	ECOTECNIA 62	1,300
ECOTECNIA	ECOTECNIA 74	1,640
MADE	AE-46	660
MADE	AE-52/56/59	800
MADE	AE-61	1,320
GAMESA	G-47	660
GAMESA	G-52/58	850
GAMESA	G-80	2,000
IZAR		600
IZAR		1,000
IZAR		1,300
GE Wind Energy	900 s	900
GE Wind Energy	1.5 s/s1	1,500
MTORRES		1,500
NEG Micon	NM750/48	750
NEG Micon	NM900/52	900

Table 17.6 Wind turbines (>100 kW) on the Spanish market

manufactures wind turbines between 660 kW and 2 MW and also manufactures the majority of the components (blades, nacelles, gearboxes, towers, etc). There are 10 subsidiary factories from Gamesa Eólica working in the country, with a total of 1,231 employees.

Gamesa is developing new models (G52 RCC 800 kW and G80 RCC 1.8 MW) using a newly developed electronic power control system (rotor current control) to optimize the efficiency of the system according to specific site conditions.

During 2002, the company supplied 854 MW to the Spanish market for new wind farms, and another 88 MW to foreign markets. The present annual capacity production of the company is over 1,700 wind turbines.

At the present time, the company is increasing the commercialization of its products worldwide, and has opened commercial offices in several countries (United States, Canada, Germany, Italy, France, Brazil, Portugal, Greece, etc).

Ecotécnia started activities in wind technology development in 1981, having more than 20 years of experience in that field. The company has a technical staff of 60 persons and has two factories, one located in Somozas (La Coruña) and the other in Buñuel (Navarra), with a total of 267 workers. Ecotécnia was incorporated in 1999 with the MCC group, one of the world's biggest cooperatives, with activities in the industrial, distribution, and financial sectors.

The models in production are the ECO/44/640 kW, the ECO/48/750 kW, the ECO/62/1300 kW, and the ECO/74/1670 kW. The company is developing new models 80 meters (m) in diameter with rated power of 1,670 kW and 100 m in diameter model with rated power of 2,500 kW. The present annual capacity production of the company is 500 MW.

During 2002, Ecotécnia supplied 225 wind turbines with a total power of 170 MW. The company already has orders to install another 154 units during 2003, for a total of 234 MW.

Made is another pioneering company in Spain that since 1982 has developed ten

Figure 17.5 Ecotécnia 62/1300 nacelle

models of wind turbines, going from the first design (24 kW) to the most recent, AE-61, at 1,320 kW. At the present time Made is developing a new 90-m-diameter wind turbine, 2-MW rated power (Class II).

The new designs of 800-kW rated power – Made AE-52 (Class I), Made AE-56 (Class II), and Made AE-59 (Class III) – are pitch-controlled wind turbines of variable-speed design using synchronous generators. The AE-61 (Class I) is a stall-controlled, asynchronous-generator wind turbine. The present annual capacity production of the company is 750 MW.

During 2002, Made supplied 392 wind turbines with a total power of 287 MW. The company expects to install about 450 MW in 2003.

Izar is manufacturing 600-kW, 1-MW, and 1.3-MW models of Bonus technology in its factory located in El Ferrol (La Coruña). Izar is also developing two new models of 2 MW and 2.3 MW. The present annual capacity production of the company is over 200 MW.

Figure 17.6 Made AE/61 model

During 2002, the company installed 87 units of the 600-kW model and another 6 units of the 1.3-MW wind turbine. During the first quarter of 2003, another 40 units of the 1.3-MW model will be connected to the grid – 26 units on wind farms in Spain and the other 14 on a wind farm in Portugal. The company expects to install 277 MW during 2003.

GE Wind Energy is producing 900-kW and 1,500-kW models (70.5 m and 77 m rotor diameter, respectively). GE has installed the first prototype of the 3.6-MW model, designed for offshore installations, in Barrax (Albacete).

During 2002 GE Wind Energy supplied 156 wind turbines with a total power of 237,6 MW. The company expects to reach a share of 16% for the Spanish market for 2003.

NEG Micon Iberica S.A. has three factories in Spain. The company has 104 workers and is manufacturing models NM/900/52 and NM/750/48. The company is preparing to manufacture model NM/1500/62, which will be on the market at the end of 2003.

During 2002, NEG Micon Iberica S.A supplied 343 wind turbines with a total power of 266.7 MW, plus another 11 wind turbines for the Portuguese market.

M. Torres company has developed a prototype of a 1,500-kW, upwind, multi-pole generator, pitch-regulated turbine that will start commercialization during 2003. The company expects to install 20 MW during 2003.

Figure 17.7 GE Wind Energy 3.6-MW prototype (Barrax-Albacete)

In the sector of small wind turbines, Bornay is the company leader, with more than 177 units installed during 2002 in the Spanish territory, and another 34 units for the international market (Germany, Portugal, Japan, Tanzania, etc). Bornay is manufacturing six models from 60 W to 6 kW. The company is developing new models of 7.5 kW, 15 kW, 30 kW, and 50 kW.

The company Solener is also manufacturing small wind turbines with nine models on the market, going from 300 W to 15 kW. The company is already developing new prototypes of 25 kW and 40 kW. During 2002 Solener supplied 150 wind turbines to the market.

Other companies, like Aitesa and Ecotécnia, are marketing small wind turbines using foreign technologies form Vergnet (France) and Bergey (United States), respectively.

Industry Development and Structure

New Spanish manufacturers are active in the wind energy industry, using foreign technology (as Nordex or DeWind) or developing their own technology (M. Torres) that will increase the capacity of the Spanish industry to fulfill not only the internal market but also other markets.

Spanish manufacturers are very actively participating in future projects not only in the Spanish market but also in other countries. The wind industries are spread throughout the Spanish territory (almost all the autonomous communities are involved in the development of wind energy industry), and new factories manufacturing components for the industry have been inaugurated during 2002.

Table 17.7 shows the new prototypes larger than 1 MW under development by the Spanish industries.

17.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The target areas defined in the National Plan for Scientific Research, Development and

Technological Innovation (2000-2003) of the Ministry of Science and Technology for wind energy projects are the following:

- Environmental impact reduction of wind systems
- Technology cost reduction
- Technology development for large wind turbines (1 MW to 2.5 MW)
- Small wind turbines for isolated applications
- Remote-control systems for grid connection
- Wind-power penetration in weak grids

During the period 2000 to 2002, more than 70 projects were submitted to the program, covering all the areas stated in the plan. The most projects were for technology cost reduction (26 projects) and large wind turbines (17 projects). Nineteen projects received the support of the program with a total budget of 3.2 million €. Projects were presented mainly by industrial companies in co-operation with engineering companies and research centers.

New R,D&D Developments

The centers and universities involved in R&D projects have continued and have increased their activities during 2002 (see Table 17.8). Utilities are also very active in the development of research projects, mainly related to specific aspects of electricity production from the wind plants and problems associated with the impact on the grid.

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 Energies (DER) is stressing activities in the field of autonomous wind systems, with a broad field of activity from the development of components (small wind turbines, flywheel storage systems, control management units, etc.), to the testing of wind turbines, components (gearboxes, generators, and blades), and the whole system, in the test plant located in the CEDER center in Soria.

At the end of 2002, seven small wind turbines of different technologies, ranging from 1 kW to 50 kW, were in the testing phase being measured for power performance characterization, durability, and noise emissions.

During 2002 operation began of the hybrid wind-photovoltaic (PV) CICLOPS system, developed by Ecotécnia, using a 10-kW Bergey wind turbine and a 5-kW PV array.

Also, a new facility for flywheel testing was installed at CEDER. In April CEDER held a

MANUFACTURER	MODEL	RATED POWER (kW)
ECOTECNIA	ECOTECNIA 80	1,670
ECOTECNIA	ECOTECNIA 100	2,500
MADE	AE-90	2,000
GAMESA	G-83/87/90	2,000
GE Wind Energy	GE 3.2 s	3,200
GE Wind Energy	GE 3.6 s	3,600
MTORRES		2,500
NEG Micon	NM1500/62	1,500

Table 17.7 Wind turbines (>100 kW) under development by the Spanish manufacturers

Figure 17.8 CEDER-CIEMAT test plant

meeting of experts supported by Annex XI called Power Performance of Small Wind Turbines Not Connected to the Grid.

The new center Centro Nacional de Energías Renovables (CENER), located in Navarra, also participated in by CIEMAT, will cover activities in the field of large wind turbine testing, blade developments, control systems, and wind forecasting techniques.

The number of university departments working on wind projects is rapidly increasing. In particular, the Politechnical University of Madrid continues work studying wakes in wind turbines, electrical systems, and blade technology. Vigo University is developing a simplified methodology for flicker analysis and voltage and frequency variations in wind farms. The University of Las Palmas (Canary Islands) works on wind farms' impact on grid stability and on desalination plants powered by wind energy systems. The University of Navarra continues its research on lightning and wind turbines.

Other research centers are also very active; for example, ITER and ITC in the Canary Islands are both involved in R&D projects in desalination of seawater using wind energy plants.Table 17.8 lists the main research centers involved in wind R&D projects.

Author: Félix Avia Aranda, Departamento de Energías Renovables, CIEMAT, Ministerio de Ciencia y Tecnología, Spain.

Table 17.8 List of research centers involved in R&D in wind energy

CENTRE	FIELD OF RESEARCH	CONTACT PERSON
Department of Renewable Energies CIEMAT	• Autonomous Wind Systems • Small Windturbines Testing • Storage Systems • Wind Forecasting	D. Ignacio Cruz Cruz Avd. Complutense 22, 28040 Madrid Phone: +34-91-346-6254, Fax: +34-91-346-6037 E-mail: ignacio.cruz@ciemat.es
Centro Nacional de Energías Renovables (CENER-CIEMAT)	• Windturbines Testing • Components Testing • Wind Forecasting	D. Javier Sanz C/ Arcadio Maria Larraona 1, 31008 Pamplona, Navarra Phone: +34-948-25 28 00/ Fax: +34-948-27 07 74 E-mail: javiersanz@cener.com
(I.T.C.) Instituto Tecnológico de Canarias	• Hybrid Systems • Water Pumping • Sea water Desalination • Small WT	Prof. D Gonzalo Piernavieja C/ Cebrian 3, 35003-Las Palmas de Gran Canaria Phone: +34-928-452018/Fax: +34-928-452-007 E-mail: gpiernavieja@itccanarias.org
I.T.E.R. Instituto Tecnológico y de Energías Renovables Santa Cruz de Tenerife	• Hybrid Systems • Water Pumping • Water Desalination • Small WT	Ing. D. Manuel Cendagorta Polígono Industrial de Granadilla Santa Cruz de Tenerife, 38594- Tenerife Phone:+34-922 - 391000/Fax:+34-922 - 391001 E-mail: mano@iter.rcanaria.es
Politechnical University of Madrid E.T.S.I.I. Department of Fuidomechanic Engineering	• Wind Resources • Wind turbine Wakes • Wind Farm Modeling • Wind Turbulence	Prof. D. Antonio Crespo C/ Jose Gutierrez Abascal 2, 28006-Madrid Phone:+34-91-336-3152(30.23)/Fax:+34-91-336-3006 E-mail: crespo@enerflu.upm.es

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Continued – Table 17.8 List of research centers involved in R&D in wind energy

University of Mondragón **Dpto. de Electrónica Escuela Politécnica Superior**	**• Wind Turbine Control**	**Prof. Miguel Angel Vidal Rodriguez** **C/ Loramnedi 4, Apdo. 23, 20500 Mondragón- Guipuzkoa** **Phone: +34 943 794700** **Fax: +34 943 7911536** **E-mail: marodriguez@eps.muni.es**
Universidad Pública de Navarra	**• Lightning in WT**	**Prof. D. Blas Hermoso** **C/ Campus Arrosadía, 31006-Pamplona** **Phone:+34-948-169330/Fax:+34-948-169281** **E-mail: hermoso@unavarra.es**
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Fundación LEIA **Centro de Desarrollo Tecnológico**	**• Small Wind Turbines**	**D. Oscar Garay** **Parque Tecnológico de Alava** **C/Leonardo da Vinci 11, bajo, 01501 Miñano, (Alava)** **Phone: + 34 945 298144** **Fax. +34 945 298217** **E-mail: itziarv.leia@sea.es**
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Chapter 18
Sweden

18.1 INTRODUCTION

Sweden has a good wind energy resource, although deployment has previously been slow. However, during the last couple of years deployment and development of wind-power technology have sped up, in accordance with implemented investment subsidy programs. One of the most important factors for wind energy deployment is the economic terms, now being revised, for renewables on the deregulated market.

18.2 NATIONAL POLICY

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 effects 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 hydro-power resources give crucial importance to the development and market introduction of alternative energy sources, as well as successful energy-efficiency measures. 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 10 TWh of electricity production from wind power in 2015, provided that economic conditions for wind-power investments are sufficient. The purpose of the target is to remove planning and permission obstacles for the implementation of wind-power plants.

An electricity certificate system will be introduced in 2003 to improve the conditions for electricity from renewable energy on the liberalized electricity market. During 2002, preparations to implement the system were made at the Swedish Energy Agency and Svenska Kraftnät (the utility that owns and operates the national electricity grid).

Strategy

An extensive energy policy program has been started to facilitate the restructuring and development of the energy system. The main thrust of this work is in the form of substantial long-term concentration on research, development, and demonstration of new energy technology.

Over one billion Euros have been allocated to the program, which consists of two parts. The first part lasts seven years and is a research, development, and demonstration program aimed at promoting renewable energy sources, new conversion, and new end-use energy technologies. These long-term efforts will focus on new technology development of bio-fuel fired CHP; bio-fuel supply and ash recycling; new processes for extracting ethanol from forestry raw materials; alternative motor fuels; wind power; and solar and energy efficiency in buildings, industry, and the transportation sector.

The second part of the energy program is to replace the electricity production loss of about 4 TWh from the Barseback nuclear power plant. This part, finalized during 2002, is a five-year, short-term subsidiary program to promote electricity production from renewable energy sources such as bio-fuels, wind, and small hydro-power plants, and to promote energy efficiency. The wind-power investment subsidy program will, however, continue during 2003 until the resources have been used.

The total cost for the two-part effort is 1.07 billion Euros, of which 0.6 billion Euros are allocated to the long-term research, development, and demonstration program.

The responsible authority for transforming the Swedish energy supply system into an ecologically sustainable system is the Swedish National Energy Agency (SNEA), which was formed on 1 January 1998.

As for wind energy, the government is supporting the development and installation of wind turbines in three programs managed by the SNEA. These problems are as follows.

- A new research and development program with a three-year budget of about 90.00 MSEK for 2002 to 2004. The program is presented in Section 18.8.
- A development and demonstration program for wind systems, with a maximum of 50% support.
- An investment subsidy program operating since 1997 that may receive 10% of the total investment cost. The program's 2002 budget was 100.00 MSEK.

The utilities are engaged in studies, demonstrations, and evaluation projects. Since 1994, the utilities' research and development activities have been 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 the five-year investment subsidy program (July 1997 to June 2002) was 0.5 TWh of wind electricity production. The program was extended in 2001 and 2002 with an increased budget, and will continue in 2003 until the money is used up. The 0.5-TWh target was reached at the end of 2002.

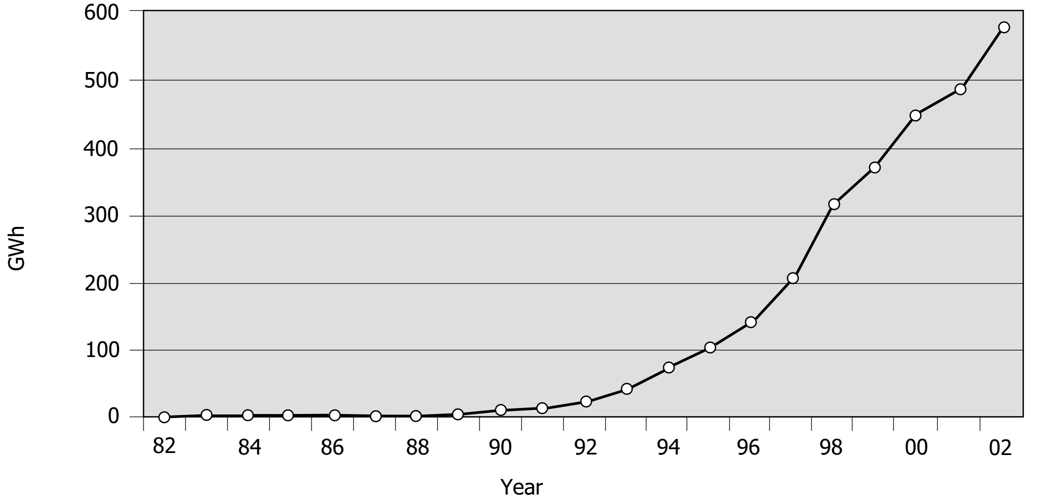

Figure 18.1 Wind-power generation (GWh)

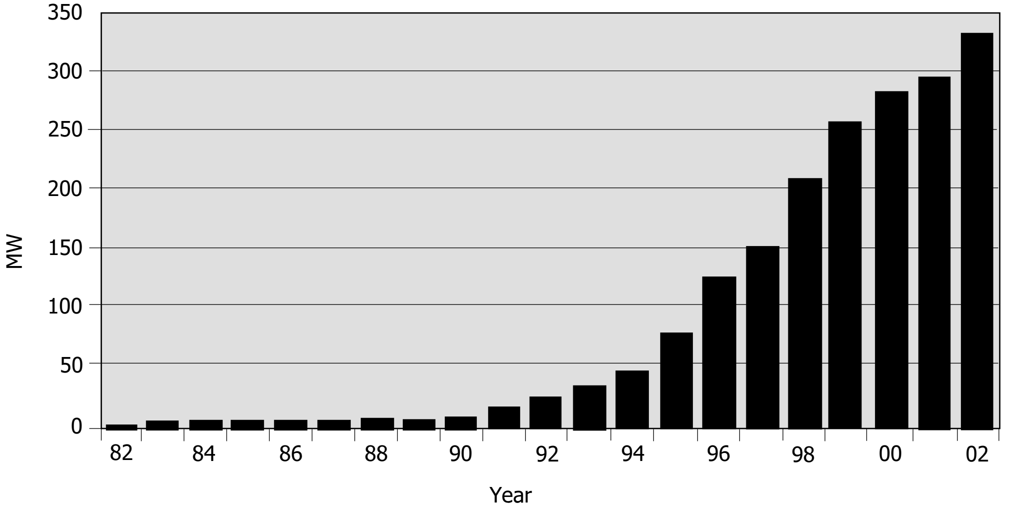

Figure 18.2 Wind-power capacity (MW)

18.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The expansion of the annual power generation from wind turbines in gigawatt-hours is shown in Figure 18.1. The installed capacity in megawatts at December 31 each year in Sweden is shown in Figure 18.2.

The total installed wind-power capacity in Sweden is 331 MW as of 31 December 2002, an increase of 41 MW, or 14% since 31 December 2001. During 2002, the number of wind turbines increased by 40, or 7%, to 610 turbines. Wind-power generation during 2002 was 565 GWh, an increase of 17% since 2001 (483 GWh). The year 2002 was a nearly normal wind year in Sweden, at 98% of normal. Wind-power generation recalculated to a normal year is 577 GWh.

Rates and Trends in Deployment

No wind turbines in Sweden are erected today without the investment subsidy. Deployment has been more or less evenly distributed over the years, since the investment subsidy budget is evenly distributed. During 2002 the budget was 100.00 MSEK.

Contribution to National Energy Demand

Wind power contributes to the national energy demand with 0.3% of the total electricity production. See Table 18.1 for the total installed electricity capacity and generation in Sweden.

18.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

During the 1990s, the Swedish electricity market was reformed in several steps. Since 1 January 1996, Sweden has had a liberalized electricity market. All consumers are free to choose their electricity supplier. The objectives of the reform have been to increase freedom of choice for electricity consumers and to create conditions for greater pressure on prices and costs in electricity supply.

	2001 (MW)	2001 (TWh)	2002 (MW)	2002 (TWh)
Hydro-power	16,229	77.9	16,239	66
Nuclear power	9 439	69.0	9,436	65.6
Thermal power production (CHP, cold condensing, GT)	4 869	8.9	5,753	10.9
Wind power	241	0.47	293	0.5
Net import		-7.1		5.3
Total	30,778	149.3	31,721	148.3

Table 18.1. Total installed electricity capacity (31 December 2001) and generation in Sweden, 2002 (provisional)

The successful deregulation of the Swedish and Nordic electricity markets has led to low electricity prices. There is an obvious risk that renewables might lose market share due to the low electricity prices. This year, however, prices have been higher because of less rain and lower hydro-power generation. The liberalization of the electricity and gas markets forces the wind industry to constantly strive to improve its efficiency and competitiveness.

Since 1 November 1999, wind energy producers compete in the same market as conventional electricity producers. The average North Pool price in Sweden during 2002 was 0.252 SEK/kWh. (See North Pool's homepage, www.nordpool.no, under Elspot and then Monthly Prices.)

On top of that market price, the law grants the wind turbine owner an "environmental bonus," which was 0.181 SEK/kWh in 2002. Additionally, a temporary support of 0.090 SEK/kWh will secure the economy of the "small-scale" electricity producers (maximum generator size 1,500 kW). The wind turbine owner also gets an income from the net owner that is 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. The deregulated market also makes it possible for the turbine owner to sell electricity to any customer. This makes a wind electricity market possible.

A second market stimulation program (15% investment subsidy) started on 1 July 1997. The investment subsidy has a 5.5-year budget totaling 488.00 MSEK. By the end of 2002, the SNEA had received applications for investment subsidies for projects with a total investment value of 4,977.00 MSEK, and the total granted subsidies amounted to 375.00 MSEK. Subsidies granted for 2002 totaled 42.00 MSEK. These projects had a capacity of 48 MW.

Unit Cost Reduction

The mean cost of producing electricity at commercial wind-power plants is 0.38 SEK/kWh (calculated with an interest rate of 6% over a period of 20 years and without state subsidy). In Sweden, support is generally required for wind power to be viable. The larger turbines (1,000 kW to 1,500 kW) erected today are getting cheaper but are still slightly more expensive than the 600-kW turbines.

18.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

The wind turbines erected from 1997 to 2001 in Sweden have a capacity between 225 kW and 3,000 kW. Most are 600-kW turbines (see Figure 18.3) manufactured primarily in Denmark or Germany.

Operational Experience

According to the *Swedish Wind Turbine Monthly* and annual statistics, the average availability during 2001 was 98.2%. During 1996, the figure was 97.8%; during 1997 it was 98.4 %; during 1998 it was 98.5%; during 1999 it was 98.3%; and during 2000 it was 98.8%.

Main Constraints on Market Development

Public attitudes about wind power, especially its impact on the landscape, are important and influence practically every wind project. Noise emission is also important, but perhaps moreso as a "technical" problem. So far, the negative impact on bird life has been minimal, but the question of migrating birds is being raised as more offshore wind-power plants are planned. The issue of marine life in connection with offshore wind power is also much discussed.

Objections 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.

Public Attitudes

A series of investigations into public attitude towards wind-power plants has been carried out. The investigations have included both year-long inhabitants and summer residents around the plants, and politicians and civil servants from the municipalities. Most of those interviewed had positive attitudes towards wind power. In the summer-house areas, there are more doubts about wind-power plants.

Public attitudes are also being investigated in a research project that examines how attitudes can be improved (e.g., by public consultation in the permission process for wind power.)

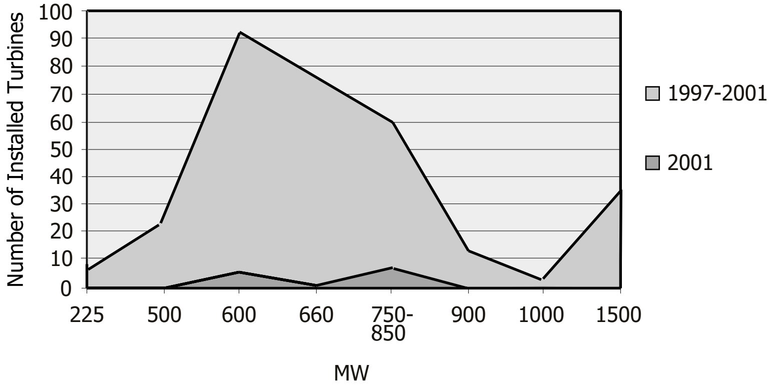

Figure 18.3 Size of installed wind turbines in the investment subsidy program 1997 to 2001. Discrepancies from the 2001 annual report are because 2001 statistics were based on applications, not on turbines actually installed

Noise

Noise is a subject frequently discussed in connection with wind turbine projects. Studies assessing wind turbine noise have shown that not only the sound level and its temporal pattern but also several other factors are important for subjective responses. Work is continuing on how to describe the noise disturbances in physical terms.

Disturbances to Military Structures

A research project is aiming to create a reliable model of the disturbance wind turbines cause for military microwave links, radar, and intelligence activities. Thus far, results show that radar disturbances due to wind turbines have until now been greatly overestimated.

18.6 ECONOMICS

Trends in Investment

During the years 1998 to 2001, approximately 400.00 MSEK per year was invested in erecting wind turbines, since the investment subsidy of 15% has had a budget of 60.00 MSEK per year. An extra 40.00 MSEK per year in 2001 and 2002 increased the investments for those years to 660.00 MSEK.

Trends in Unit Costs of Energy and Buy-Back Prices

Market prices for high-voltage electricity paid by certain customers, industrial plants, and distributors may be close to the bulk power price. On the market for low-voltage electricity, distribution costs are considerably higher, and the price of bulk power as a proportion of the price paid by the end customer is consequently relatively low -- at just under one-third of the price, excluding taxes, payable by a household without electric heating (see 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.

During 2002, wind turbine owners received a market tender price and other support as follows.

- A market tender price of approximately 0.240 SEK/kWh, a bit below average Nordpool spot.
- An environmental bonus of 0.181 SEK/kWh.

Typical customer	Network services (öre[1]/kWh)			Electrical energy, (öre/kWh)		
	2001	2002	% Change	2001	2002	% Change
Apartment	42.9	42.8	-0.2	27	35.6	31.8
Single-family house without electric heating	37.5	37.6	0.3	24.2	31.6	30.9
Single-family house with electric heating	20.8	20.9	0.4	22.5	29.6	31.6
Agriculture or forestry	22.2	22.2	-0.1	22.1	29.3	32.6
Small industrial plant	15.3	15.4	0.7	22.1	28.8	30.4
Medium-sized industrial plant				22	28.5	29.7
Electric-intensive industrial plant				21.7	28.3	29.9

[1] 100 öre = SEK 1

Table 18.2 Price of network service and electricity, excluding taxes, on 1 January 2002 in sales of electricity to various typical customers

- A temporary subsidy of 0.090 SEK/kWh for small generators (maximum 1,500 kW).
- The "local grid value" averaging 0.010 SEK/kWh.

These give a total of 0.521 SEK/kWh.

This price model will be in force until 30 April 2003. Thereafter, a new governmental quota system with green certificates for new renewable electricity generation will probably be implemented.

18.7 INDUSTRY

Two manufacturers have developed large wind turbines in Sweden: Kvaerner Turbin AB and Nordic Windpower AB.

18.8 GOVERNMENT-SPONSORED R,D&D

The overall goal for the Swedish wind energy research program is to develop knowledge within the wind energy area so it will be possible to manufacture and develop wind turbines and utilize wind energy efficiently in the Swedish energy system.

On 1 January 2002, a research and development program in the wind energy area started with a three-year budget of approximately 90.00 MSEK for 2002 to 2004. Research activities are divided into five goal-oriented categories: more confident assessment of power production, cost-effective wind energy converters, effective integration of wind power into the power system, better impact assessments, and appropriate planning and regulation.

The Swedish Defence Research Agency (FOI) manages the program on behalf of the SNEA. More information can be found at www.vindenergi.org.

The program includes basic and applied research as well as development projects. Basic research is fully financed by the SNEA, and applied research requires funding from industry.

Priorities

Research was previously very technology-oriented, but at a time when more wind turbines are put into the landscape, "softer" issues (planning, environmental, acceptance) must be given higher priority. At the same time, it is important to continue research into conventional technologies to increase availability and reduce costs.

New R,D&D Developments

This section presents some current research and demonstration projects.

1. Bird studies at the offshore sites Utgrunden and Yttre Stengrund

A bird study is being performed at the offshore wind-power plants Utgrunden and Yttre Stengrund. Radar has been used to follow bird movement in areas of intense bird migration to evaluate possible effects mainly on eider. The study shows so far that the birds fly at a distance of 200m or more from the nearest wind turbine. Almost no eiders are injured or die at the wind-power site.

2. Wind climate mapping over Sweden and adjacent sea areas

A project that aims at mapping the wind climate in Sweden was started in 2002. The project will produce a database consisting of mean wind, wind distribution, and potential energy production at several levels up to 200 m. The horizontal resolution will be 1 to 1.5 km, and the area covered will be Sweden and adjacent sea areas. The higher-order closure MIUU-model, developed at Uppsala University, will be the primary instrument for mapping the wind climate. A large number of model runs, representative of the climate conditions, will produce the basic input to a climatological weighting, from which the final database will be the result. Several wind measurements on towers will be used to verify the model output. The large database of modeled meteorological fields (wind, temperature, humidity, and turbulence) may -- apart from being used to estimate the wind potential -- also be used to estimate atmospheric dispersion.

Offshore Siting

1. Nogersund: In 1990, the first offshore-sited wind turbine was erected in Sweden, a 220-kW turbine at Nogersund.

2. Bockstigen, Valar: An offshore demonstration plant with five 500-kW turbines was erected in early 1998 4 km south of Näsudden on Gotland. The Swedish wind farm developer Vindkompaniet AB conducted the project. The Bockstigen Valar project is sponsored by EU (THERMIE) and SNEA.

3. Utgrunden: In autumn 2000, Enron/Tacke erected and commissioned a 10-MW wind farm (seven 1.425-MW turbines) south of the Utgrunden lighthouse in Kalmarsund Sound, between the mainland and the island of Öland. The plant is built 12 km offshore of Bergkvara on the Swedish southeast coast and 9 km from Öland. The Utgrunden project is sponsored by SNEA and now includes a scientific evaluation program with a focus on migrating bird studies.

4. Yttre Stengrund: In spring 2001, the company Vindkompaniet erected and commissioned another 10-MW wind farm (five 2,000-kW turbines, NEG Micon) in Kalmarsund sound, about 4 km from the mainland.

5. Other plans for wind power offshore: In Öresund Sound between Sweden and Denmark, the company Eurowind has received governmental permission for an offshore project with 48 1.5-MW wind turbines. West of the city of Karlskrona in southeast Sweden, the Vattenfall utility has conducted a feasibility study for an offshore project with large, 3-MW to 4-MW wind turbines. In the city's preliminary oversight planning, about 100 large-megawatt wind turbines are planned for the offshore site.

The total number of large offshore wind farm projects in different planning and study phases in Sweden is very large. Discussions are going on with local and regional authorities along several parts of the long Swedish coast – at the West Coast and in the Baltic Sea. The final outcome of these broad activities will depend greatly on the results from the following ongoing governmental initiatives.

- A future Green Certificate system.
- The governmental working group for pilot plants offshore and in the mountains.
- The planning preparations for implementation of wind turbines from the SNEA.
- The government determination of a long-term national deployment target for wind power.

(All of these initiatives are mentioned in the first sections of this chapter.)

Authors: Susann Persson, Swedish National Energy Agency, and Kenneth Averstad, Vattenfall AB, Sweden.

Chapter 19
Switzerland

19.1 INTRODUCTION

The harnessing of wind energy in Switzerland had a more shadowy existence in political energy activities until the middle of the 90th. Thanks to the dynamic development of wind energy in surrounding countries, the wind energy program of the federal office of energy now occupies a clear place and is an important part of the national program, SwissEnergy. Switzerland participates in the International Energy Agency (IEA) Implementing Agreement on Wind Energy Research and Development (R&D), Annex 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.

- The consumption of fossil fuels in Switzerland and the concomitant carbon dioxide emissions must be reduced by 10% from 2000 to 2010.
- The growth of electricity demand must not exceed 5%.
- The contribution of hydro-power to net demand must not be reduced despite deregulation of the Swiss electricity market.
- 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.

- The development of a greater awareness of the energy dimension among the general public as a prerequisite for the optimum implementation of voluntary measures.
- A closer co-operation among all partners.
- A spirit of innovation in all fields.
- 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

According to a 1996 study conducted on behalf of the Swiss Federal Office of Energy (SFOE), the sites suitable for wind power plants offer a potential that might cover 3% to 5% of the electricity demand.

At very windy locations outside landscape zones, approximately 500 wind power plants could produce electricity of approximately 270 GWh. This study has now been actualized when considering the newest wind turbines.

The Federal Department of the Environment, Transport, Energy, and Communications (DETEC) – including the offices of the Swiss Agency for the Environment (SAEFL), SFOE, and the Federal Office for Spatial Development (OSD) – has published a media report with a clearly positive statement concerning wind power generation in Switzerland. In accordance with the strate-

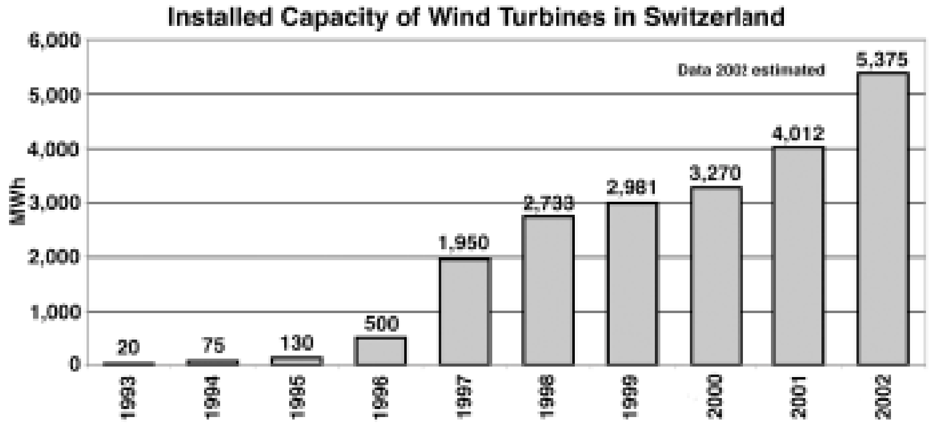

Figure 19.1 Development of Swiss wind energy production

gies developed by SwissEnergy, the report states a goal of 50 GWh to 100 GWh of wind power annual production until 2010. This equals 10% of the goal for all renewable energies set by the federal program, SwissEnergy.

Specific focal points in research for wind power generation in hilly and mountainous terrain will provide more information to enhance Swiss companies' opportunities in the globally booming wind energy market. In 2002, the budget for wind energy related R&D projects was 360,000.00 Euros. Approximately the same amount is spent on promoting activities.

Progress Towards National Targets

In 2002, 5.375 GWh were produced by wind power plants. This meets approximately 10% of the goals until 2010, and growth since 2001 was 33%. More than 95% of the electricity produced was generated at the biggest wind park in Switzerland, on Mt. Crosin by Juvent SA.

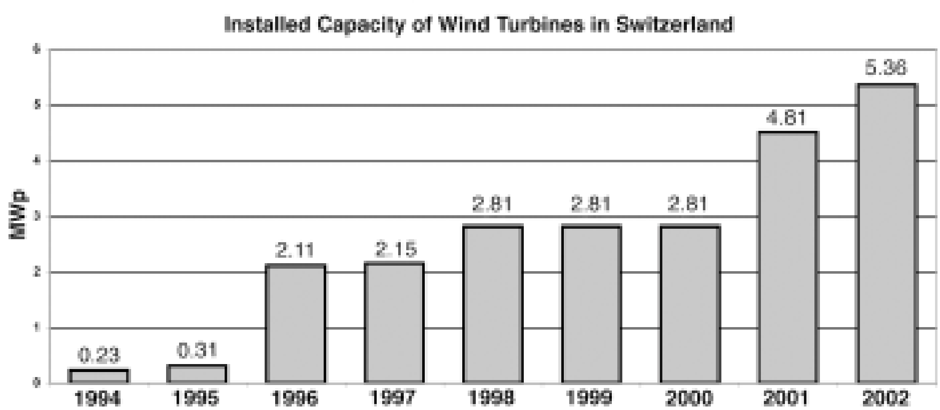

Figure 19.2 Development of installed wind power in Switzerland

19.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

The 19 plants installed so far, with a total capacity of 5.317 MW, produced 5.375 GWh in 2002. The capacity of wind power plants in Switzerland has increased by 20% in the last year.

Rates and Trends in Deployment

Current planned projects have a total production of more than 30 MW. Due to growing opposition on the part of wind energy opponents in our country, the realization of these projects may go on rather hesitatively.

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

Good locations in Switzerland are situated at altitudes above 800 m in hilly or mountainous areas, with correspondingly difficult general conditions such as climate (ice, cold, and turbulent wind regimes) and access and landscape conservation conflicts. Experience shows that wind energy plants can be operated even under these extreme conditions, although the economic viability of the projects is rather poor.

For this reason, the federal government's wind energy program supports planners and operators of wind energy projects in various ways including providing wind energy manuals, location maps, regional planning aids, and promotion subsidies.

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 and works jointly with environmental organizations.

Unit Cost Reduction

Does not apply.

19.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

Since the 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 are not yet installed due primarily to the difficult exploitation in hilly and mountainous terrains.

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 the Simplon pass (in existence since 1990 at 2,000 m above sea level), the 150-kW wind power plant on the Grenchenberg (in existence since 1994 at 1,300 m above sea level), the 80-kW plant on the 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), and the 30-kW plant on the Titlis (in existence since 1997 at 3,000 m above sea level).

With the commissioning of an 850-kW plant on the Gütsch near Andermatt (at 2,300 m above sea level) in spring 2002, important

Figure 19.3 An 800-kW wind turbine on Mount Gütsch in Andermatt, Switzerland

additional experience on the use of wind energy under climatically extreme conditions have been gained.

Wind generates the most electricity (approximately 60% to 70%) in the winter months when demand is critical. Thanks to wind energy production, additional electricity is available from storage power stations at peak consumption. Wind energy is therefore a perfect complement to electricity generated by storage lakes.

Main Constraints on Market Development

Landscape protectors fight more and more wind energy projects. The Swiss Foundation for Landscape Protection has published a position paper that would make efficient development of wind energy absolutely impossible and would clearly fall behind the position of the foundation taken in 1996. This will slow down the planning of wind energy projects even more.

For this reason, a national concept now exists that allows the realization of the goals set by the DETEC. This would also reduce the uncertainties in the planning procedure by the cantons.

There is a danger that refusal of the law for opening of the electricity market, called *Elektrizitätsmarktgesetz* (EMG), could do a favor to the real coup de grâce for the decentralized electricity production. All possibilities for a market entrance with equal rights would become invalid for independent producers. The question still remains how interested energy suppliers are in ecological energy strategies in a closed market for small-sized and average-sized customers.

19.6 ECONOMICS

Trends in Investment

Wind energy plants are not generally subsidized in Switzerland. However, the SFOE can support up to 60% of costs that cannot be recouped for pilot and demonstration projects. This is also valid for studies and concepts for site assessments. The government's wind energy program substantially supports site assessment (including wind measurements, expert opinions on climate and environmental matters, and feasibility studies) with financial aid.

Trends in Unit Costs of Energy and Buy-Back Prices

The specific costs of large wind-power plants amounts to approximately 2,000.00 CHF/kW or 1,380.00 Euros. Thus, the prime costs at windy locations are lower than 0.20 CHF/kWh or 13.50 Euro cents. 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 850-kW wind energy plants installed in 2001 amount to approximately 12.00 Rp/kWh or 8.50 Euro cents.

The Swiss energy law obligates energy suppliers to re-buy the energy produced by independent producers to 15.00 Rp/kWh or 10.50 Euro cents. Because these supplementary costs (current electricity producing price in Switzerland is 8.00 Rp/kWh or 5.50 Euro cents) cannot be passed on, the claiming of these costs turns out be difficult. A progressive solution – payment of these costs by the high voltage net – has unfortunately been prevented by the successful referendum for the EMG law.

19.7 INDUSTRY

Manufacturing

Both offshore installations and power plants in mountainous areas must achieve high reliability, considering the limited access and rough climatic conditions. This opens market opportunities for the expensive, but highly qualified, electrical and measuring industry in Switzerland.

The Swiss electrical industry's understanding of medium voltage gains in significance with increasing plant 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

The power generation by wind 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.

19.8 GOVERNMENT-SPONSORED R,D&D

Priorities

The following research strategies for promoting acceptance of wind power generation lead to the goals mentioned above.

- Well-founded data analyses concerning the influence of wind power plants on fauna, flora, and tourism.
- Compilation of founded guidelines for projects with small impact on the environment, in co-operation with environmental

organizations and the wind energy industry.

• Evaluation of wind power's contribution to sustainable energy supply and integration into global strategies.

• Elaboration of a nationally coordinated concept for wind power generation, including a definition of spatial development.

• Local electricity production in remote areas.

• 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.

• Appropriate participation models for the local population and in regard to matters of acceptance.

• Wind energy as a supplement to electricity production in insular situations (i.e., for alp co-operatives and southern countries).

• Development of a center of competence for wind power generation in mountainous areas.

• Enhancing knowledge on project development in complex terrain, support for site assessments with specific requirements, and elaboration of planning aids.

• Development of adapted modeling software for site assessments, validation, and optimization.

• Operation of test plants in mountainous areas; interpretation of operational experience; and integration into new plant concepts for networks, small insular grids, and stand-alone plants.

• Development of specific plant components and concepts for rough climatic conditions (e.g., ice, cold, and turbulence) with high reliability (e.g., difficult access and offshore sites) for erection in areas with limited access.

New R,D&D Developments

The development of wind energy projects in Switzerland is still burdened by many uncertainties and planning risks. The program P+D Wind has established various documents, studies, and planning aids that contribute to a successful realization of wind energy projects. A list of specific planning aids follows.

• The manual Planung von Windenergieanlagen (planning of wind power plants), located in the publications area of the website www.energieforschung.ch, provides complete information about the various aspects of a wind energy project, considering the specific Swiss setting. More instruments based on these publications were developed in 2001.

• A comprehensive checklist, called Wind Energy and Spatial Development, has been created in order to standardize the planning procedure in all cantons with relevant wind energy potential. The SAEFL, the OSD, and the Swiss foundation for landscape conservation, or Schweizerische Stiftung für Landschaftsschutz und Landschaftspflege (SL), were members of the group that accompanied the project. The canton's viewpoint was integrated to include a detailed consulting procedure.

• Computer models that have proven their value in lowland applications are often not adaptable to complex and mountainous terrain because physical simplifications approved in low regions are not applicable to complex terrain. Therefore, alternative methods are necessary to provide reliable wind assessments for power plants. The V3-toolbox explains the general procedure for establishing a wind assessment. A flow chart shows the decisions to be taken in the assessing process and the steps to be followed. Comments are made regarding decision basis and tools. In particular, the large choice of available computer models for wind assessment is shown.

• The software program within the V3-toolbox was validated by the pilot project Gütsch. The development method and the calculations were done in tight co-operation with the Swiss Center for Scientific Computing (SCSC) and the Federal Polytechnical Institute of Zurich. The procedure can be run for any terrain but is mainly used for topographically and meteorologically complex locations.

The following detailed information is available from the Suisse-Eole website (www.suisse-eole.ch) under the title, Windmaps of Switzerland.

- Wind measurement points run by MeteoSwiss.
- Average wind speeds at the mentioned measurement points for the years 1983 to 1997.
- Monthly averages of wind speed, beginning in 1998.
- Results of temporary measurements at supported wind energy projects.
- Location descriptions of wind power plants and wind forecasts.
- Publication of potential maps (wind speed and landscape protection aspects).
- V3-toolbox with a calculation of the WEIBULL-parameter A, k from a measured frequency distribution (program in Microsoft Excel 97).
- Detailed description of relevant geographical aspects, including zones of protected landscape.

Offshore Siting

Does not apply.

Site Assessment

The government's wind energy program substantially supports site assessment (e.g., wind measurements, expert opinions on climate and environmental matters, and fea-

Figure 19.4 The wind energy data base, located at stratus.meteotest.ch/mme shows areas of protected natural habitat and landscape

Figure 19.5 and Figure 19.6 At low temperatures, ice and snow accumulates on the mast and guy wires leading to greater loads and a larger area of attack for gusts (photos taken from a Meteotest measurement campaign on the Gotthard Pass at 2,100 m above sea level, Switzerland, courtesy NEK Umwelttechnik AG)

sibility studies) with financial aid. To some extent, plants can also be part-financed. Since 1994, the SFOE's P+D Wind program has co-financed the investigation of climatically demanding sites such as Flumserberge, Arosa Weisshorn, Grimsel and Gotthard passes, and Neuchatel Jura. In this way, a lot of information was obtained in the P+D Wind program on how climatic aspects can be considered when evaluating sites. The results of these investigations have been published in reports via ENET (located on the www.energieforschung.ch website).

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Chapter 20
United Kingdom

20.1 INTRODUCTION

In 2002, a total of 87.76 MW of capacity was installed in the United Kingdom, bringing the total installed capacity in the country to 522 MW, an increase of approximately 20% from last year. Although encouraging, this figure falls short of that anticipated for 2002, and it highlights the fact that there is a long way to go to meet the target of 10% from renewables by 2010. However, signs for 2003 are extremely good – approximately 300 MW are expected to be commissioned. In addition, the United Kingdom is overcoming planning permission problems – a total of 535 MW gained planning permission in 2002.

Notable planning decisions in 2002 included the first approval under Section 36 of the *Electricity Act*, which enables the central government to make decisions regarding any projects of more than 50 MW. Approval was granted to a 58.5-MW wind farm near Aberystwyth in Wales, which will produce roughly 1% of total Welsh electricity needs. The United Kingdom's largest Brownfield site was also recently approved; it is a 47.5-MW wind farm by Amec Wind and Corus on an old steelworks site at Redcar in Teesside.

Another noteworthy planning decision came in April with consent for the first large-scale offshore project in the United Kingdom, at Scroby Sands off the east coast of Great Yarmouth in Norfolk. This was followed in July by consent for another offshore wind farm at North Hoyle, off the coast of Prestatyn, North Wales. National Wind Power (NWP) Offshore hopes to have this 90-MW wind farm operational by autumn 2003. In the last month of 2002, the third offshore wind farm at Rhyl Flats, again in Wales, gained development consent.

There has also been success for small, local schemes with two 1.3-MW machines for the first Windworks scheme at High Sharpley, County Durham. The Windworks scheme is being run by NWP and provides guidance support at no cost to land owners with suitable sites. NWP will construct, operate, and maintain the machines, generating a useful income stream, particularly for the beleaguered farming community.

Planning permission has also been granted for what will be the single largest turbine in the United Kingdom, a 3.2-MW GE Wind Energy machine at England's most easterly point, Ness Point in Lowestoft, Suffolk. It is a prototype installation to be erected on land but only 20 m from the water's edge, with full offshore specification. If the turbine performs as expected, then further U.K. installations will follow, including, if approval is granted, GE's own offshore site at Carnfleet Sands off the coast of Essex.

The United Kingdom British Wind Energy Association (BWEA) predicts that approximately 2,300 MW could be operational in the country in three years.

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 the political agenda. In the United Kingdom, the *Renewables Obligation* (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 RO, it is currently estimated that by 2010 the value of support to the U.K. renewables industry will be 1 billion GBP per year. The government is actively considering setting targets beyond 2010, and this issue will be explored in an *Energy White Paper* to be published early next year. The RO will provide the impetus for a major expansion of renewable energy in general and the offshore wind industry in particular.

A small but growing industrial base has begun to emerge in the United Kingdom, as technology has improved and costs have been reduced. A recent study commissioned by Renewables UK (see the section below on Industry Development and Structure) suggests that the total global market for offshore renewables could be worth as much as 8 billion GBP by 2007, with the European market accounting for 90% of this. It is the intention of the government that the United Kingdom is a major player in this.

Strategy

Following the announcement in 2001 by the Crown Estate of the allocation of leases for offshore wind farm sites, approximately 20 developers obtained agreements for leases. If all of these projects come to fruition, then a total of 1.4 GWh/year of renewable energy could be produced. Three of these projects have already gained development consent from the U.K. government during 2002. The positive response to the first round, which limits development to within the country's territorial waters, has been followed by developers pressing the government to permit further development both within, and beyond, territorial waters.

In response to this pressure, the U.K. Department of Trade and Industry (DTI) issued a consultation paper titled *Future Offshore*, on 22 November 2002. The paper presents a strategic framework for the offshore wind industry and identifies certain key issues that need to be focused on and clarified before the next round of offshore developments take place.

In summary, the main themes of the strategic framework are as follows.

- Proposed arrangements for future rounds of development leases, including details of the site allocation process and the proposal to focus on strategic areas.
- Specific arrangements for the next round under the existing legal framework.
- Arrangements for a strategic environmental assessment of the three proposed strategic regions prior to the announcement of the next round.
- Proposed changes to the consents process to address specific issues relevant to offshore renewable energy installations.
- Provision and regulation of offshore infrastructure for transmitting electricity.
- Recommendations for a legal framework for future offshore development, to address shortcomings and enable development to take place beyond the limit of territorial waters.

The consultation closes on 18 February 2003.

Progress Towards National Targets

The *Future Offshore* paper also covers a strategic framework for all marine renewable technologies (i.e., wind, wave, and tidal). The paper recognizes the contribution marine renewables can make towards the United Kingdom's target of 10% from all renewables by 2010. The potential benefits for climate change and energy security are the main reasons why the United Kingdom has chosen marine renewables to be its main strand towards meeting its target.

The industry itself has made a projection of approximately 3 GW to 4 GW of new capacity that can realistically be built by 2010, in addition to the 1.4 GW under the first round. Cumulatively, offshore development on this scale would provide approximately 40% to 50% of the 2010 renewables target. Renewable energy is expected to play an important long-term role in providing electricity for households, industry, and the public sector – and ultimately for transport as well. While many renewables offer all of these benefits, the particular advantage of marine renewables is their potential for greater public acceptability. This is mainly because of the likelihood of lower visual impact.

20.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Between 1 January 2002 and 31 December 2002, the United Kingdom installed 86 onshore turbines with a total capacity of 87.76 MW. The average capacity of the turbines installed during 2002 was 1.02 MW. This brings the total number of turbines in the country to 999, generating approximately 522 MW of power. Although planning consents were granted for offshore turbines, none were installed in 2002.

Rates and Trends in Deployment

The rate of deployment in 2002 was the highest ever achieved in the United Kingdom, with more than 87.7 MW of capacity installed, just beating the 84.5 MW installed in 1997. Even so, 2002 was not as good a year as the BWEA anticipated. The initial projection showed more than 200 MW identified for commissioning in 2002. However, a number of factors, including many grid-related problems, saw this fall to less than 100 MW.

Against this background, the BWEA reported that a total of 525 MW won planning permission in 2002, which is almost exactly the total amount built during the previous 11 years combined. In addition, the BWEA reports that a total of 23 new projects are confirmed for construction in 2003. More than 300 MW of new wind power capacity is expected to come online, thus increasing capacity by approximately 60% in just one year. Current predictions for 2004 are for an additional 600 MW to be commissioned.

Contribution to National Energy Demand

With a total electricity demand of approximately 400 TWh in 2002, 1,474 GWh was supplied by wind energy, which represents 0.37% of total electricity demand.

20.4 MARKET DEVELOPMENT AND STIMULATION

Main Support Initiatives and Market Stimulation Incentives

The several possible sources of financial support for electricity generated from renewable sources are as follows.

- The *Renewables Obligation*: The RO is a requirement on licensed electricity suppliers to source a specified proportion of their total sales from eligible renewable sources. Most renewable sources are eligible, although there are restrictions on large hydro and co-firing with fossil fuels. Eligible generation supplied by a licensed supplier to customers in Great Britain attracts Renewables Obligation Certificates (ROCs) that may be sold separately from physical electricity. A buy-out option for suppliers caps the cost to consumers, although suppliers may be willing to exceed the buy-out price for ROCs because ROCs attract a share of the buy-out proceeds. The buy-out price is 30.00 GBP/MWh in 2002 and 2003 and will follow the U.K. RPI thereafter.

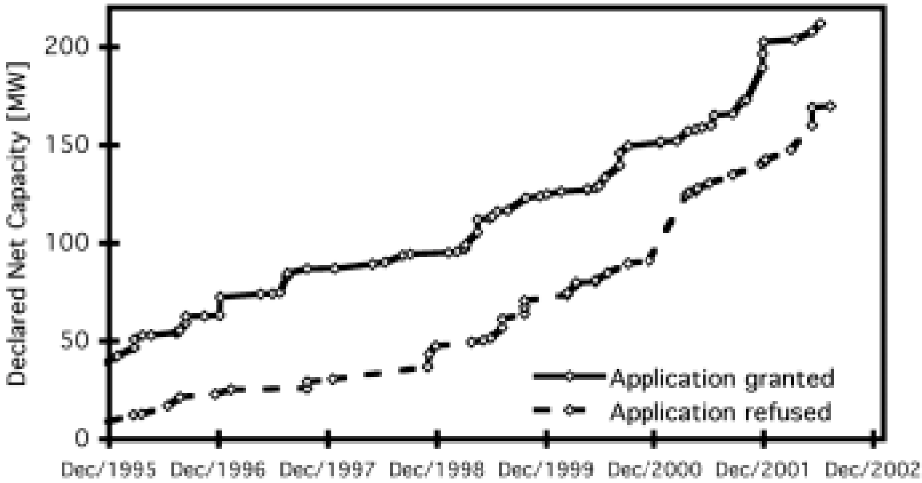

Figure 20.1 Wind farm planning application success and failure rates by declared net capacity

- The Emissions Trading Scheme: In certain circumstances, renewable energy can be used to help meet emissions reduction targets in the Emissions Trading Scheme. In particular, where individual suppliers over-achieve their obligation and do not wish to sell their ROCs to other suppliers, they may be able to convert their over-achievements to credits measured in carbon dioxide equivalents and trade them under the rules of the scheme.
- Exemption from the *Climate Change Levy*: The *Climate Change Levy* is levied on non-domestic end users of energy, including electricity. Electricity from eligible renewables is exempt from the levy and is certified by Levy Exemption Certificates (LECs), which cannot be separately traded from physical electricity. The current levy rate is 4.30 GBP/MWh. Eligibility is similar, although not identical, to that for the RO, and Ofgem operates the accreditation and certification process in parallel to the obligation process.

The government has underpinned the RO with a series of support schemes designed to bring forward technologies at the demonstration stage – these include offshore wind, energy crops, and solar photovoltaics, to name three. In addition, there is also support for community renewables and an enhanced program of industry-based research and development (R&D). The expected growth in the renewables market offers the U.K. industry a tremendous opportunity to invest in plant and equipment, create jobs, and stimulate innovation.

To assist the U.K. industry, a DTI initiative was launched in March 2002 to set up the Renewables UK. Coupled with the setting up of Renewables UK was the announcement of the new Renewables Advisory Board, which held an interim meeting in May 2002 and its first full meeting in November 2002. The board will play a significant role in the formation and delivery of government policy on renewables. The board is charged with identifying the key areas that the government needs to tackle and provide workable solutions. Specifically, the board will conduct the following activities.

- Develop strategies for improving the development and deployment of renewable technologies in the United Kingdom, and strengthen the U.K. supply chain and the infrastructure required to underpin the growth of a world-class industry.

• Examine and prioritize initiatives aimed at improving the competitiveness of the U.K. industry.

• Identify new export opportunities and the measures required to ensure U.K. companies can fully exploit them.

• Make specific recommendations by summer 2003 for actions to be taken by the industry and the government.

Unit Cost Reduction

As in 2001, no clear cost reduction has been observed in the last year. In the United Kingdom, a wind farm built today would typically cost 675.00 GBP/kW installed, including infrastructure. Costs as low as 550.00 GBP/kW are possible where accessibility is good and grid connection costs are low. Developers continue to be optimistic that onshore costs will fall further, to as low as 500.00 GBP/kW for some sites due to larger, more efficient turbines as well as economies of scale.

There have not been any additional offshore wind farms built since Blyth in 2001, so there are not any experiences to update the extrapolated figure for Blyth of 834.00 GBP/kW. However, there is considerable room for cost reduction as a result of increased experience, improved installation techniques, larger wind turbines, and larger schemes. In fact, several offshore contractors are currently pursuing various schemes that, if successful, will bring the cost down to 650.00 GBP/kW to 700.00 GBP/kW.

20.5 DEPLOYMENT AND CONSTRAINTS

Wind Turbines Deployed

A total of ten new projects, including two repowerings and two extensions to existing sites, began generating electricity to the grid in 2002. Table 20.1 lists these ten projects.

Main Constraints on Market Development

The United Kingdom has historically had problems obtaining planning consent for

Site	Online	MW	Turbines	Location
Out Newton	Jan 31st	9	7	Humberside
Cemmaes II	Feb 23rd	15.3	18	Powys
Bu Farm	Mar 6th	2.7	3	Stronsay
Burgar Hill Repowering	May	2.75	1	Orkney
Mablethorpe	June	1.2	2	Lincolnshire
Blaen Bowl	July	3.9	3	Carmarthenshire
Bowbeat	Sept	31.2	24	Borders
Hafoty Ucha II - extension	Dec 10th	1.7	2	Clwyd
Lendrum's Bridge II - 2nd phase	Dec 16th	7.26	11	Northern Ireland
Tangy	Dec 17th	12.75	12	Argyll & Bute

Table 20.1 New projects for 2002

wind farms in particular and for renewable energy schemes in general. A joint DTI/DTLR initiative requested all regions to make an assessment of the potential for renewable energy generation in 2010 and propose reasonable targets for their areas. The regional assessments were largely undertaken during 2000 to facilitate a means of encouraging the adoption of regional targets and approaches within Regional Planning Guidance and within Regional Sustainable Development Frameworks. In October 2001, DTI/DTLR commissioned a study to examine whether the targets proposed by the different regions would be sufficient to achieve the national target for renewable electricity generation. Published in February 2002, the study concluded that the 10% RO is more or less reached under the high targets proposed in the regional assessments. Just over half (53%) of the total of the regions' assessments consist of onshore and offshore wind, with 37% for onshore wind and 16% for offshore wind.

In June 2002, it was announced that a total of 1.74 million GBP of funding would be provided to support a range of different activities, including planning and promotion of renewable energy projects and development of targets in the regions throughout Britain. The funding, from a two-year program worth up to 2.5 million GBP, has been allocated to regional government office network.

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. The largest prospective source of additional renewable energy is a wind-based plant located along the western seaboard, running from the north of Scotland and Outer Isles down to the Cornish Peninsula, with offshore wind power the dominant source.

A DTI-commissioned study was completed in 2002, which investigated the feasibility of developing an offshore, high-voltage, direct-current network to connect these renewable energy resources to the existing transmission system closer to the center of demand. The study identified likely capacity requirements, network topology, and possible points of interconnection with the existing network. It also made a comparison with the alternative option of upgrading existing onshore transmission networks and commented on the cost implications and associated planning issues. Results of the study pointed in the direction of considering land-based options for strengthening the transmission capacity from north to south, although the optimum solution may well end up being a hybrid of sub-sea cable and land-based strengthening.

One constraint not common to the rest of Europe, and of increasing importance 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 a development must take into account 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 the DTI and the U.K. industry. The aim of the working group was to provide information and advice to developers, planners, military, and civil aviation personnel on the potential effects of wind turbines on radar systems.

As one of its first tasks, the working group has put together a document titled *Wind Energy and Aviation Interests - Interim Guidelines*. The guidelines, which were launched on 2 October 2002 at BWEA 24 at Brighton, set out to do the following.

- Provide a clear, readable, single source of information on all aspects of the impact of wind farms on aviation, both civil and military.
- Identify the range of interactions between wind energy and aviation interests.
- Outline the measures adopted to address the issues that are likely to arise from such interactions.
- Identify the organizations involved in the processes.

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 could affect both military and civil radar in ways that could seriously compromise their operation. A computer model is being developed that will be able to predict the impact of wind farms on specific radar installations. A second study is investigating the feasibility of measures to mitigate the effect of wind turbines on radar. This may permit wind farms to be located in areas that would currently raise an objection from the MOD. The results of these studies are expected in 2003.

20.6 ECONOMICS

Trends in Investment

Financing for wind farms is obtained largely from corporate investors and banks, although 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 while reducing exposure to penalty payments. Wind has found particular favor because of its economics, maturity, and ability to deliver quickly.

There has been no direct public funding available for capital investment in wind farms, but in 2001, the government announced a Capital Grants Scheme for offshore wind. In addition to 64 million GBP of DTI funding, the National Lottery New Opportunities Fund (NOF) will be providing an additional 10 million GBP for capital grants to build offshore wind projects. Launched in October 2001, project consortia had to pre-qualify by 31 January 2002. The pre-qualification process resulted in consortia registering interest in developing nearly 2,000 MW of capacity. The joint scheme will operate over three rounds of competition. The first round closed on 31 August 2002, the second round closed on 31 December 2002, and the third round will close on 30 June 2003. The primary aim of the scheme is to stimulate early development of a significant number of offshore wind farms. This is desirable in order to do the following.

- Deliver early contributions to the RO and emissions trading.
- Underpin development of the industry and equipment supply chains.
- Provide a learning experience that can improve confidence.
- Help reduce future costs and enable future projects to proceed without the need for grant support.

As a result of this scheme, the first two grants were announced in October 2002 for the offshore wind farms planned at North Holye in Wales and at Scroby Sands in Norfolk. Each grant was for 10 million GBP.

Trends in Unit Costs of Energy 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 3.0 GBP/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 wind farms contracted under the Non-Fossil Fuel Obligation (NFFO). The latest NFPA online auction of green electricity from NFFO contracts was completed on 19 August 2002. The auction began on Monday, 12 August, and contracts were finally awarded to a total of 12 successful bidders. In all, 241 contracts, representing approximately 609 MW of green electricity, were successfully auctioned. The contracts are for electricity produced between 1 October 2002 and 31 March 2003. The average price, at 6.50 GBP/kWh, was more than that of the previous auction, held in January 2002, when the average price was 6.44 GBP/kWh. The price for wind was 6.65 GBP/kWh, somewhat higher than the 6.31 GBP/kWh from the previous auction. These prices are more than twice the price paid for wind in 2001, when the price was 2.84 GBP/kWh. This is because this is the first auction held after the introduction of the RO in April 2002, and prices reflect the market value of the ROCs.

20.7 INDUSTRY

Manufacturing

The United Kingdom continues to supply a wide range of components to the wind

Figure 20.2 NEG-Micon's NM82 wind turbine

turbine industry, including blades, castings, towers, pitch bearings and elastomerics.

NEG-Micon Rotors Ltd. achieved continued growth through 2002 at its blade production facility on the Isle of Wight. Blade production was up by nearly 54% to a total of 860 blades, and the total number of staff was up by nearly 26% to a total of 350, making the company one of the leading employers on the island. Forecasts for 2003 anticipate further increases in blade production and number of employees of 63% and 37%, respectively. Much of this increase in production is due to significant improvements in production techniques such as resin infusion developed by NEG-Micon under the DTI's R,D&D research program.

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. It's simple goal is to maximize the country'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. One of its first tasks was to commission a study for offshore renewable energy projects, both in home and overseas markets from 2002 to 2007. The report *World Offshore Renewable Energy Report 2002-2007* was published in October and covers offshore wind, wave, and tidal technologies. The report suggests that the United Kingdom will be the next major growth market for offshore wind, with an expected 42% of generating capacity installed in 2004. Over the complete 2002 to 2007 period, the United Kingdom is likely to install 907 MW, which is 21% of total global new capacity.

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.

20.8 GOVERNMENT-SPONSORED R,D&D

Approximately 1.5 million GBP was spent on the wind program area of the DTI's R&D Programme on Sustainable Energy in 2002. The U.K. government increased the budget for R&D support of renewables to 18 million GBP in 2002. The portion of this budget assigned to wind energy has yet to be decided and will depend partially on the level of U.K. industry activity.

Priorities

The government continues to support a cost-shared program with industry – but as the technology achieves maturity, the trend is towards decreasing contributions from the government in onshore technology. Greater attention is now being directed to the development of the offshore resource, which includes the following.

- The development and evaluation of innovative techniques to reduce the cost of operation and maintenance.
- The development and evaluation of innovative techniques to increase the availability and reliability of wind turbines.
- The evaluation of electrical infrastructure options to improve the assimilation of wind turbines on the distribution network.
- The research, development, and evaluation of innovative materials, processes, and components that would contribute to improved wind turbine performance.
- The development and evaluation of systems and techniques that offer safe, cost-effective, reliable methods of access to offshore wind turbines.
- The development and evaluation of innovative techniques for the installation of offshore wind turbines that will result in the reduction of the cost of offshore wind energy.
- The development and evaluation of innovative wind turbine designs offering improved performance.

Proposals for developments specifically focused 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 concentrate mainly in the offshore area with no less than four projects looking at ways to reduce the cost and decrease installation time for offshore foundations and turbines. A typical design concept is based on a gravity base structure consisting of three cylindrical caissons connected by walls, supporting a telescopic mast and turbine. The whole installation will be assembled onshore and then floated out to site, where it is ballasted and the tower is extended to hub height. A similar concept also consists of a gravity structure but is comprised of a circular cone/pile extending out of the center of a large base slab. The tower and turbine are attached onto the foundation onshore, and the whole assembly is loaded onto a submersible barge, transported to site, and lowered onto the seabed. A novel aspect of this design is its ability to self-bury itself in sandy conditions using a series of water jets.

The above are typical examples of new and innovative concepts currently being appraised by offshore developers and contractors and supported by the DTI's Sustainable Energy Programme during 2002.

Offshore Siting

In 2002, a total of three offshore wind farms gained consent from the U.K. government: Scroby Sands on 17 April, North Hoyle on 31 July, and Rhyl Flats on 26 December. Scroby Sands will be operated by Powergen Renewables and is sited approximately 2.5 km off the coast of Great Yarmouth in Norfolk. North Hoyle and Rhyl Flats are next to each other off the coast of Prestatyn and Rhyl in Wales. Celtic Offshore Wind Limited originally made the application for consent to build Rhyl Flats. However, the project will now be taken forward by National Wind Power Offshore Limited, which already holds the consents for the neighboring North Hoyle Wind farm.

These are the first of the original 18 sites to be granted leases by the Crown Estate in 2001. An additional six projects are currently being considered by the DTI.

Further developments of offshore wind farms both within and beyond the territorial waters will be subject to the outcome of the current consultation paper, *Future Offshore*. The paper proposes the following specific measures to enable the orderly development of an offshore industry in the United Kingdom.

- The immediate future of wind farm development should focus on three strategic zones that offer the best development potential. These are the Greater Wash, the Solway Firth down to North Wales, and the Thames Estuary. This will not preclude other proposals, which should be notified as soon as possible.
- Strategic environment assessments (SEAs) of the three key areas will be made so that scale and location of development is environmentally responsible. This will be done before Crown Estate invite bids for the next round of site leases (expected in April 2003) and also before the European directive requires all member states to do so (July 2004).
- New exploration licenses will be given for sites beyond the 12-mile legal limit from the shore in order to enable work to go forward before a new legal framework is set up that enables development beyond this limit. This would be necessary, for instance, in the Outer Moray Firth where a proposal is being drawn up for outside the territorial limit.
- A new bidding process for wind farms should be introduced that will make the most efficient use of the seabed.

The potential contribution towards the U.K.'s energy requirements is substantial, and this, in turn, will underpin a substantial manufacturing market within the United Kingdom, with opportunities to then contribute to the European market.

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Chapter 21
United States

21.1 INTRODUCTION

The United States has vast wind energy resources and has been one of the leaders in wind energy research, development, and deployment (R,D&D) for more than 30 years. Today, nearly 20% of worldwide wind energy capacity is in the United States, and wind is the fastest-growing source of electricity. During the past ten years, electricity production from wind turbines has more than doubled, at a rate faster than other forms of power generation.

This report describes recent wind technology development and market trends in the United States. Emphasis in the report is on the United States Department of Energy (DOE) Wind and Hydropower Technologies Program and its role in leading the development of new wind energy technologies that can compete with other electricity sources without the need for subsidies.

21.2 NATIONAL POLICY

Strategy

The National Energy Policy (NEP), published in May 2001, contains recommendations to diversify the national energy supply, move towards clean affordable energy sources, and modernize the electricity grid and infrastructure. Renewable energy sources play a key role in this policy, including development of wind energy. Further, the policy proposed expansion of performance-based, goal-oriented research and development (R&D) focused on advanced technologies adapted to sites with lower wind speeds; extension of wind energy production tax credits; and the increased use of wind and other renewable resources on federal lands.

Consistent with NEP, the DOE Office of Energy Efficiency and Renewable Energy has as its mission: "Strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that bring clean, reliable and affordable energy production and delivery technologies to the marketplace." A goal of DOE is to increase the viability and deployment of a range of renewable technologies, including wind.

The strategy in the United States is to expand the use of wind energy through continuing wind technology R,D&D combined with market development incentives. Emphasis has shifted from government-led R,D&D to cost-shared public-private partnerships aimed at developing advanced wind turbine designs that can operate economically in broad applications and areas. The focus of financial incentives has shifted from purely federal investment incentives to a combination of national and regional/state incentive programs that will eventually become unnecessary as the cost of wind energy declines.

The DOE wind energy program supports the development of wind systems in a range of sizes for a variety of applications. For large wind energy systems with rated turbine capacity over 100 kW, the program's R,D&D activities focus on supporting U.S. industry efforts to improve low wind-speed performance to reduce the life-cycle cost of wind energy to levels that can compete in bulk electric power markets. For distributed small wind systems of less than 100 kW, R,D&D is focusing on advanced turbines designed to improve cost effectiveness for meeting a broad range of energy needs for homes, farms, isolated communities, and distributed grid-connected generation.

Specific cost reduction and performance targets have been set to position wind as an attractive advanced-technology option for the twenty-first century. The DOE program goals follow.

- Reduce the cost of electricity from large wind systems to 0.03 USD/kWh at high-wind sites with an average wind speed of 6.7 meters per second (m/s) by 2004, and at low-wind sites with 5.8-m/s winds by 2012.
- Reduce the cost of electricity from small, distributed wind systems to 0.10 USD/kWh to 0.15 USD/kWh by 2007 in an average wind resource of 5.4 m/s.
- Wind speeds are measured at the standard height of 10 m above the ground.

For wind energy to be used in many parts of the United States, it is necessary to develop turbines that can operate efficiently in areas of lower wind speed (5.8 m/s). Generally, urban load centers are located in low-wind areas, so the new turbine technology will allow wind plants to be economically viable on land that is on average five times closer to the load center. This will help relieve power transmission constraints by placing turbines in closer proximity to consumers. It will also expand the economically viable land area for wind energy development by a factor of 20 or more.

Other considerations in the DOE program are the trends towards larger multi-megawatt turbines with their economies of scale, integration and control of much bigger wind-power plants (see Figure 21.1), and in the future assessing the potential for both land-based and offshore wind-energy installations.

The program is exploring possible linkages between wind and other renewable energy technologies. In 2002, DOE's wind energy and hydro-power programs were combined into one office. Although the two technologies will be developed independently, this organizational change provides the opportunity to explore potential synergistic operations. In many parts of the country, intermittent wind and hydro-power resources can be used together with beneficial effects. Wind energy is being considered for possible use in producing hydrogen for transportation and electric power markets.

Federal and Other Government Agencies' Use of Wind Energy

DOE and other parts of the federal government are expanding their use of energy from wind and other renewable energy sources. Through *Executive Order Number 13123* issued 3 June 1999, and through other policy

Figure 21.1 GE Wind Energy 1.5-MW turbines in 150-MW Trent Mesa wind-power plant located near Sweetwater, Texas

guidance, federal agencies are required to obtain the equivalent of 2.5% of their electricity from renewable resources by 2005.

Responding to the executive order, Dyess Air Force Base, Texas, on 1 January 2003 began purchasing 100% wind-generated electricity. The Dyess purchase of 78 million kWh of wind energy annually is the largest single purchase of wind energy in the nation. Texas-based TXU Energy, through a competitively awarded contract issued by the Defense Energy Support Center, will provide wind energy from six wind-power plants in Texas.

Earlier in 2002, DOE announced the purchase of electricity generated from renewable energy for its facilities in the Washington, D.C., area. The contract calls for an annual purchase of 6 million kWh, 25% to be provided by wind and the rest to be provided by landfill natural gas plants.

The examples set by the federal government are being replicated at state and local levels. In one case, a local school district in Montgomery County, Maryland, near Washington, D.C., recently announced plans to purchase 400,000 USD in power from wind plants annually.

Power Industry Involvement

The ongoing deregulation of the electric power industry and new independent green power marketing businesses are helping wind energy by increasing competition and allowing consumers to choose to purchase electricity from clean energy sources. However, deregulation is being implemented separately by individual states, causing many variations in procedures and adoption pace. This is one reason for regional differences in the adoption of wind.

Progress Towards National Targets

No national targets for wind energy deployment have been established by the government. However, the U.S. wind industry has a goal to generate 6% of the nation's electricity from 100,000 MW of wind systems by 2020. DOE has established specific program goals intended to support industry by encouraging wind deployment across the United States.

- Facilitate the installation of at least 20 MW in 32 of the 50 states by 2005, and of at least 100 MW in 16 states by 2010.
- Increase the use of wind energy by federal facilities to 5% of the electricity used by the federal government (equivalent to approximately 1,000 MW) by 2010.

21.3 COMMERCIAL IMPLEMENTATION

Installed Capacity

Installed wind capacity in the United States has increased continuously since 1980. Most recently, the growth rate has been increasing due to the combined effects of declining wind energy costs, available financial incentives, and high costs for competing energy sources. The installed capacity and cost trends are shown in Figure 21.2. The wind industry installed an additional 410 MW of capacity during 2002, and 27 states now host utility-scale wind-power development. At the end of 2002, installed U.S. wind capacity totaled 4,685 MW (see Figure 21.3).

Rates and Trends in Development

Wind power plant installations are continuing to expand into new regions, and projects are currently being developed and are under construction in many parts of the country. Although the 2002 growth of 410 MW was down from previous years, 2003 additions are projected to return capacity to 2001 levels of 1,500 MW to 1,800 MW.

The recent year-to-year fluctuation in the construction of wind energy installations was caused primarily by a delay in the extension of the federal renewable energy production tax credit (PTC). Although there was strong support for the extension, the PTC expired in December 2001. In March 2002, the PTC was extended for two years, including a provision making it retroactive to the beginning of the year. This three-month delay caused many projects to be put on hold, disrupting turbine production plans and project financing. The coming year's expansion will be encouraged primarily by the PTC's extension through the end of 2003 as well as declining wind energy costs and the variety of incentives that are available in many states. Legislators are considering extending the tax credit for longer periods to reduce these fluctuations in construction.

Both wind turbines and wind power plants are growing in size, which is helping to reduce the cost of wind energy to the point that bid prices for several recent proposed land-based projects with excellent wind resources are approximately 0.03 USD/kWh, including the PTC. Most of the new large projects employ turbines rated from 600 kW to 1.5 MW. Two of the largest U.S. wind plants are the 278-MW King Mountain Wind Ranch near Odessa, Texas, built by Renewable Energy Systems, and the 300-MW Stateline Wind Plant on the Washington-Oregon border near Walla Walla, Washington, built by FPL Energy. In one of the first offshore projects, Cape Wind Company is planning to use 130 of the new, 3.6-MW GE Wind Energy turbines in a 468-MW project off the south shore of the state of Massachusetts.

Small wind turbine sales are increasing dramatically as a direct result of state incentive programs. For example, California implemented a rebate of up to 4,500 USD for the purchase of a wind turbine rated at 10 kW or less. As a result, one small turbine manufacturer, Southwest Windpower, sold more than 10,000 of its 400-W (see Figure 21.4) and 1 kW turbines in both 2001 and 2002. Another small turbine manufacturer, Bergey Windpower, is celebrating 25 years in the business of producing turbines from 1 kW to 10 kW, and it now has machines operating in all 50 states and in more than 90 countries. Bergey's sales increased 30% in 2002.

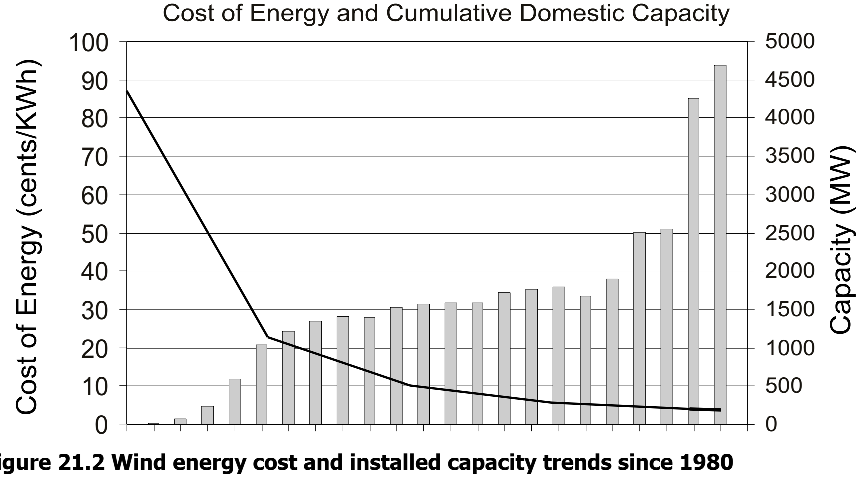

Figure 21.2 Wind energy cost and installed capacity trends since 1980

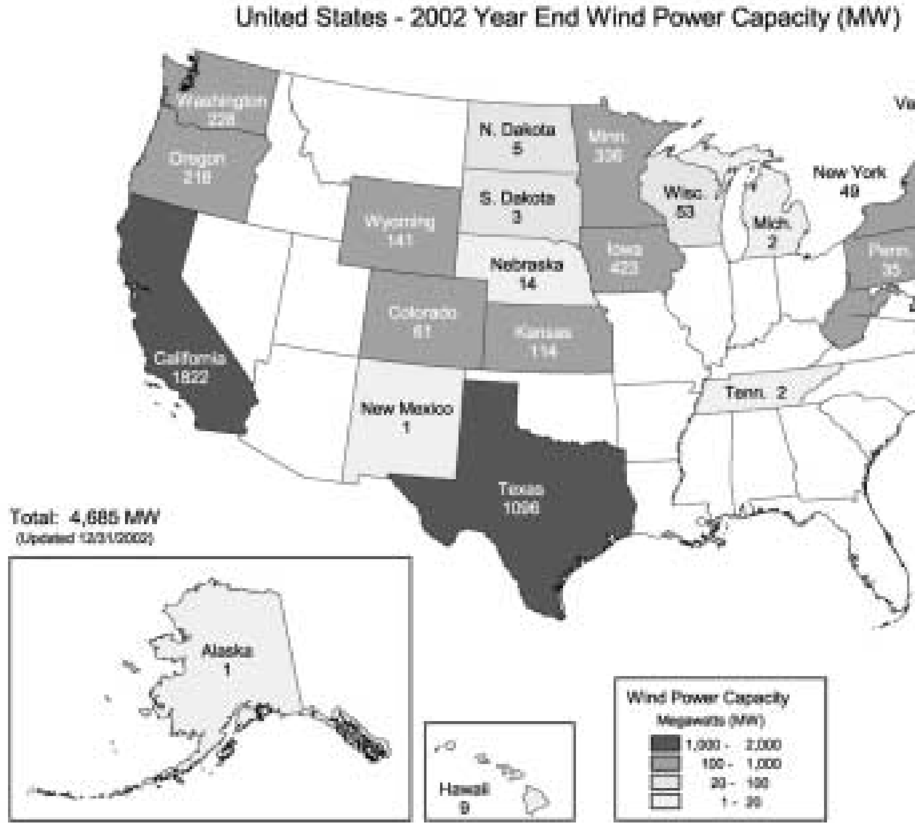

Figure 21.3 Wind-power plant installed capacity in the United States at the end of 2002

Contribution to National Energy Demand

Energy production from wind systems in the United States during 2002 is estimated to have been approximately 12 TWh, assuming 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%. Currently, wind energy is only 0.3% of the national electricity supply, but its importance is growing, especially in regions with good wind resources and incentives for development. Industry's goal is for wind to supply 6% of the nation's electricity by 2020.

21.4 MARKET DEVELOPMENT AND STIMULATION

Market Support Initiatives and Market Stimulation Incentives

State policies and incentives are having an increasing influence on regional development of wind power, especially when combined with federal tax incentives. Many different programs are being developed on the state level where local conditions and needs vary. The most successful programs feature these characteristics.

- Clearly defined goals.
- Simplicity.
- Long-term (typically 10-year) benefits and/or penalties.

Figure 21.4 Southwest Windpower 400-W turbines sold 10,000 units during 2001 and again in 2002

• Flexibility that allows suppliers and consumers to choose from various renewable energy technologies.

The following examples of mechanisms that have helped to expand wind energy use are discussed in more detail in the International Energy Agency (IEA) Wind Energy Annual Report for 2001. The incentives and policies described in the following paragraphs often work together (see Figure 21.5).

1. Wind energy production tax credit:
A tax credit offered by the federal government for energy from wind and closed-loop biomass projects. Under this program, a commercial wind plant owner is allowed a tax credit of 0.018 USD for every kWh produced (rate is adjusted annually for inflation). This tax credit can be claimed for the project's first 10 years. To qualify for the credit, these plants have to be brought on line before 31 December 2003.

2. Renewable energy production incentive:
An incentive payment is available from DOE for municipal utilities that do not pay taxes to the federal government. As with the tax credit just described, applicants can receive a payment of 0.018 USD/kWh (indexed to inflation) for energy produced over a 10-year period, for plants brought on line prior to 31 December 2003. During 2002, payments totaled 3.8 million USD for solar, wind, and biomass plants with 1.3 million USD for wind plants. This payment is subject to availability of annual funding.

3. The 2002 Farm Bill:
This legislation includes a five-year, 115 million USD Renewable Energy Systems and Energy Efficiency Program that provides low-interest loans, loan guarantees, and grants to farmers, ranchers, and rural businesses to invest in wind and other renewable energy and efficiency improvement technologies. This program is implemented by the U.S. Department of Agriculture.

4. Green power purchasing prices:
In an increasing number of states, residential and commercial customers can choose to purchase electricity from environmentally benign or green power sources. An example of this were discussed in Section 21.2.

5. Renewable energy portfolio standards:
Some states are requiring that a portion of the energy sold by utilities come from renewables. This mechanism is discussed in the U.S. chapter of the IEA Wind Energy Annual Report for 2001.

6. Compatible land use and tax benefits:
Farmers and ranch owners in the United States are finding it attractive to harvest wind along with other crops. Typically, a Midwest farmer leases land to a developer under a long-term contract. In return, the farmer normally receives an annual cash payment plus a portion of the energy sales, typically 2%, amounting to annual revenue of 2,000 to 4,000 USD per large turbine. Some states also offer property tax breaks or holidays from taxes.

	Beneficiaries					
	Electric Utilities	**Independent Power Producers**	**Public Power**	**Rural Electric Cooperatives**	**Manufacturers**	**Individuals/ Businesses • Customers • Farmers • Ranchers • Rural Business**
Federal Incentives						
Production Tax Credit	X	X				X
Renewable Energy Production Incentive			X			
2002 Farm Bill —Loans and Grants						X
State and Local Incentives						
Given Power Purchasing Choices		X		X	X	
Green Tags		X		X	X	
Renewable Portfolio Standards		X			X	
Land Use and Tax Breaks • Property Tax Waivers • Sales Tax Waivers • Tax Holidays	X	X		X		X
Net Metering						X

Matrix of Wind Energy Incentives and Beneficiaries in the United States.

Figure 21.5 Effect of federal and state renewable energy incentives on cost of electricity

To help facilitate the transition of wind energy technology into commercial markets, DOE started the Wind Powering America activity. This effort has five focus areas, as follows.

1. State-level support: Providing support in the form of workshops and technical analysis for local planners and regulators to include wind and other renewable energy sources in the power generation mix.

2. Outreach and technical support: Providing technical assistance on topics including wind resource assessment; wind mapping; economic analysis; environmental assessment, and other issues of interest to industry, utilities, and energy consumers in their decision-making on whether to build or buy wind generation.

3. Rural economic development: Providing educational and outreach materials to rural communities and developing new business models that employ wind development that includes land lease arrangements and other revenue-sharing approaches between developers and rural landowners, farmers, ranchers, and American Indian groups on tribal lands.

4. Power partnerships: Working with power generators and suppliers to encourage them to install clean generating capacity and providing information to large consumers of electricity that are considering the purchase of clean power.

5. Federal green power: Working with federal agencies to encourage the use of wind and other renewable energy technologies to fulfill requirements for purchasing electricity from clean energy sources for use by government-owned facilities. See Section 21.2.

The Wind Powering America program has been working successfully to remove obstacles to the introduction of wind technology in new regions and for new applications.

Turbine 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 wind plant installations are currently estimated to cost between 900 USD/kW and 1,000 USD/kW. These estimates are based on data from actual projects and include the turbines, electrical system interconnection, and substation costs. The cost depends on many things including turbine type, size, quantity, terrain, transportation access, grid-connection voltage and distance, and other variables.

21.5 DEPLOYMENT AND CONSTRAINTS

Operational data from successful projects are helping to reduce electric utility company concerns about allowing connection of large wind plants to the grid. However, transmission and distribution system constraints in regions with high-wind resources are expected to limit future wind energy growth unless new lines or system reinforcements are built. Several detailed power system studies are under way.

One study in New England analyzed high penetration of wind and biomass power plants operated in conjunction with existing hydro-power systems. Results showed that an addition of more than 800 MW of wind capacity could be accommodated in the state of Vermont without major costs for transmission and distribution system upgrades or reinforcements. Further, the value of wind power was found to be up to 22% higher if stored in hydro-power plants in the United States and Canada during their peak demand periods than if sold at local spot market prices.

In some parts of the country, transmission system capacity and integration issues have constrained wind energy development. The unbundling of the transmission function from the formerly vertically integrated monopoly electric service industry has eliminated investment in transmission upgrades and grid expansion in many states. Some transmission owners have adopted an interconnection policy that places responsibility for any network upgrades on the incremental new generator without providing clearly defined ownership rights in network capacity in return for that investment. As a result, it is rare for a new generation project to be built other than in a location where transmission capacity already exists.

The need to schedule the use of a transmission system can also be a constraint for wind plants, but solutions are being developed. Recently the California Independent System Operator (CAISO) proposed that intermittent renewable energy generators not be subject to heavy penalties for deviations from scheduled transmission line usage. The CAISO proposal allows intermittent renewable generators to forecast their output power and resulting transmission needs on an hourly basis and for schedules of transmission usage to be based on those forecasts.

Environmental concerns can also be an issue in the planning and development of wind plants. Areas populated with protected species of birds should be avoided. Visual impact and noise are also concerns, but aesthetics and noise are becoming less of an issue as landowners realize the income potential of harvesting wind energy. Considering the large quantities of windy areas in the United States, avian and aesthetic concerns are not considered to be significant constraints. These and many other topics are covered in a report titled *Permitting Wind Energy Facilities* published by the National Wind Energy Coordinating Committee and available online at www.nationalwind.org/pubs/permit/permitting2002.pdf.

21.6 ECONOMICS

Trends in Investment

Investment patterns for wind-power projects are changing in the United States. Wind-power plant projects are growing larger, driven by demand for clean energy and project economies of scale. Large companies are now becoming developers because they are better able to handle the necessary capital-raising and financial commitments. In addition, the wind energy business is becoming more profitable, attracting major new investors.

Some of the developers are subsidiaries of electric utility companies, while others are associated with other fields of the energy business or are energy equipment suppliers. Some of the major developers associated with utilities are FPL Energy, American Electric Power, Texas Utilities (TXU), Nebraska Public Power District, and Xcel Energy. Other energy sector companies that are now delving into wind projects are Chevron-Texaco, Exelon, and Zilkha Renewable Energy. In addition, about 20 small companies are developing projects across the country.

Trends in Unit Cost of Energy 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. (See Figure 21.2.) In the best wind areas, project bids are approximately 0.03 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 DOE program goal is to advance wind energy technology so that utility-scale, grid-connected systems can produce electricity for 0.03 USD/kWh at widely available low wind-speed sites. As will be described later, DOE has launched a turbine development effort to produce concepts, components, and prototype systems that will be cost effective, without subsidies, at low-wind sites.

21.7 INDUSTRY

Nine U.S. companies are currently manufacturing wind turbines, and numerous businesses are building components, developing projects, and providing engineering services and related equipment. Currently three companies are building turbines larger than 50 kW, and six are building smaller turbines. Information about U.S. firms is available on the American Wind Energy Association web site, www.awea.org.

In May 2002, GE Power Systems announced that it had purchased some of the assets of Enron Wind Corporation. The new company is GE Wind Energy, a subsidiary of GE Power Systems. Worldwide, GE Wind Energy employs more than 1,500 people, with wind turbine factories in Spain and Germany as well as in California. To date the company has deployed more than 5,500 wind turbines with a total rated capacity exceeding 3,100 MW.

Some of the larger European wind turbine manufacturers are establishing assembly or component manufacturing plants in the United States. The Danish firm NEG Micon has a large turbine assembly facility in Illinois. In addition, LM Glasfiber is building rotor blades in North Dakota.

21.8 GOVERNMENT-SPONSORED R,D&D

The DOE wind energy program for 2002 was composed of three elements: applied research, turbine research, and cooperative research and testing.

Applied Research

Much of the applied research directly supports the development of the low wind-speed turbine. The program includes research into wind inflow and turbulence; aerodynamics; systems and controls; materials, manufacturing, and fatigue; design codes; advanced component testing; university research; and distributed wind applications.

Significant progress was made in the applied research effort in several important areas. One area focuses on understanding the interaction between the large rotors on low wind-speed turbines operating an atmospheric phenomenon known as the low-level nocturnal jet. The nocturnal jet is a poorly understood phenomenon that occurs in the Great Plains at night as cooling allows high-level, high-velocity winds to dip close to the Earth's surface, creating violently turbulent wind regimes. Because it typically occurs at heights of 60 m to 400 m above the ground, the wind shears that occur below the jet may interact with the top portions of the turbine rotor disk -- dramatically increasing structural loads, but possibly also increasing energy production, especially during the summer.

Work continued on the National Wind Technology Center's 600-kW Controls Advanced Research Turbine (see IEA Wind Energy Annual Report for 2001) to develop control systems and approaches that improve energy capture, reduce extreme and fatigue loads, and mitigate noise. In 2002, the program collected detailed inflow and turbine data on relevant turbine parameters necessary for use as control inputs.

Other important applied research advances were made in the development and validation of models of the wind inflow and loads analysis techniques to characterize the rate of occurrence, magnitude, and sequencing of the entire spectrum of loads-producing events. In another effort responding to requests by the wind industry, several upgrades are being made to the current suite of design tools supported by the program, including the AeroDyn library of aerodynamics routines to improve the generalized dynamic wake model.

Turbine Research

Emphasis in this element is on developing new, low wind-speed turbine technology. The program encompasses four areas, as follows.

- Next-generation turbine.
- Low wind-speed technology.
- Wind partnerships for advanced component technology (WindPACT).
- Distributed wind technology

Next-generation turbine development projects with industry are nearing completion. GE Wind Energy has installed more than 1,000 of its 1.5-MW turbines worldwide, with several hundred units operating in the United States. This turbine is undergoing further development and testing to improve and verify the design for lower wind-speed sites. The Wind Turbine Company (WTC) is developing a 500-kW turbine prototype under a next-generation turbine project, which is continuing extensive field testing in California. This turbine's flexible, hinged-rotor design has the potential to significantly reduce component weight and cost.

The low wind-speed technology project is assisting U.S. industry in developing advanced, cost-effective, low wind-speed turbines with a cost goal of 0.03/kWh USD in 5.8 m/s winds by 2012. During 2002, the first awards were made to companies under this program in three technical areas: conceptual design studies, component development, and full-scale prototype turbine development. Six development projects were selected through a competitive solicitation with industry, and these multi-year cost-shared efforts will commence in 2003.

Expected improvements from the low wind-speed research include advanced rotors and controls (flexible, low-solidity, higher-speed, hybrid carbon-glass, and advanced and innovative designs); advanced drive trains (hybrid drive trains with low-speed permanent magnet generators and other innovative designs); new tower concepts (taller, modular, field-assembled, load feedback control); improved availability and reduced losses (better controls, siting, and improved availability); manufacturing improvements (new manufacturing methods, volume production, and learning effects); and site-tailored designs.

Concept studies being pursued include independent blade pitch control strategies and tall hybrid steel-concrete wind turbine towers. Component development activities include a direct-drive permanent magnet generator; an advanced power conversion system designed for use as a subsystem in multi-megawatt-scale direct-drive, permanent magnet turbines; and a 100-m telescoping, tubular, steel monopole tower.

Prototype turbine development by Clipper Windpower on its 2.5-MW Quantum turbine includes a multiple drive train consisting of a single-stage gearbox driving multiple generators. The turbine design also incorporates advanced controls and a self-erecting tower.

The program is also supporting a research effort by GE Wind Energy to develop a 3.6-MW to 5-MW prototype turbine targeting land-based, low wind-speed sites. GE Wind Energy is currently testing a 3.6-MW prototype turbine in Spain that is designed specifically for offshore applications.

Under the WindPACT effort, studies have been completed on composite blades, turbine rotor and blade logistics, self-erecting tower and nacelle feasibility, balance of station costs, turbine rotor designs, and blade systems designs. In addition, WindPACT is sponsoring hardware development efforts that include a 1.5-MW drive train using a

Figure 21.6 Northern Power Systems' 100-kW cold weather turbine undergoing field tests at the National Wind Technology Center in Colorado and operational tests in Kotzebue, Alaska

single-stage gearbox with a medium-speed permanent magnet generator and an innovative power conversion system, a 1.5-MW direct-drive permanent magnet drive train, and advanced carbon-fiber blade designs.

Under the distributed wind technology area, Southwest Windpower is pursuing a 1.5-kW turbine design that would be mass-produced in ways similar to those used by the household appliance industry. Bergey Windpower continued to test its 50-kW prototype furling wind turbine design for distributed generation applications. Northern Power Systems completed the development of a direct-drive 100-kW turbine designed specifically for cold climates. The first prototype turbine is being field tested for certification at the National Wind Technology Center in Colorado (see Figure 21.6). A second unit was installed in Kotzebue, Alaska, in May 2002, and has performed well in field performance verification tests.

Cooperative Research and Testing

Cooperative research and testing activities address opportunities and barriers to the use of wind energy. Under this element of the program, researchers work with industry partners and utility system stakeholders to help remove market and institutional barriers to wind turbine deployment. Sponsored efforts include electrical system integration studies on voltage stability, power regulation, and other performance issues; turbine field

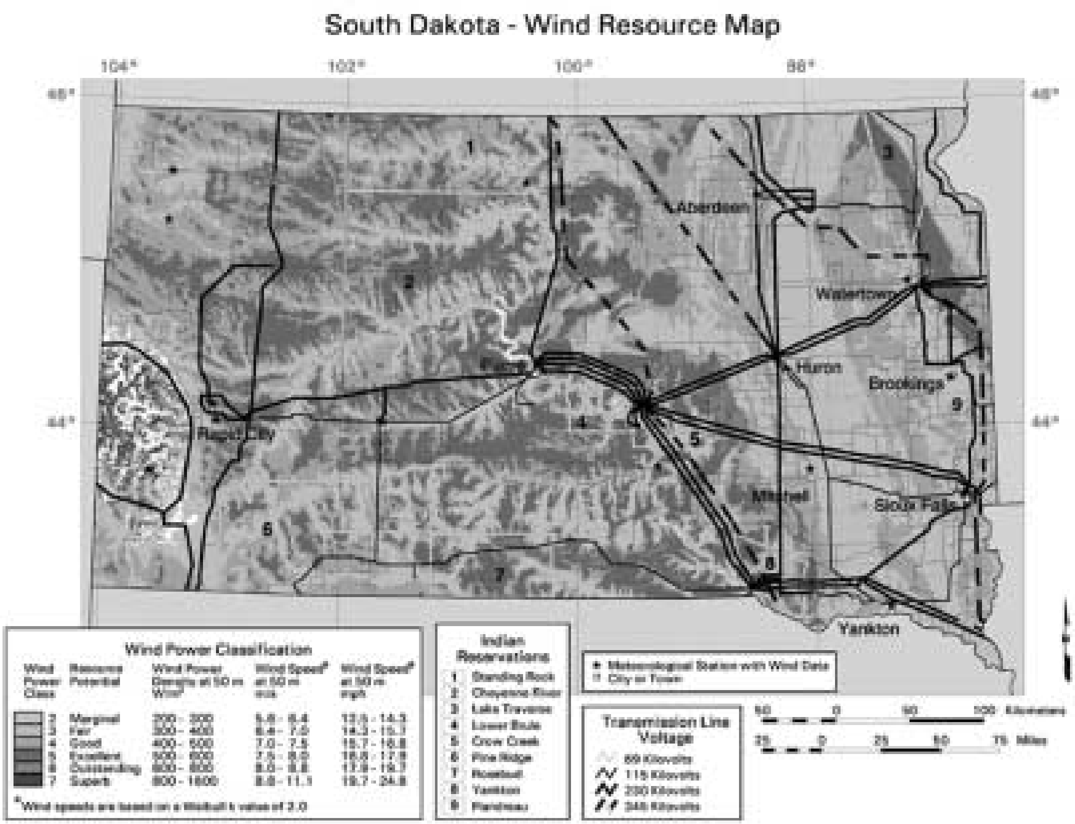

Figure 21.7 Wind resource map of South Dakota with 1-km resolution and overlay of power transmission system maps of most other parts of the country are available through the National Renewable Energy Laboratory at www.eere.energy.gov/windpoweringamerica

verification projects; and support for turbine certification testing and standards development.

New, high-resolution wind resource mapping is being done through cooperative efforts with the states. These maps are based on improved atmospheric flow models and have resource estimates with 1 km resolution compared with about 25 km in prior wind atlases dating back to the 1980s. Overlays showing power lines and key geographic features are shown on the wind maps. (See Figure 21.7.)

The Wind Powering America outreach activity continues to focus on reaching a broad base of stakeholder groups to help overcome informational and institutional barriers to wind's greater use. States are an important focus of this effort because of the important role that state policy can play in facilitating deployment. Important stakeholder groups being targeted include farmers and Native Americans because of the potential for wind to contribute to local economic development. This outreach effort is also targeting U.S. governmental entities, to increase the rate at which the government uses wind-produced electricity.

Offshore Siting

During the past year, there has been increasing interest in offshore wind energy development along the east coast of the United States. Developers have recognized the resource potential of offshore locations, combined with the value of locating projects near the urban load centers. As a result, numerous permit applications have been submitted for commercial projects in the relatively shallow waters located within 12 miles of the east coast. Several offshore wind projects have entered the permitting and wind resource measurement stage of development. In addition to the Cape Wind project mentioned previously, Long Island Power Authority has invited proposals for an offshore wind plant located along the south shore of Long Island in New York state. It is seeking an experienced developer to build, own, operate, and maintain a plant consisting of 25 to 50 offshore wind turbines that would produce approximately 100 MW to 140 MW and that could be operational by late 2007.

Despite the growing interest, several important issues are slowing offshore wind project development. Technical issues relate to the water depths along the continental shelf and sea conditions in the exposed North Atlantic. In addition, concerns from local residents focus on environmental issues, namely possible impacts on navigation safety, noise, fishing and recreation, birds, and visual impact. DOE is assessing possible efforts aimed at better understanding the technical, environmental, and regulatory issues affecting offshore installations; assessing the R&D needs for offshore wind technology; and expanding offshore wind resource assessment and mapping in shallow and deep water.

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Appendix A

Attendees of the 49th Executive Committee meeting in Magdeburg, Germany.

Appendix B

The IEA R&D Wind Executive Committee 2002 For the latest contact information, please visit the IEA Wind public Web site www.ieawind.org. M = Member A=Alternate Member			
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Appendix C

Currency conversions rates for IEA 2002 review

Country	Currency	rate/Euro	rate/USD
Australia	AUD	1.696	1.778
Canada	CAD	1.507	1.580
Denmark	DKK	6.757	7.085
Finland	Euro	1.000	1.049
Germany	Euro	1.000	1.049
Greece	Euro	1.000	1.049
Ireland	Euro	1.000	1.049
Italy	Euro	1.000	1.049
Japan	JPY	113.252	118.750
Mexico	MPS	9.942	10.425
Netherlands	Euro	1.000	1.049
New Zealand	NZD	1.821	1.909
Norway	NOK	6.617	6.938
Spain	Euro	1.000	1.049
Sweden	SEK	8.292	8.695
Switzerland	CHF	0.690	0.723
United Kingdom	GBP	0.593	.621
United States	USD	0.954	1.000

Source: Federal Reserve Bank of New York www.x-rates.com 31 December 2002

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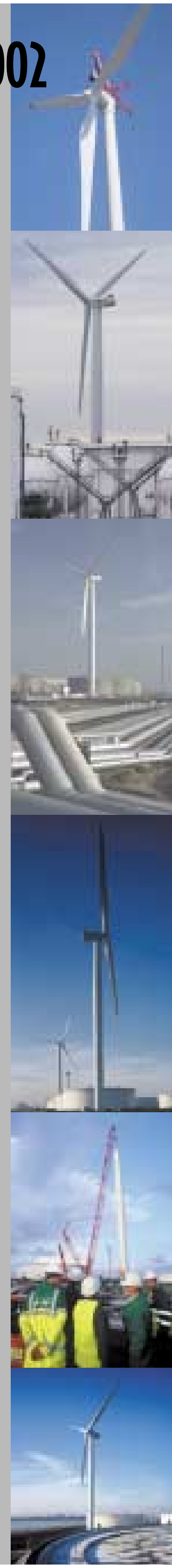
IEA WIND ENERGY ANNUAL REPORT 2002

For countries implementing wind energy, the main benefits are economic and environmental. Wind generators can be brought online quickly and have very low lifetime emissions of harmful gases. With the liberalization of electricity markets, countries also expect benefits from diversity and security of electricity supply and from stable prices.

In 2002, worldwide wind energy generating capacity increased to 31 gigawatts, and 90% of this capacity was in countries belonging to the International Energy Agency Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA Wind). In the reporting member countries, installed capacity grew almost 28%. In these countries, wind turbines generated 47 Terawatt hours of electrical energy, nearly enough electricity to meet the equivalent energy needs of Greece. The value of the global wind energy market in 2002 was estimated at over 6 billion U.S. Dollars.

This growth in capacity is being driven by improved technology, supportive government policies, and improved information about the advantages of wind energy. Even more is possible. Continued R&D is essential to provide further reductions in cost and uncertainty. With these reductions, visionaries in the public and private sectors foresee a 10 to 20% contribution by wind energy to worldwide energy consumption.

IEA Wind began in 1977 to facilitate development of wind energy technology. Under this agreement, parties from 19 countries and the European Commission improve information exchange 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 projects conducted during 2002. This year's report also recounts some history of the 25 years of collaboration.



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25 YEAR ANNIVERSARY

IEA WIND ENERGY ANNUAL REPORT

2002