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R&D
Wind

International Energy Agency (IEA)
Executive Committee for the

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

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Cover Photo: Noshiro wind farm, Japan

The twenty-fourth *IEA Wind Energy Annual Report* reviews the progress during 2001 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 19 contracting parties from 17 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 comprehensive international energy programs, carries out a comprehensive program about energy among 24 of the 29 OECD member countries.

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

Jaap 't HOOFT
Chair of the
Executive Committee
(1999-2001)

Patricia WEIS-TAYLOR
Secretary to the
Executive Committee

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

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EXECUTIVE SUMMARY

MESSAGE FROM THE CHAIR

The year 2001 was another good year for the expanding use of wind energy to supply electricity around the world. The strength of the sector continues to build on that of 2000, with worldwide electricity generation from wind energy now providing electric power sufficient to meet the entire needs of Denmark.

Much of the current market for wind energy is driven by the extremely low lifetime emissions the technology offers. But the value of wind energy goes beyond this. It also provides an opportunity for industry, enables rapid capacity building, removes fuel supply cost uncertainties, and increases the diversity and security of electricity supply.

The value of wind energy is being increasingly recognized by governments, and that has enabled sustained high growth at 30% per annum or above since 1994. In 2001, wind energy development continued to grow at more than 35% globally and nearly 40% in the countries belonging to IEA R&D Wind. At the end of 2001, global wind capacity reached 24.3 GW. The total installed capacity in the IEA R&D Wind member countries reached 21.5 GW; the IEA countries now account for 89% of global installed capacity. The value of this global market in 2001 is estimated to be approximately 6 billion USD.

Germany and Spain have sustained their high rates of turbine installation of the last several years and have put in more new wind plants than ever before. This reflects these countries' strong markets, which offer fixed and generous tariffs for wind energy. The United States continued its recent acceleration in wind energy deployment. Italy and Greece also sustained strength in the home market through continued political support and government incentives. Canada also had an exceptional year in 2001.

The new and vigorous markets of Japan and Australia continued the trend set in 2000. The estimated installed capacity in Japan shows growth has reached nearly 100%. Australia more than doubled its previous capacity, encouraged by the introduction of the Renewable Energy Certificate market in 2001. Australian wind energy expectations are for rapid growth in the next four years.

The cost of the energy generated commercially from wind power continues to fall steadily. More effective and less costly machines and the use of larger machines drive this reduction in costs. The average new turbine deployed is now close to 1 MW, which is approximately 200 kW more than last year. In 1995, the average new turbine had a capacity of just 440 kW.

Offshore wind energy expectations continue to gain momentum. The German offshore wind program received a big boost in 2001 with huge targets announced by the Ministry of Environment, Nature Conservation and Reactor Safety (BMU) and the launch of the Investment Program for the Future (ZIP). As a part of ZIP, Germany intends to build three or four offshore measuring platforms in the North and Baltic seas. In Denmark, the first two large-scale offshore wind power farms, each rated at 160 MW, will be ready for operation in 2002 and 2003. The Dutch have estimated that approximately 6,000 MW of offshore wind energy is possible as well as needed to reach targets. In October, a final draft document designated an area of the continental shelf for this new capacity.

In 2001, the Crown Estates of the United Kingdom announced a first round of offshore sites with the potential for more than 1,000 MW of new capacity. The new market for large, offshore machines has created fresh thinking about foundation and installation methods. Offshore reliability has been identified as an area needing continued research in to achieve acceptable availabilities.

In 2001, IEA R&D Wind issued its report titled "Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020. If wind energy is going to supply 10% of the world electricity needs in 2020, cost reductions in the technology of 30 to 50% are still necessary, to be able to compete with conventional energies head to head. R&D can contribute up to 40% of those cost reductions. The report identifies the research results needed in the mid-term (5-10 years) and long term (10-20 years) time frames.

I hope you will find this *IEA Wind Energy Annual Report* both interesting and informative. The Overview (Chapter 7) provides a synthesis of activities in our member countries. Feedback on the annual report is appreciated and can be sent to the secretariat at pwtcommunications@compuserve.com.

Jaap 't Hooft

Chair, IEA R&D Wind

(1999-2001)

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 24 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 for deployment. In this process, the IEA R&D Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

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 co-operative research, development, and demonstration of wind systems. Specifically, members agree to the following objectives for the extension of the agreement.

- 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,
- Extension of cooperation to non-participating OECD countries, as well as promotion of wind energy in developing countries and in Eastern Europe, preferably in cooperation with the World Bank and other international financing institutions.

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. They are concerned with work at home and in other countries. A summary of progress in each country is given in Chapters 8 through 23.

At present, 19 contracting parties from 17 countries and the European Commission participate in IEA R&D Wind. Australia, Austria, Canada, Denmark, Finland, Germany, Greece, Italy (two contracting parties), Japan, Mexico, the Netherlands, New Zealand, Norway, Spain, Sweden, the United Kingdom, and the United States are now members. 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.

COLLABORATIVE ACTIVITIES

Participants in the IEA R&D Wind Agreement are currently working on five tasks, that are Annexes to the original Implementing Agreement. Countries choose to participate in tasks that are relevant to their current national research and development programs. Several additional tasks are being planned as new areas for cooperative research are identified by Members. To date, 13 tasks have been successfully completed and one task has been deferred indefinitely (See Table 1.3). 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 their work. The projects are either cost-shared and carried out in a lead country, or task-shared, when the participants contribute in-kind, usually in their home organizations, to a joint program coordinated by an Operating Agent. Reviews of the progress in each active task are given in Chapters 2 through 6. A brief account of the status of tasks follows here. To obtain more information about these activities, contact the Operating Agent Representative for each task. Contact information for operating agent representatives is listed in Appendix B.

TASK XI – BASE TECHNOLOGY INFORMATION EXCHANGE

Operating Agent: Swedish Defence Agency (FOI), Sweden

The two main activities of this task are to prepare documents in the series "Recommended practices for wind turbine testing and evaluation" by assembling an Experts Group for each topic needing recommended practices and to conduct Topical Expert Meetings and Joint Actions in specific research areas designated by the IEA R&D Wind Executive Committee (ExCo). Work on this task began in 1987 and has been extended through December 2003. (See Chapter 2.)

TASK XVI - WIND TURBINE ROUND ROBIN TEST PROGRAM

Operating Agent: National Renewable Energy Laboratory - NREL, United States

This task was begun in 1996 to validate wind turbine testing procedures, analyze and resolve sources of discrepancies, and improve the testing methods and procedures. Anemometers from eight countries have been calibrated in ten wind tunnels. Site calibration measurements have been completed at NREL and RISØ National Laboratory (Denmark). Three standard turbines underwent tests in Canada, the United States, and Denmark in 1998. Testing at CRES in Greece continued through 2001. The ExCo voted to extend work on this task and a final report is expected in 2002. (See Chapter 3.)

TASK XVII - DATABASE ON WIND CHARACTERISTICS

Operating Agent: RISØ National Laboratory, Denmark

This task was adopted by the ExCo in 1999 to extend, maintain, and disseminate the knowledge of a database on wind characteristics developed under a European Union project, DG XII (JOULE). In 2001, the task participants continued adding data sets, maintaining the database, and disseminating information about the database. The ExCo voted to extend the task through December 2003 with the additional activity of supporting international wind turbine standardization efforts. (See Chapter 4.)

TASK XVIII – ENANCED FIELD ROTOR AERODYNAMICS DATABASE

Operating Agent: Netherlands Energy Research Foundation, ECN, the Netherlands

In 1998, the ExCo approved Task XVIII to extend the database developed in Task XIV and to disseminate the results so that extensive use of the database can be expected for years to come. In 2001, the database continued to be available on an Internet site. Access to the information is possible for parties who agree to inform the IEA Annex XIV participants about the experiences they gain with the database. The database has been extended, and 23 organizations have received access to it. A final report will be issued in 2002. (See Chapter 5.)

TASK XIX – WIND ENERGY IN COLD CLIMATES

Operating Agent: Technical Research Centre of Finland

In 2000, the ExCo approved Task XIX to supply information on the operation of wind turbines in cold climates. In 2001, the participants began gathering information on wind turbines in cold climates and establishing a site classification formula that combines meteorological conditions and local needs, they will monitor the reliability and availability of technology, and establish guidelines for applying wind energy in cold climates. (See Chapter 6.)

EXECUTIVE COMMITTEE ACTIVITIES

Officers

Mr. J. 't Hooft (the Netherlands) served as Chair, Mr. J. Lemming (Denmark) served as Vice-Chair, and Mr. P. Goldman (US) served as second Vice-Chair for 2001. At the 48th Executive Committee (ExCo) meeting, Mr. J. Lemming (Denmark) was elected to begin as Chair in 2002. Mr. P. Goldman was elected to begin as Vice-Chair in 2002.

Participants

In 2001, total membership continued to be 19 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, Ireland, 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). Beginning in 2001, 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 47th ExCo meeting was hosted by the Norwegian Water Resources and Energy Directorate (NVE), in Kristiansand, Norway on April 24 to 25, 2001. There were 23 participants from 14 of the contracting parties and six operating agent representatives of the tasks. The editor of the newsletter, a representative from IEA headquarters, and several observers from member countries also attended the meeting. The ExCo reviewed and approved progress reports of ongoing tasks XI, XVI, XVII, and XVIII; adopted the final text for Annex XIX Wind Energy in Cold Climates; and considered new proposals on advanced aerodynamic modeling and wind energy forecasting. Plans were approved for completion of the document on long-term R&D needs for wind energy. Market development activities were also discussed. The audit report of 2000 accounts of the Common Fund was approved.

On April 26, the ExCo visited the windmillpark at Fjeldskår, Lindesnes and toured the Agdar Energi office building and hydropower station.

The 48th ExCo meeting was hosted by the Japanese Government in Kyoto, Japan, on October 2 to 3, 2001. There were 22 participants from 11 of the contracting parties, three operating agent representatives of tasks, and several observers, including one from the Department of Renewable Energy of Portugal. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2002. In order to balance the budget for the Common Fund, the contribution amount from each country was increased, the newsletter was discontinued, and production of the Annual Report was consolidated. The ExCo also approved publication of the document *Long-term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020* as an official document of the IEA R&D Wind agreement. The ExCo considered proposals to tasks on advanced aerodynamic modeling, wind energy forecasting, HAWT (horizontal axis wind turbine) aerodynamics and models from wind tunnel measurements, and market acceleration. The ExCo invited the Government of Portugal to become a contracting party to the IEA R&D Wind Implementing Agreement.

On October 4, 2001, the ExCo visited the Hisai Sakakibara wind farm at Hisai City, the Mie University test site in Aoyama, and the AIST (MEL) test site.

The 15th issue of the *Wind Energy Newsletter* was published in July 2001.

The 23rd issue of the *IEA R&D Wind Annual Report* was published in May 2001.

Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020 was published in December 2001 (See Chapter 1 for summary).

CHAPTER 1

The Implementing Agreement

1.1 Activities of IEA R&D Wind

The IEA co-operation in wind energy began in 1977 with the signing of the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind). In 2001, the 19 contracting parties to this agreement included 17 countries and the European Commission (See Table 1.1).

The objectives of IEA R&D Wind are to exchange information among countries on the planning and execution of national large-scale wind system projects and to undertake collaborative R&D projects called tasks.

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

Australia	Australian Wind Energy Association
Austria	The Republic of Austria
Canada	Natural Resources Canada
Denmark	Ministry of Energy
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)
Italy	ENEL 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
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—2001

COUNTRY	TASK				
	XI	XVI	XVII	XVIII	XIX
	Technology information	Round robin test program	Database on wind character- istics	Enhanced field rotor aerody- namics database	Wind energy in cold cliamtes
Australia	x				
Canada	x	x			
Denmark	x	x	OA	x	x
European Commission	x				
Finland	x				OA
Germany	x				
Greece	x	x		x	
Italy	x				
Japan				x	
Mexico	x				
Netherlands	x		x	OA	
New Zealand					
Norway	x		x		x
Spain	x				
Sweden	OA		x		x
United Kingdom	x				
United States	x	OA	x	x	x

Table 1.2 Participation per country in current Tasks. OA indicates Operating Agent.

Task I	Environmental and meteorological aspects of wind energy conversion systems OA: The National Swedish Board for Energy Source Development Completed in 1981.
Task II	Evaluation of wind models for wind energy siting OA: U.S. Department of Energy - Battelle Pacific Northwest Laboratories Completed in 1983.
Task III	Integration of wind power into national electricity supply systems OA: Kernforschungsanlage Jülich GmbH, Germany. Completed in 1983.
Task IV	Investigation of rotor stressing and smoothness of operation of large-scale wind energy conversion systems OA: Kernforschungsanlage Jülich GmbH, Germany. Completed in 1980.
Task V	Study of wake effects behind single turbines and in wind turbine parks OA: Netherlands Energy Research Foundation. Completed in 1984.
Task VI	Study of local flow at potential WECS hill sites OA: National Research Council of Canada. Completed in 1985.
Task VII	Study of offshore WECS OA: UK Central Electricity Generating Board. Completed in 1988.
Task VIII	Study of decentralized applications for wind energy OA: UK National Engineering Laboratory Technically completed in 1989. Completed in 1994.
Task IX	Intensified study of wind turbine wake effects OA: UK National Power plc. Completed in 1992.
Task X	Systems interaction. Deferred indefinitely.
Task XI	Base technology information exchange OA: FFA, Sweden. Continuing through 2001.
Task XII	Universal wind turbine for experiments (UNIWEX) OA: Institute for Computer Applications, University of Stuttgart, Germany Completed in 1994. Final report published in 1995.
Task XIII	Cooperation in the development of large-scale wind systems OA: National Renewable Energy Laboratory (NREL), USA Completed in 1994. Final report published in 1995.
Task XIV	Field rotor aerodynamics OA: Stichting Energieonderzoek Centrum Nederland (ECN), the Netherlands Final report published in 1997.
Task XV	Annual review of progress in the implementation of wind energy by the member countries of the IEA OA: ETSU, on behalf of the United Kingdom. Completed June 2001.
Task XVI	Wind turbine round robin test program OA: the National Renewable Energy Laboratory (NREL), United States To be completed in 2002.
Task XVII	Database on wind characteristics OA: RISØ National Laboratory, Denmark. Continuing through 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. Continuing through 2001.
Task XIX	Wind energy in cold climates OA: Technical Research Centre of Finland - VTT Energy Continuing through 2003.

Table 1.3 IEA R&D Wind tasks defined in Annexes to the Implementing Agreement

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.

The R&D tasks performed under IEA R&D Wind are approved by the ExCo as Annexes to the original Implementing Agreement (as revised in 1991). These tasks are sometimes referred to by their Annex number. Each task is managed by an Operating Agent organization within one of the Member countries. The level of effort varies for each task. Some tasks involve only information exchange and require each country to contribute less than 0.1 person-year of work. Other tasks involve test programs requiring several people working over two or more years to complete them. Some of these R&D projects are "task shared" by each country performing a subtask; other projects are "cost shared" by each country contributing to the budget for a designated lead country to perform the task. The technical results of tasks are shared among participating countries. Only countries with parties interested in the outcome of a task choose to participate by signing the Annex agreement. (See Tables 1.2 and 1.3.)

1.2 LONG-TERM RESEARCH AND DEVELOPMENT NEEDS FOR WIND ENERGY FOR THE TIME FRAME 2000 TO 2020

1.2.1 Official Document of the ExCo

In 2001, the IEA R&D Wind Energy Implementing Agreement developed a document to serve as a basis for discussion of what can be done within the agreement to meet long-term research needs. In March 2001, long-term research and development needs were identified at a topical experts meeting sponsored under Task XI of IEA R&D Wind (Base Technology Information Exchange). At the meeting, an ad hoc group was assembled that generated a draft report to the ExCo titled "Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020." This draft report was eventually approved by the ExCo as an official document that was published as a booklet, 2,500 copies being distributed to the member countries. A summary of the major conclusions follows.

1.2.2 Summary of Conclusions

Research and development has been an essential activity in achieving the cost and performance improvements in wind generation to date. During the last five years, company R&D has put emphasis on developing larger and more effective wind turbine systems utilizing knowledge developed from national and international generic R&D programs. Continued R&D is essential to provide the necessary reductions in cost and uncertainty to realize the anticipated level of deployment. Many countries hope that wind energy could supply 10% of the world electricity needs in 2020. To reach this level of contribution, cost reductions in the technology of 30 to 50% are still necessary, for wind energy to compete with conventional energies head to head. R&D can contribute up to 40% of those cost reductions. Continued R&D will support revolutionary new designs as well as incremental improvements. Researchers will improve understanding of how extreme wind situations, aerodynamics, and electrical generation affect wind turbine design. The challenge is to try to find those evolutionary steps that can be taken to further improve wind turbine technology.

For the mid-term time frame, R&D areas of major importance for the future deployment of wind energy are forecasting techniques, grid integration, public attitudes, and visual impact. R&D to develop forecasting techniques will increase the value of wind energy by allowing electricity production to be forecast from 6 to 48 hours in advance. R&D to facilitate integration of wind generation into the electrical grid and R&D on demand-side management will be essential when it is necessary to transport large quantities of electricity from wind

Research Area	Focus On	Time Frame/ Priority		Present Activity in IEA R&D Wind
		Mid-term	Long-term	
Increase value and reduce uncertainties				
Forecasting power performance	Increase value of electricity	++		Topical Expert Meeting 2000
Reduce uncertainties related to engineering integrity, improvement and validation of standards	Supply background material	++		Topical Expert Meeting 2001
Storage techniques	Storage for different time scales		++	
Continue cost reductions				
Improved site assessment and new locations, especially offshore	Extreme wind and wave situations, forecasting techniques	++		Annex XVII Wind Characteristics
Better models for aerodynamics/aeroelasticity	3D effects, aeroelastic stability	++	++	Annex XI Joint Action on Aero
New intelligent structures/materials and recycling	Extremes, adaptive intelligent structures, recycling		++	Topical Expert Meeting 2002
More efficient generators, converters	Combined solutions for generation and transmission	++	+	Topical Expert Meeting 2001
New concepts and specific challenges	Intelligent solutions for load reduction		+	
Stand alone and hybrid systems	Improved system performance	++		

Table 1.4 Research priorities in the mid- and long-term time frames

Research Area	Focus On	Time Frame/ Priority Mid-term	Time Frame/ Priority Long-term	Present Activity in IEA R&D Wind
Enable large-scale use				
Electric load flow control and adaptive loads	Improve models, load flow control, power electronics		++	
Better power quality	Power electronics	++		Recommended Practice
Minimize environmental impacts				
Compatible use of land and aesthetic integration	Information and interaction	++		Topical Expert Meeting 2002
Noise studies	Offshore issues	++		Topical Expert Meeting 2000
Flora and fauna	Background data	++		

++ Denotes high priority + Denotes priority

Table 1.4 Research priorities in the mid- and long-term time frames cont.

through a grid. R&D to provide information on public attitudes and visual impact of wind developments will be necessary to incorporate such concerns into the deployment process for new locations for wind energy both onshore and offshore. (especially offshore)

For the long-term time frame, it is of vital importance to perform the R&D necessary to take large and unconventional steps to make the wind turbine and its infrastructure interact in close co-operation. Adding intelligence to the complete wind system and the grid and allowing it to interact with other energy sources will be essential in areas of large-scale deployment. R&D to improve electrical storage techniques for different time scales (minutes to months) will could increase value at penetration levels above 15% to 20%.

There is a need for continued long-term research supported by society, in addition to the internal product development and research that is carried out within the industry. These are the R&D priorities this paper recommends in the mid-term and long-term time frame. (See Table 1.4.)

CHAPTER 2

Task XI - Base Technology Information Exchange

The objective of this Task is to promote wind turbine technology by co-operative activities and information exchange on R&D topics of common interest. These particular activities have been part of the 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 needing recommended practices. In the series of Recommended Practices, 11 documents have been published. Five of these have appeared in revised editions (Table 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, and offshore wind systems. 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 22 years since these activities were initiated, 37 volumes of proceedings from Expert Meetings (Table 2.2), 15 volumes of proceedings from symposia on Aerodynamics of Wind Turbines, five from symposia on Wind Turbine Fatigue, and two from symposia on Wind Characteristics have been published.

Activities during 2001:

- Topical Expert Meeting 35 on Long Term Research Needs
- Ad Hoc group work on Long term R&D Needs, 2000 - 2020
- Topical Expert Meeting 36 on Large scale integration into the grid
- Topical Expert Meeting 37 on Structural Reliability of Wind Turbines
- Joint Action Symposium on aerodynamics

The 35th Topical Expert Meeting addressed Long Term Research Needs. The subject of the meeting was to identify Long term R&D needs for wind energy, for the time frame 2000 – 2020. This meeting was an essential element in the process of developing a long term R&D strategy for the Implementing Agreement. A similar meeting was held in the Netherlands in 1995. At that meeting, the discussions mainly focused on technological issues. The meeting 2001 also focused on these things, and in addition to that made reference to such areas as sociotechnical aspects (visual intrusion, public acceptance, etc.) and wildlife, flora, and fauna. This seems natural in a stage when wind turbines are becoming a more common element in the society.

The Long term R&D strategy report was adopted by the 48th ExCo meeting in Japan. The document can be downloaded from http://www.pwtcommunications.com/ieaexco/offdocs.htm.

The 36th Topical Expert Meeting, held in Hexham UK, addressed Large Scale Integration into the Grid. The conclusion from the meeting was that it is essential to have good simulation tools and reliable

No.	Area	Edition	Year	First Ed.	Valid	Status
1	Power Performance Testing	2	1990	1982	no	Superceeded by IEC 61400-12, Wind power performance testing
2	Estimation of Cost of Energy from WECS	2	1994	1983	yes	
3	Fatigue Loads	2	1990	1984	yes	Part of IEC 61400-13 TS, Measurement of mechanical loads
4	Acoustics Measurement of Noise Emission From Wind Turbines	3	1994		no	Superceded by IEC 61400-11, Acoustic noise measurement techniques
5	Electromagnetic Interference	1	1986		yes	
6	Structural Safety	1	1988		no	See also IEC 614000-1, ed2
7	Quality of Power Single Grid-Connected WECS	1	1984			See also IEC 614000-21 FDIS, Measurement and assessment of power quality of grid connected wind turbines
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 2.1 IEA R&D Wind List of Recommended Practices.

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 2.2a List of Topical Expert Meetings held since 1990

models of the wind turbines when performing grid simulations. There was a great interest for further co-operation within this field. At the meeting it was decided to prepare a proposal for a new Annex to the R&D Wind Implementing Agreement. The work will cover:

1. Model exchange/evaluation/comparison

2. A common database with model parameters and measurements

3. Best practice guidelines, such as, grid connection codes specific for wind turbines

18	Noise generating mechanisms for wind turbines	Petten, Netherlands	1989
17	Integrating wind turbines into utility power systems	Herndon, USA	1989
16	Requirements for safety systems for LS WECS	Rome, Italy	1988
15	General planning and environmental issues of LS WECS installations	Hamburg, Germany	1987
14	Modelling of atmospheric turbulence for use in WECS rotor loading calculations	Stockholm, Sweden	1985
13	Economic aspects of wind turbines	Petten, Netherlands	1985
12	Aerodynamic calculation methods for WECS	Copenhagen, Denmark	1984
11	General environmental aspects	Munich, Germany	1984
10	Utility and operational experience from major wind installations	Palo Alto, California	1983
9	Structural design criteria for LS WECS	Greenford, UK	1983
8	Safety assurance and quality control of LS WECS during assembly, erection and acceptance testing	Stockholm, Sweden	1982
7	Costing of wind turbines	Copenhagen, Denmark	1981
6	Reliability and maintenance problems of LS WECS	Aalborg, Denmark	1981
5	Environmental and safety aspects of the present LS WECS	Munich, Germany	1980
4	Rotor blade technology with special respect to fatigue design	Stockholm, Sweden	1980
3	Data acquisition and analysis for LS WECS	Blowing Rock, USA	1979
2	Control of LS WECS and adaptation of wind electricity to the network	Copenhagen, Denmark	1979
1	Seminar on structural dynamics	Munich, Germany	1978

Table 2.2b List of Topical Expert Meetings held 1978-1990

The 37th Topical Expert Meeting was held in Denmark on Structural Reliability of Wind Turbines. Structural reliability is presently an area in wind turbine design that draws attention from many different interest groups. Manufactures are looking for reliable methods to design larger and more optimised wind turbines in a safe way. Research institutes and universities are currently involved in activities aiming at developing and refining basic tools within the field. Standardisation bodies, such as the International Electrotechnical Commission (IEC), are putting great emphasis on developing rules and regulations in the area.

As a result of this common interest, the symposium attracted 15 participants from universities, research institutes, classification bodies and industry giving 11 presentations covering different aspects of the theme of the symposium. The meeting participanats decided to put forward a proposal to form a new Annex to the IEA R&D Wind Implementing Agreement dealing with (amongst others) external load conditions, assessment, and uncertainties related to the design of wind turbines.

The 15th Joint Action Symposium on Aerodynamics was held at NTUA, Athens, Greece. The agenda was open to all aspects of aerodynamics. Aeroelastic stability was one of the topics. Related to this, the aerodynamic design of blades and structural damping were discussed.

Another topic was the presentation and discussion of the two proposals for new annexes to the IEA R&D Wind Implementing Agreement dealing with Aerodynamic Modelling and further evaluation and comparisons of the large wind tunnel experiments performed by NREL and NASA in the United States last year.

All documents produced under Task XI are available from the Operating Agent representative (Coordinates in appendix B) and from representatives of countries participating in Task XI (Table 1.2).

More information can be found on:

http://www.windenergy.foi.se/IEA_Annex_XI/ieaannex.html

Author: Sven-Erik Thor, FOI, Sweden

Task XVI - Wind Turbine Round Robin Test Program

3.1 INTRODUCTION

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

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

3.2 OBJECTIVES

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

Task descriptions

- Development of test and analysis plan
- Procurement and installation of test turbines
- Preparation of test sites
- Testing of standard turbines and data analysis

Participants

- Risø Test Station for Wind Turbines, Denmark
- Italian Agency for New Technology, Energy and the Environment (ENEA), Italy
- Center for Renewable Energy Sources (CRES), Greece
- Atlantic Wind Test Site (AWTS), Canada
- National Renewable Energy Laboratory (NREL), the United States (Operating Agent)

3.3 STATUS

This annex to the Wind Energy Agreement was approved with a starting date of April 1996. After the program kickoff meeting, in April 1996, participants began detailed preparations for testing. These included drafting test plans, initiation of anemometer wind tunnel calibrations, and initiation of site calibration measurements.

ENEA participated in Annex activities at the beginning of this project. In 1998, ENEA withdrew from the Annex because funding and organizational changes prohibited further participation.

Wind tunnel calibrations were conducted in co-operation with a European Wind Turbine Standards program, MEASNET, in which anemometers from eight countries are being calibrated in ten wind tunnels. Final calibrations have been completed, but the results have not been made available. Annex participants agreed to conduct a follow-on calibration of anemometers at CRES. These tests were complete in March 1999, and portions of the 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.

The Standard Turbine is an AOC 15/50, a 50-kW, free-yaw turbine that is relatively easy to transport and install. Participants will complete tests on three of these turbines, 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, and both NREL and AWTS engineers have completed several operational tests of their turbines. NREL has also completed noise, power performance, and structural loads testing of its turbine. AWTS completed power performance testing in 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 has been delayed. At present, CRES expects to complete testing by August 2002. The original plan to test the third turbine in Italy has been cancelled due to funding and organizational constraints at ENEA.

Status meetings were held at Risø in June 1998 and at CRES in February 1999. The Executive Committee has approved several extensions for the Annex to accommodate the delayed production of the European test turbine, the change in test sites from ENEA to CRES, and the longer than expected testing schedules. Participants expect to complete all final reports by October 2002.

Some comparisons of test results have begun. Present plans call for completion of detailed comparisons of all available test data by August 2002. Interim results have been presented at Executive Committee meetings and through a paper at the American Wind Energy Association's Windpower 2001 conference.

Author: Hal Link, NREL, United States

Task XVII – Database on Wind Characteristics

4.1 INTRODUCTION

In 1996, the EU-DG XII (JOULE) project Database on Wind Characteristics was started. The project 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 a simple analysis through an Internet connection using the World Wide Web.

As a follow-up to the JOULE project, Task XVII (also known as Annex 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 entered into force on 1 January 1999, and an initial annex period of two and a half years was successfully concluded on 30 June 2001. IEA has agreed to run the Annex for an additional two and a half years, with the purpose of continuing ongoing maintenance and dissemination, accomplishing the initiated extension of facilities and content, and continuing to support international wind turbine standardization efforts. The continuation of Annex XVII covers the period 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 two-and-a-half-year period, the scope has been widened to also include support to international wind turbine standardization efforts.

4.2 OBJECTIVES

The specific objectives of Annex XVII are as follows.

- Assure that users, now and in the future, 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 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 possibilities for running Database on Wind Characteristics on a commercial basis after the prolongation has expired

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

4.3 STATUS

Presently, the database contains more than 108,000 hours of high-sampled meteorological time series data from 48 different sites in Europe, Egypt, the United States, and Japan that represent a wide variety of wind climates, terrain types, and wind turbine wake situations. For 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 338,000 hours of resource data from 11 sites is 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 is stored as ten-minute statistics. As with the time series measurements, emphasis has been given to ensure a high level of documentation of the measurement setups.

The accomplishments achieved in 2001, within each of the defined work tasks, are summarized below.

4.3.1 Maintenance

The maintenance of the database includes both routine software updates and routine hardware updates. The following activities have been performed during 2001.

- Tuning of the database (software) to improve the database performance by minimizing access time
- Updating web pages

4.3.2 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 prominent activity has been a complete reorganization of the database structure in order to allow for inclusion of two new categories of data, resource data and structural time series data, as a supplement to the existing data category restricted to wind field time series.

A description of the efforts performed within upgrade of the database facilities as well as within extension of the amount

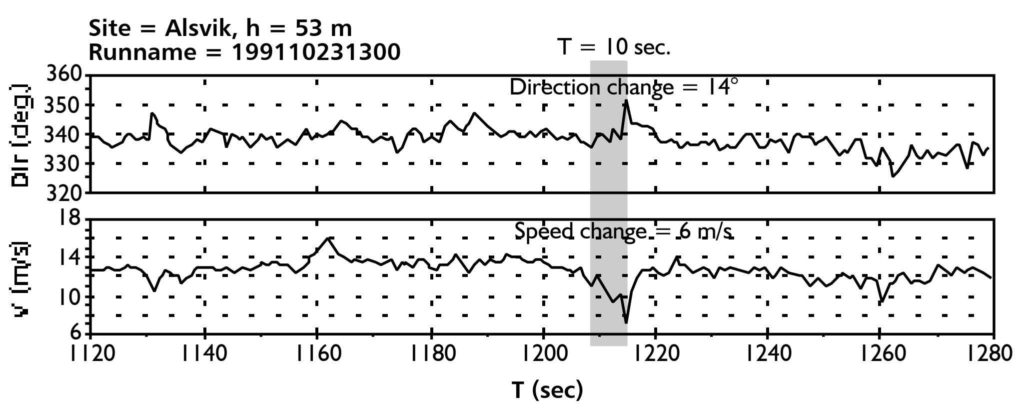

Figure 4.1 Example of simultaneously extreme wind speed (down) guest and wind direction change identified using database search and analysis tools]

of available wind field time series appears below.

1. Database utilities

- Implementation of a new database structure suited for wind resource data
- Implementation of a new database structure suited for implementation of wind turbine structural load time series
- Implementation of the multi-user class software system
- Development and implementation of a site classification system (based on such information as data category, type of climate, type of terrain, orographic class, spatial resolution, time resolution, recording period, 1-D/3-D type measurements, etc.)
- Release of an updated version of Dbwind.exe (i.e., improved facilities for multiple download of time series from the ftp server)
- Release of a new interactive version of the online plotting facility (enabling zooming and channel browsing)
- Development and implementation of features to evaluate and plot (annual) probability density functions of arbitrary resource data signals

Database Bank Implementation:

- Sky River wind farm data (164 hours of data from a complex site in California, U.S.A.)
- Abisko wind field data (229 hours of 20-Hz recordings from a flat terrain, a frozen lake in Sweden)
- Näsudden wind farm data (2,870 hours of 1-Hz recordings from a flat coastal terrain in Sweden)
- Horns Rev data (773 hours of 3-D, 20-Hz recordings from a Danish coastal ocean water offshore site)
- Roedsand data (619 hours of 5-Hz and 20-Hz recordings from a Danish shallow water offshore site)
- Hurghada site data (1,385 hours of 8-Hz recordings from flat, sand terrain in Egypt; cups; includes information required to make a determination of the atmospheric stability)
- CIBA site (435 hours of 20-Hz and 5-Hz recordings from pastoral, flat terrain in Spain; sonics and cups)
- Mt. Tsukuba site data (2,400 hours of 4-Hz recordings from mountain, forest terrain in Japan; sonics)
- Horns Rev wind field data (3,163 hours of 3-D, 20-Hz recordings from a Danish coastal ocean water offshore site)
- Cabauw site wind field data (472 hours of 2-Hz recordings from pastoral, flat terrain in the Netherlands, measuring heights of 20 m to 200 m; propeller-vanes)
- Hanford site data (1,071 hours of 5-Hz recordings from pastoral, flat terrain in Washington, U.S.A., measuring heights of 10 m to 40 m)
- Calwind site data (4,182 hours of 5-Hz recordings from scrub, hill terrain in Tehachapi, CA, U.S.A., measuring heights of 10 m to 40 m)
- Windland site data (3,667 hours of 5-Hz recordings from scrub, hill terrain in Cameron Canyon, CA, U.S.A., measuring heights of 10 m to 40 m)
- Equinox site data (72 hours of 5-Hz recordings from scrub, hill terrain in Equinox mountain, Vermont, U.S.A., measuring heights of 10 m to 40 m)
- Flowind site data (5,947 hours of 5-Hz recordings from scrub, hill terrain in Horned Hills, Mojave, CA, U.S.A., measuring heights of 10 m to 40 m)
- Gorgonio site data (1,399 hours of 5-Hz recordings from scrub, hill terrain in

San Gorgonio Pass, Palm Springs,CA, U.S.A., measuring heights of 10 m to 40 m)

- Jericho site data (7,000 hours of 5-Hz recordings from scrub, hill terrain in Jericho, Texas, U.S.A., measuring heights of 10 m to 40 m)
- Tughill site data (2,983 hours of 5-Hz recordings from scrub, hill terrain in Tug Hill plateau, New York, U.S.A., measuring heights of 10 m to 40 m)
- Tjaereborg resource data (five years of 10-minute statistics from a flat, Danish terrain)
- Alsvik resource data (five years and two months of 10-minute statistics from a flat, coastal Swedish terrain)
- Vindeby resource data (six years and ten months of 30-minute statistics from a Danish shallow water offshore site)
- Skipheia resource data (11 months of 10-minute statistics from a hilly, coastal Norwegian terrain)
- Cabauw site resource data (15 years of 1-hour statistics from a pastoral, flat terrain in the Netherlands, measuring a height of 10 m)
- Risø mast resource data (five years of 10-minute statistics from a coastal, flat terrain in Denmark, measuring heights of 44 m to 125 m)
- Hanford resource data (two years and six months of statistics from a pastoral, flat terrain in Washington, U.S.A.)
- Calwind resource data (two years and ten months of statistics from a scrub, hill terrain in California, U.S.A.)
- Windland resource data (two years and 11 months of statistics from a scrub, hill terrain in California, U.S.A.)
- Burger Hill, Orkney Islands resource data (one year and six months of 10-minute statistics from a coastal, flat terrain in the United Kingdom, measuring heights of 60 m to 64 m)
- Tjaereborg data (79 hours of structural wind turbine measurements from a 2-MW, 60-meter diameter wind turbine located in coastal, flat terrain in Denmark)

4.3.3 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. Initiatives taken in 2001 are listed below.

- Eight electronic newsletters were issued.
- Database on Wind Characteristics was utilized in a number of ongoing research projects (the JOULE project NewGust, the JOULE project ENDOW, the JOULE project ADAPTURB).
- A link to the home page for the Middelgrunden offshore wind farm was established.
- Leaflets were distributed (Danish Ministry of Energy Wind Energy Conference, Ringkoebing, 26-27 March 2001; EWEC 2001, Copenhagen, 2-6 July 2001).
- Risø and DTU obtained national funding of a project on extreme wind direction gusts in which the database will be used.
- An online presentation of Database on Wind Characteristics was given at the UNAM, Mexico City, in April 2001.
- In July 2001, four papers were presented at EWEC 2001, Copenhagen, describing the database or partly based on data originating from the database (Database on Wind Characteristics general description, Statistics of Offshore Wind Speed Gusts, Validity of the Assumption

of Gaussian Turbulence, and A Probabilistic Method for Extreme Wind Turbine Loading)

- The following sections of the Database on Wind Characteristics project were completed in November 2001: Structure and Philosophy, Larsen, G.C. and Hansen, K.S., RISO-R-1299; Users Manual, Larsen, G.C. and Hansen, K.S., RISO-R-1300; Contents of Database Bank, Larsen, G.C. and Hansen, K.S., RISO-R-1301.

The database is available on the web server (www.winddata.com) and its use is free of charge for users from IEA Annex XVII participating countries.

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

CHAPTER 5

Task XVIII – Enhanced Field Rotor Aerodynamic Database

5.1 INTRODUCTION

International Energy Agency (IEA) Annex XVIII is an extension of the IEA Annex XIV project in which five parties from four countries (the Netherlands, Denmark, the United Kingdom, and the United States) co-operated in performing aerodynamic field experiments on full-scale horizontal axis wind turbines. The project resulted in a unique database of local aerodynamic properties taken under atmospheric conditions [1]. In conventional measurement programs, the aerodynamic behavior of a wind turbine has to be analyzed by means of measurements of integrated, total (blade or rotor) loads. These loads consist of an aerodynamic and a mass-induced component, and they are integrated over a certain span-wise length. This gives only indirect information about the aerodynamics at the blade element level. The supply of local aerodynamic measurements, as carried out in Annex XIV, is a major step forward in understanding the aerodynamic behavior of wind turbines.

Until October 1999, the IEAAnnex XIV database was stored on CD-ROM and on an ftp site, which was protected by a password. The CD-ROM and/or the password are available for outside parties under the condition that they inform the IEA Annex XIV participants about experiences gained from the database. In October 1999, the database also became available on an Internet site. The conditions to obtain the database from the Internet site remain similar to the conditions described above.

The present project (IEAAnnex XVIII) has been defined on the basis of the recommendations that have been formulated at the end of IEAAnnex XIV. The main objectives of IEA Annex XVIII are as follows.

- Maintenance of the IEA Annex XIV database (feedback from the above mentioned users of the database is essential in order to reach this objective)
- Extension of the IEAAnnex XIV database with new measurements

The participants in the IEAAnnex XVIII are as follows.

- Netherlands Energy Research Foundation (ECN), the Netherlands, Operating Agent
- Delft University of Technology (DUT), the Netherlands
- Risø National Laboratory, The Test Station for Wind Turbines, Denmark
- National Renewable Energy Laboratory (NREL), the United States
- Mie University (MU), the Department of Mechanical Engineering, Japan
- Center for Renewable Energy Sources (CRES), Greece

5.2 CHARACTERISTICS AND STATUS OF THE TEST FACILITIES

1) Wind turbine at ECN, the Netherlands

Diameter is 28 m; two blades; blades with twist and taper; instrumented at three radial stations, measured simultaneously. Tests are complete. Much data have been collected, both for standstill as well as rotating conditions. The data are stored in the Annex XIV database.

2) Wind turbine at Risø, Denmark

Diameter is 19 m; three blades; blades with twist and taper; instrumented at three radial stations, measured simultaneously. Tests are complete. Much data have been collected and stored in the Annex XIV database.

3) Wind turbine at NREL, the United States

Diameter is 10 m; experiments are carried out in different phases. Phase II: Three blades; blades without twist and taper. Phase III and Phase IV: Same as Phase II, but blades have twist. The difference between Phase III and Phase IV is the measurement of the inflow conditions. This is performed with a flag device, respectively a five hole probe. Phase V: Two blades; blades with constant chord, twisted. Instrumented at four or five radial positions, measured simultaneously. Much data have been collected. Phases II, III, and IV are complete, and data are stored in the Annex XIV database.

4) Wind turbine at MU, Japan

Diameter is 10 m; three blades; blades with twist and taper; instrumented at four radial stations, partly measured simultaneously. Tests continue. Data have been collected and stored in the Annex XVIII database.

5) Wind turbine at DUT, the Netherlands

Diameter is 10 m; two blades; blades without twist and taper; instrumented at four radial positions. Until 1999, these stations could not be measured simultaneously. Since January 1999, two stations can be measured simultaneously. Much data have been collected for the 30%, 50%, and 70% sections, which were measured independently. These measurements have been made available for the Annex XVIII database.

6) Wind turbine at CRES, Greece

Diameter is 19 m; three blades; blades with twist and taper; instrumented at three radial positions. Due to some delays in the measurement program, the data could not be included in the database.

5.3 STATUS OF THE DATABASE

At the end of 2001, the following measurements were stored into the database.

- Power curves delivered by NREL, Risø, and MU
- 2-D airfoil coefficients delivered by ECN, NREL, Risø, DUT, and MU
- 2-D pressure distributions delivered by NREL, DUT, and MU
- Rotating airfoil coefficients delivered by ECN, NREL, Risø, and MU
- Time series delivered by DUT, ECN, NREL, IC, Risø, and MU. Time series were delivered for aligned conditions and for yawed conditions (yaw angle ranging from -40 to +40 degrees). The angle of attack ranges from negative values to deep stall.

5.4 USER DATABASE EXPERIENCES

As mentioned, until October 1999 the IEA Annex XIV database was only available through CD-ROM and on an ftp site, which was protected by means of a password. The CD-ROM and/or the password were available for outside parties under the condition that they inform the IEA Annex XIV participants about experiences gained with the database – for example, by means of relevant project reports. This feedback gives the IEAAnnex XVIII participants the opportunity to improve the quality of the database, to get insight into the research that has been performed with the measurements, and to defend against possible criticism. In October 1999, the database also become available on an Internet site. On this site, a registration form has to be completed by the user that asks the user to share individual experiences with the IEAAnnex XIV/XVIII participants. The request to share experiences is based on a Gentlemans/Ladies Agreement and no obligations can be imposed.

Through the end of 2001, 23 users gained access to the database, either through the CD-ROM or through the Internet site. The EU-JOULE project group, Viscel, also gained access to the data. In addition, several students from different universities around the world have visited the database.

During the IEAAnnex XVIII project period, several comments were received from users. They include such comments as recommendations on accessibility, preferences for data formats, usefulness of data, and errors in the data.

Some interesting topics that have been studied using aerodynamic field measurements are as follows.

- In stationary and 3-D effects in stall (see [3], [4], and [5])
- Validation of codes such as free wake panel methods, NS codes, and bem-like methods (see [6], [7], and [8])
- The variation of the induced velocities at yawed conditions (see [9])
- Rotor tower interaction (see [10])
- The effect of different pitch angles on airfoil characteristics

In reference to the effect of different pitch angles on airfoil characteristics, it was already expected from helicopter and propellor experiences that the airfoil coefficients at rotation would differ from the 2-D airfoil coefficients (i.e., at rotation, a much higher maximum lift coefficient was expected – in particular, at the root of the blade). The field measurements led to a definite confirmation of this expectation and also gave some indication that the differences between 2-D data and rotating data may depend heavily on pitch angle.

5.5 ACTIVITIES TO BE PERFORMED

The final report of the project is finished in draft [2] and will be completed in the beginning of 2002. The only remaining task is to finalize the Internet site, which will also be completed in the beginning of 2002.

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[10] J.M.R. Graham and C.J. Brown: ROTOW-Investigation of the aerodynamic interaction between wind turbine rotor blades and the tower and its impact on wind turbine design, Final Publishable Report, Department of Aeronautics, Imperial College of Science and Medicine, London, UK, September 2000.

Authors: LGJ Janssen and J.G. Schepers, ECN, the Netherlands

CHAPTER 6

Task XIX – Wind Energy in Cold Climates

6.1 INTRODUCTION

Wind energy is increasingly being used in cold climates, and technology has been adapted to meet these challenges. As the turbines incorporating new technology are 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) R&D wind implementing agreement was officially approved in 2001. The resulting task began in May 2001 and will continue for three years.

It has been agreed upon that the sites involved in this task will be wind turbine sites that either have icing events or low temperatures outside the standard operational limits of wind turbines. Participants will work to achieve the following objectives.

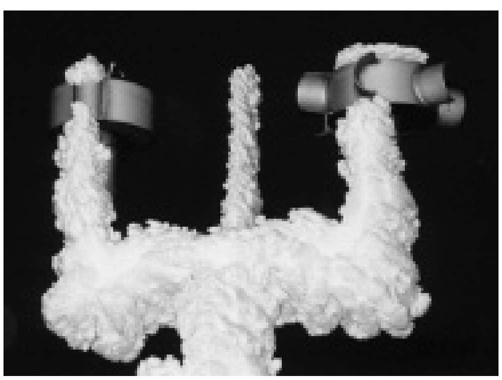

Figure 6.1 This HydroTech, operating in Olos, Finland, illustrates how large amounts of heating power are needed to keep the rotating parts of wind sensors operating during harsh icing events

- 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, Denmark, Finland (Operating Agent), Norway, Sweden, Switzerland, and the United States.

6.2 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 of the operating agent, participants will supply information and attend task meetings. The main activities are divided to five sub-tasks, which follow

6.2.1 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. Failures will give information on the adapted technology need-

Figure 6.2 This Pyhätunturi test station in Finland has been the base for developing blade-heating systems for wind turbines

ed, as well as information on how cold-climate modifications work. Technical availability will give information on the reliability of turbines in cold climates, as well as operation and maintenance experience. In addition to this, construction experience in cold climates is gathered. The reliability of anemometers, ice detectors, and other sensors is also an issue for wind power utilization in cold climates. Information of wind measurement reliability, power performance, and the amount of production losses as well as expected technical availability is important when considering the production estimates for sites. The wind resource is easily underestimated when anemometers are iced-up part of the time and rotate slowly. The reliability and power performance of the 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.

6.2.2 Extraordinary Operational Events

In addition to general information gathered from several cold-climate sites, detailed monitoring of extraordinary events such as icing, storms, lightning strikes, and voltage losses is produced by participants on selected sites.

6.2.3 Site Assessment and Classification

To help with site assessment under cold conditions, the work will include methods for monitoring icing events and wind conditions. A classification procedure will be developed taking into account the following conditions.

- Climate (type and rate of icing, extremes and variations of temperatures, wind)
- Grid infrastructure, energy demand (energy system related matters)
- Site accessibility and other demands related to infrastructure; offshore

The classification procedure will be based on existing information or recommended ways to obtain new data.

6.2.4 Technology and Operations Classification

The technical and operational features of wind turbines will be classified according to the site classification above. This will result in guidelines for turbine manufacturers and developers. Combining this information with the estimated number of sites that require adapted technology will give market information to manufacturers.

6.2.5 Dissemination of Results

To disseminate general information and the operational experiences, as well as to gather more information, Internet pages have been opened for the project at arcticwind.vtt.fi. The operational experience and the final result – guidelines for wind turbine technology and operational strategies applied in cold climates – will be disseminated to developers and turbine manufacturers. Standardization of wind turbines is also important to this task.

6.3 STATUS

There was a short kick-off meeting in Copenhagen on 6 July 2001. Since this time, participants have worked to launch the national projects. New participants are still welcomed to the task during 2002. So far, Switzerland and Canada have decided to join, beginning in 2002. The first meeting was organized at Risø, Denmark, on 17 December and 18 December. There will be two meetings per year. In November 2002, the next IMTS meeting, hosted by FOI, Sweden, will have cold-climate issues in its agenda, and the Annex XIX meeting will be co-ordinated with that meeting.

The Internet project pages have been opened at arcticwind.vtt.fi, and there are pages for general information (project information, participants, literature, links); password-restricted, internal pages for the project material; and a form for reporting events or questions. The first task of dissemination will be to attract visitors to the pages to be able to gather operational experience from individuals other than the participants.

The first draft to be produced will be a "state-of-the-art" paper on wind energy in cold climates. Parts of it will be published at the Global Windpower Conference in Paris, France, in April 2002.

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CHAPTER 7 OVERVIEW

7.1 INTRODUCTION

The basis of this overview chapter is the national reviews of the IEA R&D Wind Implementing Agreement Member Countries presented in Chapters 8 through 23. As was done in 2000, the following summary provides a compressed analysis suitable for presentation to decision makers in government, planning authorities, the electricity supply sector, financial institutions and the wind sector.

7.2 THE INTERNATIONAL CONTEXT

7.2.1 Meeting the Challenge

Much of the current market for wind energy is principally driven by the very low life-time emissions that the technology offers. But the value of wind energy goes beyond this. There are several other benefits making wind energy increasingly attractive to existing and new markets.

The value of wind energy includes the following benefits.

- Extremely 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
- Provides employment and opportunity for industry through turbine and component supply and assembly, provision and installation of turbines, and infrastructure and ongoing plant servicing

For most European countries actively involved in implementing wind energy to date, the primary value is in the control or reduction of greenhouse gas emissions. In these countries the top down policies start by setting targets for CO2 emissions. Many of these result from the Kyoto protocol of 1997, aiming to control emissions of such greenhouse gasses to, for example, 1990 levels.

To achieve levelized emissions, against a background of growth and increase in energy use, governments set out policies and goals for both energy efficiency and renewable energy.

Better wind energy resources are often in rural areas, where unemployment is higher and economic and social development are much needed. For such regions, these benefits can be the driver for wind energy. For example, the Mexican state government of Oaxaca now wishes to promote wind power on the basis of economic and social development. Mexico is also an example of a country with a demand for increased generation capacity, where wind energy can make a contribution.

Currently, most of the IEA countries with significant installed wind capacity have a strong national commitment to environmental goals, but lack a strong hydro-resource (Germany, Denmark, Netherlands, Spain). However, even in those countries with a large hydro resource, there remains little additional potential and further increase in generation from renewables requires the use of other resources such as wind energy, biomass, and small-scale hydro (Sweden, Norway). In the United States and some other countries with many hydro plants, draughts have resulted in water shortages that reduce the hydropower production. This increases the value of wind energy and shows the benefits of having a balanced portfolio of energy sources for generation. Nuclear energy has an uncertain future, 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 and has formed a strong part of government forward thinking.

7.2.2 National Policies

Government policies and strategies vary due to circumstances and how aggressively environmental goals are pursued. However, 2001 has seen several examples of increased commitment to renewables, especially from offshore wind energy.

The German offshore wind program had a big boost this year with huge targets announced by the Ministry of Environment, Nature Conservation and Reactor Safety (BMU) (see Section 7.2.3 below) as well as from the launch of the Investment Program for the Future (ZIP) concerning environmental technologies and run by BWWi. With large budgets (41 million Euros per year or 36.5 million USD per year for the next three years), the ZIP program has an objective to "contribute to the modernization of the economy, maintain the German technology position, and improve exports." As a part of this, three or four offshore measuring platforms will be built in the North and Baltic seas.

Against the backdrop of revised targets in the Netherlands for renewables, there is now a realization that approximately 6,000 MW of offshore wind energy is both needed and thought to be possible. In October, a final draft document designated an area of the continental shelf for this new capacity. In the United Kingdom this year, the Crown Estates announced a first round of offshore sites with the potential for more than 1,000 MW of new capacity (see Section 7.3.3). It is likely that some announcement on an additional round of offshore sites will be made during 2002.

There is also a drive toward offshore wind energy in Finland, due to constraints on the development of onshore sites. For Finland, offshore means exploiting islands, small coastal rock cliffs, and artificial islands of gravel in low waters. In Spain, there are early plans for two offshore wind farms, with monitoring in place at one.

1. Australia (AU)

Over the last couple of years, Australia has increased its commitment to renewables. The Australian 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 in order to meet the end target of 9,500 GWh per year from renewables at the start of 2010. This will necessitate the installation of up to 900 MW of wind turbines.

2. Canada (CN)

Canada has set out to conduct field trials, as well as R&D on resource assessment, technology development, and information/technology transfer. They are also pursuing wind/diesel technology for off-grid systems and have the Atlantic Wind Test Site at North Cape, for testing wind turbines and wind/diesel systems.

3. Denmark (DK)

The present strategy for Denmark is based on the government's action plan, "Energy 21," and setting ceilings for carbon dioxide emissions from electricity generation. Renewable energy quotas were announced in 1999, and all consumers will be obliged to purchase an increasing share of electricity from renewables. This should result in 20% of electricity consumption being covered by renewables at the end of 2003. Land-based wind turbines will form a significant part of this expansion as well as the first 350 MW of offshore wind energy. The long term goal is to reach 5,500 MW by 2030, of which 4,000 MW is expected to be offshore. In November, a new government in Denmark announced some changes in measures for promotion of renewable energy. No formal change in policy has been adopted, however the intent is to base future wind power development on commercial terms. Also utilities were released from obligations for offshore projects other than the two planned at Horns Rev and Rødsand.

4. Finland (FIN)

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 bio energy. The action plan for renewable energy resources from 1999 strives to increase the contribution of renewables sources in total primary energy supply, from about 83 TWh/y in 1995 to 105 TWh/y and 140 TWh/y in 2010 and 2025 respectively. The corresponding targets for wind energy are 500 MW in 2010 and 2,000 MW in 2025.

5. Germany (DE)

Germany has become increasingly concerned with the environment, and this change is reflected in changing policy. Germany now seeks to maintain a strong technology position and 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 (GR)

Greece recognizes a high wind energy potential and the government wishes to exploit wind energy to replace expensive imported fuel in decentralised energy production. The government also aims to actively involve Greek industry in creating new jobs. There are now plans for a new, high-voltage grid in the North that will enable this windy area to be exploited. The Greek electricity market is undergoing deregulation. New law maintains support for renewables in the competitive framework, but no effect on wind energy development has yet been observed.

7. Italy (IT)

Italy has progressively changed its position in favor of renewables. A white paper of August 1999 stated a goal to double 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 approximately 2,500 MW per year. The ongoing policy is in developing technology, promoting the domestic wind energy market, providing technical assistance to private installers and local authorities, and providing technical support to the industry.

8. Japan (JP)

Positive national policy and capital subsidies from the National Institute of Advanced Industrial Science and Technology (NEDO) have been supported by the utilities offering private, long-term electricity purchase contracts. In 1998, the government developed a plan to stabilize carbon dioxide emissions at 1990 levels by 2010, with renewable energy increasing from 1.1% to 3.1%. Reflecting very strong progress in the last two years, this year the government changed its target for wind energy from just 300 MW to 3,000 MW.

9. Mexico (MX)

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 6.6% over the next decade. This will require a projected 30 GW of new capacity, 18.5 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." Negotiations are in place with the Global Environment Facility (GEF-UNDP) to support the program, which is expected to be launched next year. The initial phase of this program will include resource assessment and an educational campaign geared towards raising awareness of the benefits of wind energy among government officials, followed by three pilot projects that will emulate an incentive program and provide technical and economic information through monitoring.

10. The Netherlands (NL)

Upwardly revised targets for renewables and the expected contribution from wind energy were announced this year (see Section 7.2.3). The government also decided it was unrealistic to reach its renewables targets purely from domestic generation and expects to import some green energy from other European Union (EU) countries. The Netherlands is the first country to base its expectations partially on imported renewable energy.

For the Netherlands, reducing carbon dioxide is a key objective. By the year 2000, emissions should have reached 1990 levels. The policy is now to stabilise emissions by first limiting energy demand as much as possible and then meeting the remaining demand with renewable energy. For renewable energy, the target is set to a 10% contribution in 2020.

11. New Zealand (NZ)

New Zealand's government carried out a ministerial enquiry into the electricity industry this year, which resulted in the release of the National Energy Efficiency and Conservation Strategy in September. A target was set to increase the supply of renewable energy by an additional 19% to 42% by 2012. Although this target is welcome, no quantifiable targets have yet been set for the electricity sector, and it is unlikely that any wind specific targets will be made.

12. Norway (NO)

During a year with above average rainfall, Norway could be self sufficient with electricity from renewables, almost all of which is hydro. However, with the increase in energy demand, it is more typical now for Norway to depend on importing some electricity, mainly from Sweden and Denmark. There are limited opportunities for new hydro projects, and in 1998 the Norwegian government stated an overall goal to reach 3 TWh per year of electricity from wind energy by 2010. However, the current market incentives and subsidising scheme are probably insufficient to fulfill this ambition.

13. Spain (SP)

Spain is notable for its success in both building wind farms and developing an indigenous wind turbine manufacturing industry. The policy has progressed from resource evaluation at national and regional levels, from 1980 to 1990, to large-scale implementation. The high priority and payments given to wind could well continue. During 2000, a target was adopted for renewables for a 12% contribution to the national primary energy demand by 2010. This is also attributed to a target installed capacity of 8,974 MW.

14. Sweden (SW)

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 hydro-power, make renewables – and wind energy in particular – a crucial element of the future power system. In 2001, an extensive energy policy program was started, in order to facilitate the restructuring of the energy system. One billion Euros have been allocated to a two-part program. The first part of this program, accounting for approximately 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 subsidise renewables to replace the 4-TWh Barseback nuclear power plant. Only 0.7 TWh per year by 2002 should result from the previous investment subsidy program. The government is now considering a green certificate system, which may be in place by 2003.

15. The United Kingdom (UK)

In February 1999, the UK government published a policy document with a number of key 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) and 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.

16. The United States (US)

A new National Energy Policy report was published in 2001 in the United States. It contained recommendations to diversify the national energy supply, moving towards clean and affordable energy resources and modernizing the electricity infrastructure. It also recommended extension of the energy production tax credits.

In response to the National Energy Policy there is an increasing interest in expanding the use of domestic energy supplies such as renewables. The Department of Energy (DOE) Wind Program goal is to develop wind turbine technology that will reduce the life cycle cost of energy to levels that will allow wind to compete in electric power markets without subsidies. If these goals are achieved , projections show resulting wind energy capacity of 60,000 MW by 2020. To encourage uptake, state and federal government agencies are expanding renewable energy use, including wind systems.

7.2.3 National Targets

About half of the national governments of participating countries have announced formal targets for the amount of wind power capacity they wish to see installed, or the amount of wind electricity generated. (See Table 7.1) Progress towards those targets is very uneven. This year, the Netherlands did increase their expectations and targets for renewables, and wind energy and biomass are expected to make the greatest contribution. There was

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 per year 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. 35% of primary energy consumption by 2030.	1,500 MW by 2005 (now exceeded); 5,500 MW by 2030, of which 4,000 MW is offshore.
Finland	Increase generation from renewables by 50% over 1995 levels, by 2010 (3 Mtoe/a).	Anticipate 3% of new renewables to be wind energy, providing 500 MW by 2010.
Germany	To reduce carbon dioxide 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.	350 MW by 2005.
Italy	Double the renewables contribution to the energy balance by 2010.	3.4 million tons per year of avoided carbon dioxide emissions should come from wind power. This equates to about 2,500 MW by 2010 or 200 MW per growth per year.
Japan	Reduce the output of greenhouse gases by 6% compared to 1990 levels by 2012. Renewables 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.	1,500 MW by 2010. 7,500 MW by 2020.
New Zealand	None.	None.
Norway	By 2010, have 3 TWh per year of electricity from wind energy plus 4 TWh per year of energy from other renewables (and industrial waste heat), including fired central and district heating systems.	3 TWh per year from wind energy in 2010 (approximately 1,100MW).
Spain	Achieve 12% of primary energy demand from renewables by 2010.	8,974 MW installed capacity, with an average yield of 21.5 TWh per year.
Sweden	Maintain greenhouse emissions at 1990 levels.	0.7 TWh per year by 2002 (equal to a 0.5 TWh increase compared to 1997).
United Kingdom	Increase the electricity supplied from renewables to 5% by 2003 and 10% by 2010, subject to consumer acceptance of cost.	None.
United States	20,000 MW of non-hydro renewables generation by 2010.	60,000 MW by 2020.

Table 7.1 Wind and renewables electricity generation targets

much discussion and upward pressure on renewables targets in other reporting IEA countries as well. In Germany and Sweden, government departments issued reports recommending raised targets for wind.

A report this year from Germany's BMU set huge targets for offshore wind energy. Published in June, the report recommended a phased approach, building from 500 MW by 2007 to as much as 25,000 MW by 2030. This is nearly four times the current onshore installed capacity for Germany. In May, the Swedish National Energy Administration (SNEA) recommended wind energy planning targets to the Swedish government. SNEA suggested a target of 10 TWh within ten to fifteen years. By the end of the year, no target was established, but the government has made a commitment to set a target soon.

With wind already contributing more than 3% of electricity generation in Spain, as much as 9,000 MW is anticipated by 2010, which will exceed the current target. Although no national government targets exist for wind in Australia, the State of New South Wales has set its own target of 1,000 MW, 16 MW of which had been built at the end of the year.

7.3 THE WIND ENERGY MARKET

7.3.1 Wind Sector Turnover

The value of the wind energy market globally during 2001 is estimated at more than 6 billion USD. This figure is based on an average total project cost of 1,000.00 USD/kW installed. This excludes the routine maintenance of all the installed capacity. Germany alone reports a total sector turnover in 2001 of 3.5 billion Euros (3.1 billion USD) and approximately 35,000 people employed either directly or indirectly. This covers both manufacturing and servicing the existing 8.75 GW of capacity, with Germany accounting for 40% of the new capacity installed worldwide in 2001 (although much of this was imported).

Italy reported more than 1,000 people employed in manufacturing alone, and Finland estimated sale of its components as more than 1 billion FIM (160,000.00 USD).

7.3.2 Installed Capacity Growth

1. High sector growth sustained

Wind continued to show excellent growth at approximately 37% globally and almost 40% in the reporting IEA countries. This is a very strong performance, and expectations continue to be high for the coming years. The IEA countries now account for 89% of global installed capacity, and growth has now been sustained at 30% per annum or above since 1994. At the end of 2001, the global wind capacity reached 24.3 GW. The total installed capacity in the IEA countries reached 21.5 GW. (See Table 7.2 and Figure 7.1)

2. Growth markets

Germany and Spain sustained the very high rate of turbine installation that has been seen for the last couple of years, putting in more new wind plant than ever before. Their growth rates were 44% and 37%, respectively. This reflects the strong markets, offering fixed and generous tariffs for the energy produced, combined with a high success rate within the planning process. Planning is becoming an issue of increased significance in Germany now though and also delayed some projects for the first time in Spain this year.

The United States continued its recent acceleration in wind energy deployment, with wind also going into more parts of the country. Kansas, Oregon, and Washington all showed rapid growth, but Texas saw the greatest growth this year with an increase in capacity of 915 MW. Combined state and federal support

Country/region	Capacity at year end 2000	New capacity	Capacity at year end 2001
Australia	33.0	41	74.0
Canada	137.5	60.5	198.0
Denmark	2417.0	75	2,492.0
Finland	38.0	1	39.0
Germany	6,095.0	2659	8,754.0
Greece	179.4	89.6	269.0
Italy	427.0	270	697.0
Japan	121.1	128.9	250.0
Mexico	3.0	0	3.0
Netherlands	441.0	42	483.0
New Zealand	35.4	0	35.4
Norway	13.0	4	17.0
Spain	2,334.0	861	3,195.0
Sweden	241.0	49	290.0
United Kingdom	408.5	59.3	467.8
United States	2,566	1694	4,260.0
Ireland*	118.0	7.0	125.0
Portugal*	91.0	36.0	127.0
France*	79.0	6.0	85.0
Austria*	78.0	17.0	95.0
Turkey*	19.0	-	19.0
Egypt*	63.0	62.0	125.0
Morocco*	54.0	-	54.0
India*	1,220.0	287.0	1,507.0
China*	344.0	55.0	399.0
Costa Rica*	51.0		51.0
Rest of world*	133.0	49.0	182.0
Grand total	17,739.9	6,553.3	24,293.2

* Data from Windpower Monthly

Table 7.2 Global installed wind capacity helped to stimulate all these markets. This trend is expected to continue.

Italy also sustained strength in the home market through continued political support and government incentives, growing its installed capacity by 60%. Greece and Canada both had good years, nearly doubling their capacity. The new and vigorous markets of Japan and Australia continued the trend set last year. Although the installed capacity in Japan has only been estimated (due to many new projects under construction), growth in 2001 is thought to be close to 100%. This reflects a positive national policy, and capital subsidies from NEDO supported by the utilities offering private, long-term electricity purchase contracts. Australia did not quite meet its high expectations for 2001, but it still more than doubled its previous capacity, encouraged by the introduction of the Renewable Energy Certificate market in 2001. Expectations are for rapid growth in the next four years.

3. Steady growth

Sweden and the Netherlands saw similar new installed capacity to previous years, rather than continued growth. The United Kingdom had continued solid growth in 2001, providing 59 MW of new capacity and high expectations for next year.

4. Less active countries

Denmark had a record low installation this year of less than 100 MW, which is in sharp contrast to last year's record high of 606 MW. Norway and Finland each had one new project built, of 4 MW and 1 MW capacity, respectively. No new machines were installed in Mexico or New Zealand.

5. Outlook

The strong markets this year (Germany, the United States, Spain, Italy) are not expecting any major changes next year and should continue to perform well. Spain estimates that more than 900 MW of wind capacity will be added next year. Two new, major Norwegian wind farms, each of 40 MW, have received both permission and financial support and are likely to be built next year. In the United Kingdom, expectations for next year are still higher. The British Wind Energy Association (BWEA) anticipates just under 200 MW to be constructed in 2002. The medium-term outlook is looking positive for Australia. The rate of development is expected to increase sharply over the next four years, and there are 1,800 MW of projects planned between 2003 and 2005, although none of them have consents yet.

7.3.3 Offshore

Interest in offshore wind energy continues to widen, driven by a number of factors as below.

- Constraints on-shore resulting from concerns about visual intrusion (the Netherlands, the United Kingdom, Germany, Sweden).
- A lack of unexploited good on-shore sites (Germany, Denmark)
- A lack of appropriate on-shore sites sufficiently close to major demand centres (the United States)
- A shortage of any suitable sites on-shore (Japan).

The interest and level of commercial activity associated with offshore wind energy increased again during 2001, although the longer-term prospects for Denmark have become uncertain. Projects were built in Denmark and Sweden.

The largest offshore installation yet was commissioned in Denmark early this year. The 40-MW project at Middelgrunden, 2 km outside Copenhagen, was set at full power in March. The owner reports outputs slightly higher than expected for the year. The much more ambitious Horns

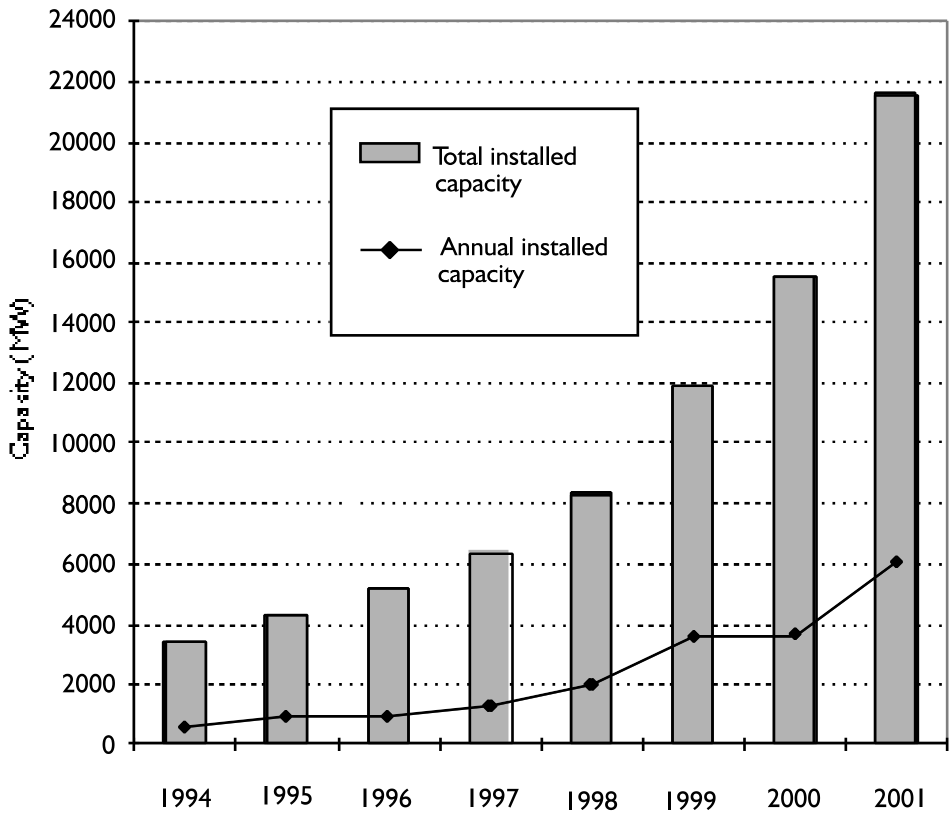

Figure 7.1 Growth of wind power across the IEA countries since 1994

Rev project is planned to be built next year. ELSAM/Eltra were granted permission to develop the 150-MW project 14 km off the coast of Jutland. A similar development was also granted permission at Rødsand, to be developed in 2003. Other offshore plans have been put on hold by the new government.

The Swedish company Vindkompaniet commissioned another offshore wind farm in spring this year. It comprises five NEG Micon, 2-MW turbines, 4 km from the shore.

Interest in offshore siting of turbines is mainly limited to those countries where there is a shortage of suitable sites on land (Sweden and Japan) or where population density precludes extensive on-land development because of visual intrusion (Denmark, the Netherlands, the United Kingdom, Germany).

In addition to the new capacity mentioned above, Denmark has two demonstration offshore wind farms of 5 MW in operation, the Netherlands has four 500-kW machines and Sweden one 220-kW, five 500-kW and seven 1.5-MW machines.

7.3.4 Energy Contribution from Wind Power

1. Electricity generated by wind

More electricity was generated in the IEA countries than in any previous year. This was approximately 37 TWhrs, up 20%

from last year and providing electricity equivalent to the entire needs of Denmark. Globally, it is estimated that approximately 40 GWh of electricity were generated from wind in 2001.

2. Wind speeds

Across northern Europe it appears to have been a less than average wind year. The Netherlands reported a wind index of 90% (i.e., the mean annual wind speed was 90% of the long-term average), and Sweden reached 88% of expected electricity production. Finland also reported lower production than during 2000.

7.4 MARKET DEVELOPMENT

7.4.1 Electricity Markets

The development and liberalization of electricity markets is having a great effect on the way wind energy is attributed a commercial value. Consequently, the support mechanisms for wind are also changing. Some countries insulate generation from wind and other renewables from the wider electricity market – by maintaining pre-determined fixed tariffs for the electricity, for example (Germany, Spain, Denmark). A few other countries are trying to integrate green electricity into the liberalized market. This has been done by the United Kingdom, the Netherlands, and Australia through trading electricity and the green value separately by issuing green certificates.

In February 2001, the liberalization of the electricity market came into force in Greece. The newly formed Regulatory Authority for Energy (RAE), tasked with ensuring the market is working, approved 748 MW of wind in its first year for connection to the mainland network and 146 MW of autonomous wind for the islands.

7.4.2 The Drive to Larger Wind Farms

In addition to larger wind turbines, some countries are seeing a drive toward larger wind farms, which brings economies of scale. In the United States, several multi-year projects with capacities of between 250 MW and 300 MW are planned in the states of Washington, Oregon, Texas, and Nevada. In the United Kingdom, permission to build one wind farm of more than 50 MW was granted, with developers looking ahead to wind farms of up to 1,000 MW in Scotland. Offshore wind energy plans are also increasingly for large wind farms of 100 MW or more (Denmark, the United Kingdom, Sweden, Germany).

7.4.3 Green Power Companies

ENEL GreenPower, part of the Italian Enel group, became the world's largest electricity producer exploiting only renewables. The company owns and operates 2,500 MW, made up of geothermal, mini-hydro, wind, photovoltaic, and bio gas power plants located in Italy, the United States, Canada, and Latin America. Wind plant capacity reached 140 MW, with an additional 400 MW planned in Italy over the next two years.

7.5 SUPPORT INITIATIVES AND MARKET STIMULATION INCENTIVES

To date, there is little grid-connected generation from wind outside of any government or state incentives. The main market stimulation instruments used in the IEA countries are a combination of capital subsidy and the payment of premium prices for the energy produced. Increasingly, premium prices are preferred to investment subsidies. Premium prices come in several different forms ranging from a pre-determined fixed pricing regime (Denmark, Germany, Spain) to a separate free market for green certificates to increase the value over the selling price of the electricity alone. A competitive bid-in system has been used in the United Kingdom, Ireland, and France, with contracts awarded to the lowest bidders. The primary emphasis is price reduction and convergence with the market price for electricity. Tax incentives are also used and have been the principal driver in the United States.

In 2001, the federal government of Canada announced a budget of 260 million CAD (163 million USD) for production-based wind energy incentives. This will apply to projects developed after March 2002, in which production support will be available for the first ten years of operation, providing some stable revenue. Provincial and territorial governments are being encouraged to provide additional support.

Currently, market support and stimulation incentives do not exist in New Zealand. However, it is likely that incentives will be needed to achieve the country's latest renewable energy targets. This is the subject of a work program being carried out by the New Zealand government.

7.5.1 Main Market Stimulation Instruments

Table 7.3 summarizes the main market stimulation instruments in the participating countries. The table makes an important differentiation between basic types of mechanisms. These can be either investment support, which contributes to the build cost of wind turbines; production support, which directly boosts the value of the electrical output of turbines; or demand creation, which creates a demand and consequently increases the value of wind energy. Investment support has the potential disadvantage of installing wind turbines without maximizing their output. The first three mechanisms described below are all examples of production support that does maximize generation. Obligations on electricity suppliers or users to buy a portion of electricity from renewable resources are examples of demand creation.

1. Mechanisms for high deployment

In terms of achieving rapid deployment, the market mechanisms used by Germany and Spain have had notable success recently as has that used in Denmark in previous years. In all of these markets, the utilities have been obligated to connect wind power and pay set prices for the electricity generated.

Since 1993, the payment for wind-generated electricity in Denmark has been related to the utilities' production and distribution costs (tariffs). A law has obligated power utilities to pay wind turbine owners a kilowatt-hour rate of 85% of the utility's production and distribution costs. Additionally, until now, the government has reimbursed wind turbine owners carbon dioxide tax and added direct subsidy.

The Electricity Feed Law (EFL) in Germany became effective in 1991. Since then, the utilities have been obligated to pay 90% of the average tariffs per kilowatt-hour that private consumers had to pay, with taxes of 15% excluded.

In Spain, utilities are obligated to pay a price guaranteed to generators for a five-year period. This price and the related bonus is revised and fixed every year in accordance with the variation of the electricity market price.

2. Green certificates

As a means of monitoring and meeting generation targets and encouraging competition, some countries are introducing green certificate trading (the Netherlands, the United Kingdom, Denmark, Italy, Australia, Sweden and parts of the United States). Certificates are issued against electricity generated by renewable sources, which can then be traded nationally. In the Netherlands, some electricity companies have even started trading internationally, and the government now recognizes that some imported green energy is needed in order to reach their renewables targets. One of the two U.K. offshore turbines will supply certificates to the Dutch utility Nuon.

Green certificate trading started in Australia this year. Target trade levels were exceeded, traded on the dedicated Green Electricity Market (GEM). The GEM trades the green value, with electricity traded separately. All new wind farms in Italy will now be built on the basis of the green certificate system.

3. Green electricity tariffs

Customers in several countries are being offered green electricity, usually at slightly higher rates (i.e., about 5% to 30% above the price for electricity generated from conventional sources). Green electricity, generated from renewable energy sources, is offered in deregulated markets by both electricity suppliers and private generators (Australia,Canada,Germany, Finland, the Netherlands, the United Kingdom, the United States).

In the Netherlands, distribution companies offered green electricity for about the same price as brown electricity. Customers became free to buy green electricity from any company in the Netherlands in the middle of this year. Vigorous marketing campaigns resulted in the size of this market growing by 40% over the year, with about 800,000 households buying green electricity.

Several companies in Finland are also offering green electricity sold at slightly elevated prices, but success is modest and only a few percent of households have changed their supplier at all since liberalization of the electricity market.

4. Japanese green funds

The Tokyo Electric Power Company has established a Green Power Fund for people who wish to make a social contribution. A single donation is 500.00 Yen per month. The scheme supports wind and photovoltaic projects and is non profit making. A similar new company called the Japan Natural Energy Company started in 2000.

5. Other market drivers

In the United States, environmental policy considerations are also driving wind development. The Environmental Protection Agency (EPA) and state environmental agencies are pursuing enforcement of the Clean Air Act and other laws that restrict emissions from many sources, including electric power plants. Partly through enforcement of the Clean Air Act, many power plants have switched to natural gas, which has increased demand and greatly increased price. The spot price for natural gas has risen considerably over the last two years, making wind energy more cost competitive but also increasing its attractiveness through immunity to such price fluctuations.

There is also an increasing interest in generation to supply local loads. This involves individual or small clusters of turbines, for businesses, farms, and landowners. In some states, favorable net billing is in place, though usually limited to 100 kW or less. Such distributed generation could account for 20% of new installations in the next ten years.

In April 2001, the United Kingdom introduced a Climate Change Levy on energy use by businesses. The levy on electricity sales is 0.43 p/kWh, and electricity from renewable sources will be exempt, raising the value of wind by a similar amount.

Market stimulation instruments	
	Australia
Investment support	• There are various grants available for demonstration and promotional projects as well as for R&D.
Demand creation	• The most powerful market stimulant is the mandatory requirement for an increase of 2% in the use of electricity from renewables and specified waste sources by 2010. This is achieved through a special market in Renewable Energy Certificates (RECs), which started operating in 2001.
	Canada
Investment support	• In 1994, installations were for R&D and field trials and supported by the government program. Additionally, and still applicable, is the capital investment write-off (30% per annum of the declining balance). • In 1998, the Canadian Renewable and Conservation Expense (CRCE) category was introduced into the income tax system, allowing the extension of the use of flow-through share financing currently available for non-renewable energy and mining projects. Through CRCE, the Income Tax Act also allows the first, exploratory wind turbine 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 is being written off. • Federal government production-based wind energy incentives will apply to projects developed after March 2002, in which production support will be available for the first ten years of operation, providing some stable revenue.
Demand creation	• There is now substantial support through Green Power purchase. • The Federal Government has introduced a grant, to encourage the use of wind energy in its buildings, aiming to reach 20% of electricity consumption.
	Denmark
Investment support	• Low-voltage connection is paid by the owner, and grid reinforcement costs are paid by distribution companies.
Production support	• Since 1989, there have been production subsidies for energy produced by private generators and utilities. • Until April 2001, buy-back rates were fixed relative to the normal electricity selling price to distribution companies. This buy-back rate will continue under the new regulations (below) until the market for green certificates is established. • From April 2001, the revised regulations will require that new turbines will be paid electricity market price plus green certificate market price, once the market for green certificates is established. Until then, the value of green certificates is set at 0.1 DKK/kWh.
Demand creation	• Renewable energy quotas will be announced by the government, in which consumers will be obligated to a steadily increasing share of electricity from renewables. The initial quota aims to have 20% of electricity consumption from renewables by the end of 2003.This is part of the measures for reaching future carbon dioxide reduction targets.

Table 7.3 Main market stimulation instruments used in the participating countries

	Finland
Investment support	• Investment subsidies are provided of up to 30% total investment costs depending on technical innovation.
Production support	• Production subsidy are available for wind and other small local energy production.
Demand creation	• The Green Power Tariff is offered by utilities and some private generators also selling green energy directly to customers.
	Germany
Investment support	• Grants exist under the 250-MW Wind demonstration program. • Individual states may offer capital subsidies or soft loans.
Production support	• The Erneuerbare-Energien-Gesetz (EEG) law came into force on 1 April 2000. This replaces the Electricity Feed Law (EFL) with a fixed tariff of 0.178 DEM/kWh for 5 years, then 0.121 DEM/kWh. • The first offshore installations, installed before 2006 and more than three nautical miles from the coast, will receive the higher 0.178 DEM/kWh rate for nine years.
	Greece
Investment support	• There are 40% capital investment subsidies available and a possible 40% soft loan.
Production support	• There has been a premium price for energy since year-end 1995.
	Italy
Investment support	• Some regional authorities provide investment subsidies. • In July 2000, the Ministry of Environment issued Decree 377, diverting carbon tax revenues to provide up to 40% subsidies for wind plants on the smaller islands.
Production support	• There is a premium price for renewable and assimilated energy sources.
Demand creation	• Large importers or producers of electricity become obligated, starting from the year 2002, to produce a quota from new renewable energy plants, through a green certificate system.
	Japan
Investment support	• Support is provided for 100% of wind measurements, 50% of construction costs for public sector projects over 1,200 kW, 33% of construction costs for private sector projects over 1,500 kW, and 50% of design costs.
Production support	• Some financing is available at preferential rates and tax incentives for profitable companies. • Buy-back prices are negotiated between generator and utility.
	Mexico
	• None.

Table 7.3 Main market stimulation instruments used in the participating countries cont.

	Netherlands
Investment support	• Up to 1996, a subsidy was given per m2 swept rotor area and wind turbine capacity, up to a maximum of 35% of the investment costs. • Income available from "Green Funds" subject to lower interest rates on capital borrowed. • Since January 1997, a 40% deduction of capital investment from company profits has been provided. • Since January 1996, there has been an accelerated depreciation on wind turbine investment.
Production support	• Up to 1998, there were various levels of premium price for energy produced. • The utilities must feed back part of the Eco Tax to generators for each kWh produced.
Demand creation	• The "Green Label" scheme was introduced in 1998, which also applies to historical projects. • There is an exemption from Regulatory Energy Tax for end users of renewables .
	New Zealand
	• None.
	Norway
Investment support	• There are investment or shared development costs within a defined budget, up to 25% of eligible costs. (In 1999, two wind turbine installations were granted support of approximately 20% of investment costs, of which one was fulfilled. The other two are still at the planning stage.) • There is an investment tax exemption for up to 7% of costs.
Production support	• At the end of 1998, a production support for generators was introduced. This is half the electricity levy for all installations with installed capacity of more than 1,500 kW. In 2000, the production support was 4.28 Norwegian øre/kWh.
	Spain
Investment support	• In 1994, there were investment subsidies up to 26% for commercial projects, 35% for demonstration projects, and 49% for innovative projects, and a premium price for energy produced. • Third party financing is available through the national energy agency, IDAE.
Production support	• Since the end of 1998, the mechanism is through a premium tariff, either of fixed value or of floating value but with a fixed bonus above the base price. Most developers use the fixed price.
	Sweden
Investment support	• There is an investment subsidy of 15% (program limited to 60 MSEK per year).
Production support	• There is no annual cost for using the electricity net (maximum size of 1,500 kW). • Until 1 November 1999, there was a premium tariff based on household tariffs plus environmental bonus (15,1 öre/kWh), plus a small addition against local grid value (maximum size of 1,500 kW). • After 1 November 1999, there is the environmental bonus (16.2 öre/kWh) plus temporary subsidy (9 öre/kWh), plus a small addition against local grid value (maximum size of 1,500 kW).

Table 7.3 Main market stimulation instruments used in the participating countries cont.

	United Kingdom
Investment support	• Investment subsidies of up to 40% are expected, specifically to support early offshore wind farms.
Production support	• There is a premium price for energy produced, and contracts are warded after competitive bidding. • A Climate Change Levy on energy use by businesses was introduced in April 2001. The levy on electricity sales is 0.43 p/kWh and electricity from renewable sources will be exempt, raising the value of wind by a similar amount.
Demand creation	• Regional obligations, placed on the electricity supply companies, are in the process of being introduced, expected to come into force in late 2000. These will involve the trading of green certificates and the payment of a penalty charge if obligations are not met.
	United States
Production support	• There are federal subsidies of 0.017 USD/kWh, adjusted annually for inflation, in the form of tax credits for investor-owned utilities and production incentive payments for municipal (tax exempt) power producers. • There are a wide range of individual state incentives (e.g., waiving of sales or property taxes).

Table 7.3 Main market stimulation instruments used in the participating countries cont.

6. Autonomous systems

The United States has seen large growth in small- and medium-sized wind turbines for both on-grid and off-grid applications. A record breaking 10,000 machines of 10kW or less were estimated to be sold this year, having a value of around 10 million USD. The reliability and self sufficiency has attracted home owners, who value insulation from price volatility as much as the generation companies.

In Australia, the prospects for wind-diesel power systems are also excellent, with the introduction of the Renewable Remote Power Generation Program in late 1999. There are a large number of potential diesel installations where renewables, such as wind, can supplement diesel generation.

7.5.2 Constraints on Market Development

An insight into the main factors that constrain the deployment of wind turbines may help to explain the differences in the number of machines deployed in different countries.

1. Cost and price constraints

The primary constraint affecting market development is the comparatively low cost of conventional generation and surplus capacity. This can also be viewed as a failure of national and international policies to pass on environmental costs to generators. 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 constraint in Norway continues to be the cost of wind energy against low-base electricity costs, although some wind energy projects are now approaching the cost of new hydropower.

In the United Kingdom, the New Electricity Trading Arrangements (NETA) have penalized wind energy as an unpredictable supply. To combat this, co-generation is now being considered with early plans to combine wind with natural gas offshore – and an Anglo-German co-operation is looking at combining wind with landfill gas. Both of these ideas present a way of evening out generation to fulfill obligations and therefore add to the value of the electricity.

2. Resources

The availability of good sites is becoming a significant constraint in a couple of cases. Both the Netherlands 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.

3. Political stability

The high dependence of markets on government policies is an ever-present concern. Overall, the sector benefits from the global market, which smooths the effects of single-market policy changes. During 2000 in Denmark, legislation on reform changed from fixed prices to a market-based system with green certificates, which caused uncertainty on future buy-back rates and resulted in a sharp down-turn in new installations for 2001.

7.5.3 Institutional Constraints

1. Legal issues

A constraint on the electricity industry of New Zealand was released this year, enabling network companies to own embedded renewable generation. This had previously been disallowed in the electricity reform act of 1998 and was detrimental to the commercialisation of wind power.

2. Planning policies

For several countries where the existing market stimuli make wind power attractive, the main constraint on the rate of development is difficulty obtaining building consent. Objections are often on the grounds of environmental concern – in particular, the visual impact of wind farms (Denmark, Germany, Italy, the Netherlands, Norway, Sweden, the United Kingdom, the United States, Finland). Land use planning is often a local matter that 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 interpretation.

In the Netherlands, about two-thirds of all initiatives fail at an early stage because of difficulties in getting building permits and the necessary policy changes in the municipalities that do not want wind energy "in their backyard". In the United Kingdom, planning consent also remains the biggest impediment to deployment. Scotland has a better planning record than England and has seen further positive moves. In Spain, some delays are occurring in gaining consent. Opposition has appeared in the areas with the most development on the bases of landscape impact and possible avian effects. Even in Finland, land use restrictions and visibility, especially in relation to summer residents and vacation activities, may well be a significant obstacle.

In attempts to resolve these difficulties, more countries are introducing legislation on both the siting and the operation of wind farms. Land planning studies are in progress in several countries. In the Netherlands, provinces are working on spatial plans, and in 2000, a publication supported by the provinces and the Foundation for Nature and the Environment indicated locations suitable for an additional 1,695 MW to 1,840 MW across the country. The U.K. government has implemented a proactive, strategic approach to planning through the introduction of regional targets for renewables based on resource assessments. This process is ongoing.

In the United Kingdom and Sweden, many projects have been prevented or held up because of military/defense objections within the planning process. The reasons cited are interference with radar and microwave transmission systems and causing a hazard within low fly zones. Initial results from a Swedish study showed that the disturbance on radar, caused by wind turbines, was less than expected. In the United Kingdom, a project that started in September will try to quantify the effects wind turbines have on radar systems. Interim guidelines on the siting and assessment of the effects of wind farms is anticipated in 2002.

3. Grid limitations

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 problem. Denmark has already achieved more than a 12% contribution from wind energy nationally, with no major integration problems.

However, it is not unusual for the more promising areas for wind energy to be located away from population centers and on weak areas of electricity networks, making the export of power problematic. This is the case in Spain, but concerted action between developers and utilities is expected to solve this problem. Grid limitations are the major constraint to rapid market growth for Greece as well, with most of the potential in remote sites at the end of transmission lines. Grid reinforcement is considered high priority, especially in high-wind potential areas (Evia and Lakonia). Among the 1,111 MW approved by the RAE this year, 217 MW is for development in the windy North (Thraki region) and will be combined with the construction of a new, high-voltage grid.

Some grid problems have been encountered in the northern part of Japan, which has a weak grid structure. In some cases, utilities are already limiting wind power development. Developments have also been restricted in the Australian states of Victoria and South Australia because of difficulties in complying with local connection codes. These stipulate that generators must provide power regardless of grid fluctuations. However, changes to the codes are being proposed, and manufacturers are also considering turbine modifications in order to comply.

In the United States, Italy (especially Sardinia and Sicily) and the United Kingdom grid reinforcement will be needed in the future if wind is not to be constrained. In recognition of the need for grid reinforcement in the United Kingdom, an initial investigation was launched into the feasibility of an undersea transmission cable to enable large-scale renewables development in Scotland and the North. Germany's plans for offshore wind energy will require extensive grid reinforcement. This grid expansion is also expected to be very difficult in some regions due to planning, public acceptability, and legal constraints. In Finland, local generation is being discouraged in some areas through the high system charges used by some local grid operators.

4. Certification

Certification is concerned with the design and performance of wind turbines for a given climate. It aims to ensure survival of the machine within specified conditions, make sure operation and maintenance are safe, and verify the electrical energy output. The certification of turbines by approved organizations is increasingly becoming a requirement for planning consent. It may also be a requirement of insurers and affect tax incentives. Although the requirement for certification does not prevent projects from being developed, it does have an impact on the development of the manufacturing industry, particularly in new markets. New entrants to the industry can more readily develop a national turbine manufacture through joint ventures with the well-established European manufacturers than through new machine development.

Certification is obligatory in Denmark, Germany, Greece, Sweden and the Netherlands, and it is being considered in Spain. The European Union has produced a harmonized safety standards guide, based on IEC (International Electro-technical Commission) standards. The IEC has produced standards for safety, power performance measurement, and noise measurement. The IEC group is now looking to extend the current safety standards to offshore wind energy.

The Center for Renewable Energy Sources (CRES) is, by law, the certifying authority for Greece. It is currently working on procedures and standards suited to the Greek climate, considered important for the successful implementation of new strategic plans for extensive use of wind energy. CRES has an advanced blade-testing facility that will be a part of this. The facility is capable of static, dynamic, and fatigue tests of blades up to 25 m long. It is currently accepting type approval by outside authorized institutions.

7.5.4 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 (the United Kingdom, the Netherlands, Denmark) have shown that the environmental advantages of wind power are recognized and, in general, the majority of the public is supportive of wind energy installations. In many countries, although the non-polluting benefits of wind renewable energies like wind are recognized, they are not assigned a monetary value and are therefore not directly included in any economic appraisals or electricity prices.

All the countries actively pursuing wind development are conducting environmental impact assessments that typically address the following topics.

1. Visual effects

Visual impact continued to be a major issue in obtaining planning consent for projects and, as would be expected, the concern was greatest in countries with a high population density. In many of these countries it is considered the primary planning issue.

2. Noise emissions

The assessment of noise levels from turbines near dwellings is seen by most countries as a local issue, but national statutory limits are in force in Denmark, Italy, the Netherlands, Norway, Sweden, and Germany and are being considered in other countries. Developers and manufacturers in all countries regard noise imissions as a technical problem that can be solved through good engineering practice.

The complexity of sound transmission, especially in hilly locations, and the subjective nature of sound perception means many acoustic studies are being undertaken within national programs. The IEA has produced recommended practices on the Measurement of Noise Emission from Wind Turbines (last edition, 1994).

3. Effects on bird life

The potential effects of wind farms on birds is an important consideration for all new installations. The principle potential effects are on behavioral patterns, most importantly migration, feeding, and breeding. Although many studies have now been conducted across Europe and in the United States, uncertainties remain and a precautionary approach is often adopted. Overall the observed effects on birds suggest that turbines have a very low effect, especially compared to other human activities, but this remains a species and site-specific issue.

Concern also remains about the possibility of bird strikes in many countries, although the incidence is low. The problem of birds varies greatly from site to site, with the vast majority of wind farms reporting no problems. Some bird strikes were reported in Spain and the United States in the early 1990's. The few wind farms concerned were on bird migratory routes, but the species involved were not migratory. Bird strikes since 1992 have been minimal. Germany has also seen concern about the effects of shadows from moving turbine blades on wildlife, including birds.

4. Ecology

Planning consents usually lay down conditions for the development of a wind farm site and for its restoration afterwards. Little or no long-term damage to local eco systems has been reported from the installation of wind farms.

7.6 TECHNOLOGY AND INDUSTRY

7.6.1 New R,D&D Developments

1. New turbines

The Dutch company Lagerway is hoping to erect a prototype of its new, 1.5-MW to 2.0-MW Zephyros turbine in March of 2002. In 2001, Lagerway completed some component tests, including tests on the 3-MW permanent magnet direct drive generator, developed with ABB Finland. In Sweden, Nordic Windpower AB erected its first, new, light-weight, two-bladed, 1-MW turbine this year at Nasudden.

A new Finish manufacturer, WinWinD, installed its first prototype, a 1-MW machine with single-stage planetary gearbox and permanent magnet generator. There are plans to develop the concept further at a larger size for offshore applications.

A prototype 3-MW Norwegian Scanwind turbine is expected to be completed in 2002. The buoyant Spanish market has resulted in some new manufacturers, like Mtorres and EHN. Mtorres, with an aeronautical background, has developed a 1.5-MW, multipole, direct-drive machine using permanent magnets.

NEG Micon Holland, Aerpac, LM glasfiber Holland, TU Delft, Van Oord, and ECN continue a concept study for a 3-MW offshore machine. The machine should be capable of withstanding severe North Sea conditions, and it is hoped that a prototype will result with a capacity of 5 MW to 6 MW and a diameter of 100 m. The work is being carried out under the Dutch Offshore Wind Energy Converter (DOWEC) project. In Germany, BMWi projects include a 3-MW to 4-MW turbine with a 110-m rotor diameter.

2. Offshore foundations, installation, and environment

The new market for large, offshore machines has created much fresh thinking on both the foundations and installation methods. While foundation types might loosely be categorized as either gravity or pile type, there are many different options being considered against few practical examples as yet. This will be an area of continued research. There is also the likelihood of specialized installation vessels emerging. A company in the Netherlands is developing a lower-weight trussed tower and tracked vehicles for installation and maintenance, running along the sea bed.

Offshore reliability and access has also been identified as an area needing large improvements in order to achieve acceptable availabilities (the Netherlands, Denmark, the United Kingdom, Sweden). A novel approach to the offshore access problem came out of a feasibility study by the Dutch company P&R Systems. In this system, a flexible gangway attaches to a vertical bar on the turbine, using a vessel with dynamic positioning to compensate for waves. It is hoped this will enable access in seas with significant wave heights of up to 3 m, enabling access for approximately 350 days per year. A prototype is expected next year.

In Finland, foundation and installation design must also take account of waters that can ice over. These special design requirements are the subject of an ongoing collaborative project between academia and industry to research suitable technology.

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.

3. Forecasting

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 program under-supply. Several R&D programs recognize that the value of wind power is increased if the output can be more accurately predicted, and research has begun in this area (the United States, the United Kingdom, the Netherlands, Denmark). The possibilities of aggregation of the output from several geographically distributed wind farms is also being examined in the United Kingdom.

Greece, Italy, and Norway have a strong interest in improving their understanding of wind flow in complex terrain, since many of the more favorable sites lie in mountainous and elevated regions. Research is trying to develop computer models that can characterize the main features of complex terrain and identify the crucial parameters that affect power performance and loads. A Norwegian project looking at short-term forecasting started in 2001. The project, which is due to run for five years, will focus on complex terrain turbulence modelling and rotor design. It is a joint initiative involving the Meteorological Institute, IFE, and Kjeller Vindteknikk AS, supported by NVE.

4. Autonomous systems

In Japan, the Ministry of Economic, Trade, and Industry (METI) and NEDO started construction of a 100-kW prototype turbine for remote islands. The wind turbine will have to cope with the combination of typhoons, gusts of up to 80 m/s, poor accessibility, a lack of large cranes, and a weak grid. Construction is scheduled for April 2002, with a local penetration of 40% to be created by managed local network isolation.

5. Other research areas

A new area for study in the United States concerns low-level, atmospheric jets that occur in the midwest. It is hoped that additional energy can be harnessed with the use of taller towers of up to 80 m, but preliminary data shows potentially hazardous levels of turbulence that will require specially adapted designs.

6. Government programs

All of the IEA countries are currently providing underlying support through national and regional R,D&D programs. In Spain, a new national research center for renewables opened this year. The Centro Nacional de Energias Renovables

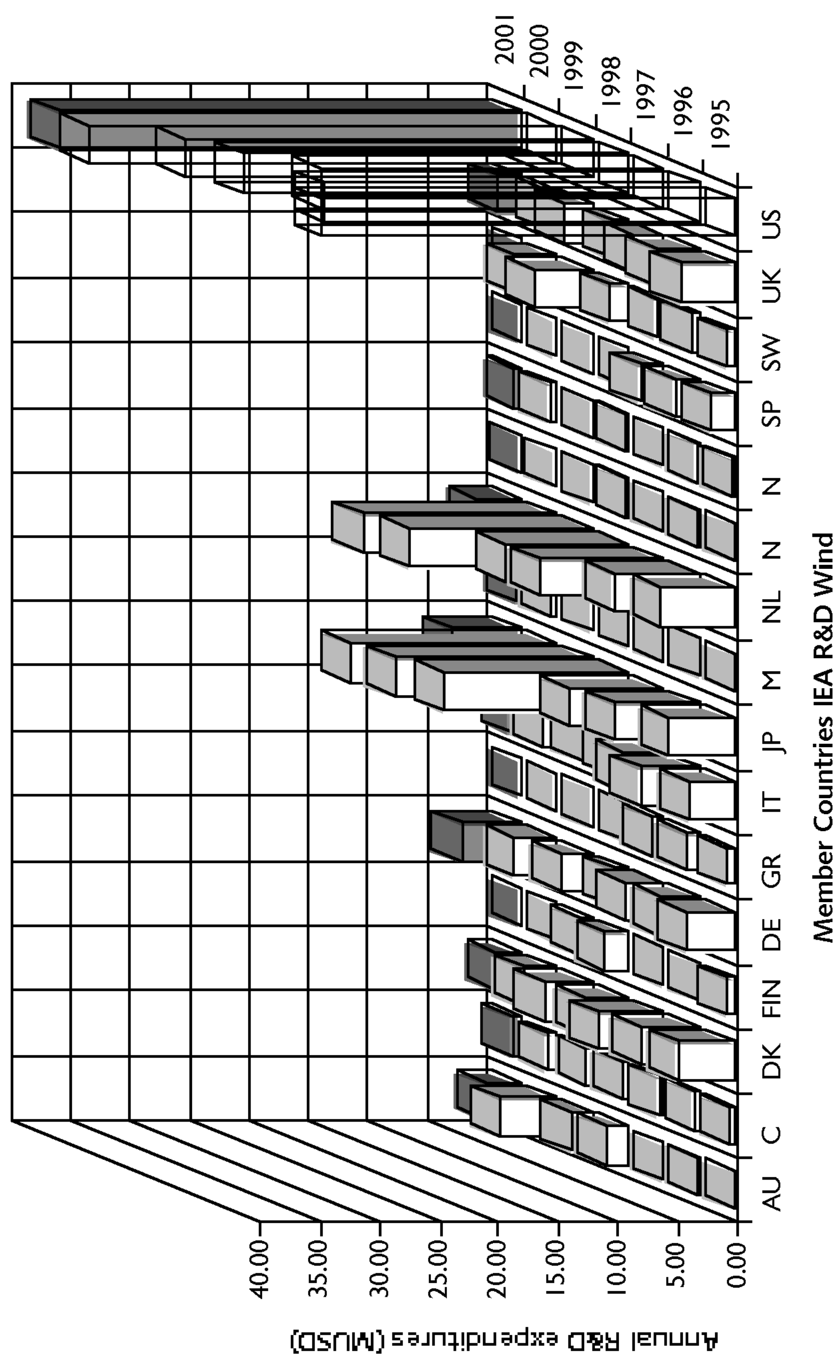

Figure 7.2 Funding for national R&D programs, 1994 to 2001

(CENER) is located in Pamplona, Navarra. Wind activities will include large-scale turbine testing, blade development, and control systems development.

The change in government in Denmark has resulted in a cut in the Energy Research Program (EFP) by almost two thirds. The situation for next year is not clear.

Figure 7.2 below shows the levels of government spending on national R&D programs. The figures do not include industry co-funding, subsidies or demonstration programs.

7.6.2 Operational Experience

1. Availability

In general, the installed turbines have performed well with few operational difficulties. Most commercial plants operate with availabilities greater than 98%. Statistics collected by Denmark, Sweden, and Italy this year showed average availabilities of 98.3%, 98.8%, and between 98% and 99%, respectively. Capacity factors, the fraction of continous full production, are typically between 0.20 and 0.35, depending on the wind speeds at the sites and the degree of plant optimization. Italy reported an average capacity factor of around 0.3, with a highest of 0.36 in Benevento. In Japan, the load factor was approximately 20% on average, but this varies widely due to complex terrain, even within a wind farm. For example, the Tappi wind park saw load factors form individual turbines between 15% and 33%. In the United States new installations at good sites are showing capacity factors of 35% and above.

2. Turbine life

Wind turbines are designed with a life of 20 years or more, but relatively few wind turbines have been in operation for half that period yet. 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 Program is nine years, and no significant increase in

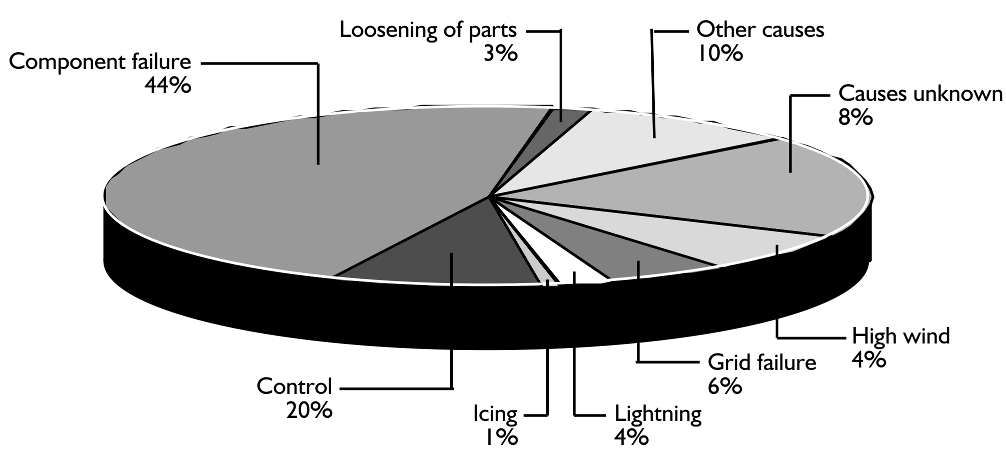

Figure 7.3 Distribution of failure causes in Germany during 2000

failures with operational time has yet been found.

The vast majority of long-term operation has been in the United States. Globally, approximately 10% of current installed capacity has been operational for ten years, and less than 6% for 15 years.

3. Reliability

Overall reliability can be considered high, reflected in the availabilities achieved, detailed above. Figure 7.3 shows the distribution of failure causes in Germany in 2000, recorded on the scientific monitoring and evaluation program. These statistics have not yet been updated for 2001, but they will be very similar.

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 some cases of gearbox fatigue this year.

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.

In Greece, CRES is preparing a database to monitor the operation and performance of all the wind farms.

7.6.3 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.

1. Capital costs

Because of the commercial nature of wind farms, there is very little firm cost data available, although most countries provide estimates. For complete wind farms, the estimates of average cost vary accord-

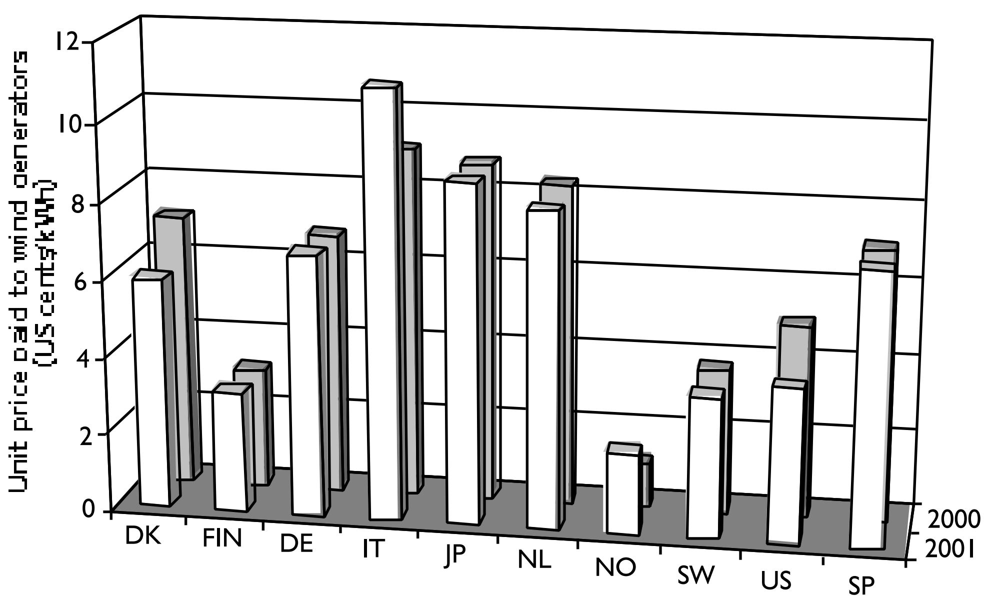

Figure 7.4 Unit price paid to wind generators (UScents/kWh)

ing to country, between approximately 800.00 USD/kW to 1,150.00 USD/kW of installed capacity, but with 950.00 USD typical for the more active markets. The cost of the turbine and tower alone varies between about 600.00 USD and 700.00 USD, with 650.00 USD typical for the more active markets. 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.

2. Offshore costs

Costs extrapolated from the United Kingdom's only offshore installation at Blyth provide a figure of approximately 853.00 GBP/kW installed (1,240.00 USD), based on a wind farm of 60 MW. This is 26% higher than for a typical U.K. onshore wind farm.

In Germany, offshore costs are expected to be around 1800.00 Euros/kW (1,600.00 USD/kW), based on double the cost of the turbine supply only for onshore.

3. Generation costs

Figure 7.4 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 (Finland, Norway, Sweden), there are also capital subsidies to support wind energy.

Overall, there has been little movement in the prices paid since last year. Italy has increased the price paid by 20%. In Norway, the value of the electricity was much higher as a result of higher electricity prices on the Nordpool, though prices still remain low. The price fell a little in the United States and in Denmark.

7.6.4 Development in Industry

The United States has seen large companies becoming developers because they are better able to handle financing. Additionally, large company interest has increased as wind power becomes more profitable. New companies are subsidiaries of utilities or are associated with other parts of the energy business. The United Kingdom also reports an accelerated involvement of utilities and their power generation spin-off companies. Even the nuclear industry is looking to invest in wind, with British Energy partnering with AMEC Wind.

The freeing up of the green electricity market in the Netherlands saw some new green electricity trading companies spring into existence. These will now compete for customers with the traditional companies like NUON, Essent, and Eneco.

Norway has decided to build a wind test station on the west coast. This is considered to be important in developing know-how and encouraging wind development in the country. The average wind speed at the site is around 8.4 m/s at 50 m. NVE will fund the station due for installation next year.

In New Zealand, Vortec Energy Ltd. finally ceased trading in June. The company, started in the mid 1990s, initially had government support and had been trying to commercialize a diffuser augmented design. Meanwhile, Windflow Technology secured shareholder funding for its launch as a potential manufacturer, using a two-bladed, teetered design that it intends to demonstrate at 500 kW late next year. The technology was first tested by the Wind Energy Group (WEG) in Britain some years ago.

Country	Installed capacity	Offshore Capacity	No. of Turbines	Annual Installed Capacity (MW)					Electricity Generated	National Demand
	(MW)	(MW)		1997	1998	1999	2000	2001	GWhrs/yr	TWhrs/yr
Australia	74.0	0.0	102.0	1.1	5.8	3.3	22.0	41.0	154.0	192
Canada	198.0	0.0	295.0	3.0	48.0	50.4	13.1	60.5	*370.0*	550
Denmark	*2492.0*	50.0	*6361.0*	300.1	308.0	302.0	606.0	*75.0*	*4000.0*	*35.3*
Finland	39.0	0.0	63.0	4.6	5.6	20.6	0.0	1.0	*71.0*	81
Germany	8754.0	0.0	11438.0	534.0	792.0	1571.0	1650.0	2659.0	*10700.0*	477
Greece	298.0	0.0	615.0		11.5	67.5	105.0	89.6	756.0	50
Italy	697.0	0.0	1242.0	28.5	79.7	102.0	145.0	270.0	*1150.0*	*298*
Japan	*250.0*	0.0	*286.0*	6.5	14.4	39.0	50.5	*128.9*	*163.3*	838
Mexico	3.0	0.0	10.0	0.5	0.6	0.0	0.0	0.0	7.0	*216*
Netherlands	483.0	2.0	1346.0	44.0	39.0	45.0	32.0	42.0	*900.0*	*100*
New Zealand	35.4	0.0	56.0	0.0	0.0	33.3	0.0	0.0	*n/a*	*n/a*
Norway	17.0	0.0	28.0	0.0	5.4	3.7	0.0	4.0	29.6	125.4
Spain	3195.0	0.0	0.0	205.0	407.0	705.0	795.0	861.0	*6692.0*	205.4
Sweden	290.0	23.0	565.0	17.0	52.0	46.0	21.0	49.0	466.0	149
Untied Kingdom	467.8	3.8	924.0	84.5	13.0	18.0	64.0	59.3	*955.0*	*394*
United States	4260.0	0.0	0.0	11.0	147.0	565.0	99.0	1694.0	*10800.0*	3817
Total	21553.2	78.8	23331.0	1239.8	1929.0	3571.8	3602.6	6034.3	37213.9	7528

Table 7.4 Capacity and output data for IEA R&D Wind Member Countries

1. Manufacturing industry

Danish wind turbine manufacturers still dominate manufacturing with a world market share of around 45%, in spite of the decreased size of the home market. This figure does include turbines and components manufactured abroad by Danish companies, but excludes Nordex Borsig, which now has most of its manufacturing in Germany.

Italy's home industry continues to benefit from the strong home market. Italian Wind Technology (IWT) is the most successful Italian manufacturer and continues its high growth rate, with turnover increasing by 50% in 2001 to 160 million Euros. It is capable of building 400 medium-sized turbines annually and employing 350 people. IWT will start manufacturing the Vestas 850 in 2002.

2. New factories

A Norwegian maritime investment company has decided to establish a new blade production facility at the naval shipyard of Umoe Mandal, in Norway. It will be an independent supplier seeking to be internationally competitive in the supply of megawatt-class composite blades.

In January, the Dutch blade manufacturer Aerpac BV went bankrupt, with the large factory in Almelo and some assets being sold to Enron Wind of Germany. LM Glasfiber also closed its blade production facility in Heerhugowaard in the Netherlands because the large blades needed for the European market could not be made there.

3. Turbine size

The average turbine continues to grow in size and capacity, though the size of machines typically deployed does vary between different markets. For the countries reporting both new installed capacity and number of machines (Australia, Canada, Germany, Greece, Italy, the Netherlands, Sweden, the United Kingdom), the average new turbine deployed exceeded 1 MW (1.1 MW) and increased by approximately 200 kW over last year.

It is worth noting that Germany's new machines averaged 1,285 kW, while the balance of countries in this group averaged 883 kW. In 1995, the average new turbine had a capacity of just 440 kW. The most recent offshore installations (Denmark, the United Kingdom) have both used 2-MW turbines. Germany has consistently exploited large machines. This results from the high population density and shortage of good sites, with larger machines thus offering higher capacity projects. The premium on space and accompanying drive to larger machines is compounded by a noise constraint for all commercial scale machines, requiring a minimum of 500 m between any turbine and the nearest dwelling. Spain and Italy are different, in that the remote and elevated sites being exploited do not favor the use of very large machines. This results from the difficulty in transporting the machines to site and in getting large cranes on site for erection. It is unlikely that the larger megawatt-class machines will be substantially exploited here in the near future, with the average new machine being less than 700 kW in 2001.

4. Offshore

In October, the Dutch government announced the selection rules for contracts to build the planned 100-MW wind farm at Egmond aan Zee. Several consortia come together that will tender for this project including Shell Renewables, NUON, Siemens Renewables, Van Oort ACZ, ENECO, RABO bank, and building company Heijmans.

Author: Ian Fletcher, AEA Technology, United Kingdom.

CHAPTER 8

8.1 INTRODUCTION

Australia has an abundance of renewable energy resources. In particular, the wind resources of Australia are excellent for wind generation and more than compara - ble with other countries with significant wind energy industries. There are potential wind farm sites in all states of Australia.

In the 1970s and 1980s, specialized wind monitoring of potential sites began in most states. In the late 1980s, the first commercial machines of wind farm size were demonstrated. The 1990s have seen the development of small- to moderate-sized wind farms, and during 2001, a number of wind farms over 100 MW were announced.

Development of wind generation has been historically hampered by the low price of thermal generation (mainly coal) and the lack of support measures for the large-scale implementation of wind energy. Support for wind energy (and other renewables) as a means of reducing greenhouse gas emissions has been building since the late 1990s.

Australia's emissions in 1999 were 17.3% above 1990 levels, according to1999 National Greenhouse Gas Inventory figures (which differ from Kyoto Protocol accounting definitions) released in 2001 by the Australian Greenhouse Office (AGO). The increase is attributed to the higher than anticipated rate of economic growth. Energy use is the dominant source of greenhouse gas emissions in Australia, contributing 55% of the nation's total emission and electricity generation alone and 37.5% of total net greenhouse emissions. Encouraging the development and use of renewable energy is thus seen as an effective approach in a raft of initiatives to contain the increase to Australia's Kyoto target of 8% above 1990 levels by 2010.

Significant increases in wind generation observed during 2001 are largely due to the introduction of the Mandated Renewable Energy Target that was designed to assist Australia to meet its greenhouse gas emission targets by reducing the growth in emissions from electricity generation.

Australia currently has more than 40,975 MW of generation capacity that produces more than 192,000 GWh of electricity per annum. Approximately 9% of Australia's electricity is from renewables sources, mostly hydro. Wind energy currently produces about 0.04% of total electricity generation.

8.2 NATIONAL POLICY

8.2.1 Strategy

Current policies on renewables, including wind, have their basis in the National Greenhouse Response Strategy and the National Sustainable Energy Policy. In recent times, sustainable energy policy is being pursued as part of a sustainable energy and energy market reform, driven within Australia's national greenhouse strategies.

The strategies for the development of renewables in Australia were unchanged during 2001 and currently include the following.

- Mandated target for the uptake of renewable energy, specifying a proportion of renewables in new generation requirements
- Support for green electricity schemes and accreditation of green energy products
- Funding the development, commercialization, and demonstration of renewable energy and greenhouse technologies

- Identifying and removing barriers to the development of a renewables industry

In 2001, the federal government, through COAG, agreed to establish a national energy policy framework and a Ministerial Council on Energy. The long overdue review to establish the policy is expected to take more than 12 months. Its scope includes energy use, existing gas and electricity market, regulatory structures, and integrating networks.

8.2.2 Progress Towards National Targets

Significant progress towards the development and growth of a national renewable industry has been achieved in 2001 with a real commitment towards the development of a renewable industry as a means of limiting the increase in national greenhouse emissions.

Specific progress during 2001 Australia includes the following

- Established the Office of the Renewable Energy Regulator (ORER) in February to implement the Renewable Energy (Electricity) Act 2000
- Brought into force in April the regulations establishing the Mandatory Renewable Energy Target (MRET)
- Undertaken comprehensive monitoring and reporting of progress in relation to the National Greenhouse Strategy for 2000
- Progressed the Renewable Energy Action Agenda, including production of a Renewable Energy Industry Roadmap
- Continued operation of the national GreenPower program by New South Wales' (NSW) Sustainable Energy Development Authority (SEDA)

The government – through the AGO, the Renewables Target Working Group, the Greenhouse Energy Group, and the Ministerial Council – has set a mandatory target for electricity retailers and large purchasers (liable parties) to source an additional 2% of their electricity from renewable energy sources by 2010. The measure is being made through the Renewable Energy (Electricity) Act 2000 and the Renewable Energy (Electricity) (Charge) Act 2000, supported by the Renewable Energy (Electricity) Regulations. The Renewable Energy (Electricity) Act specifies a number of interim yearly targets over the period 2001 to 2020.

The measure uses a system of tradeable certificates called Renewable Energy Certificates (RECs), administered by ORER, that are earned on the basis of one REC per megawatt-hour of eligible renewable generation. At the end of the first year of the RECs market, the contribution from wind energy was 44 GWh (see Figure 8.1).

More than 600,000 RECs were created last year, providing more than enough certificates to cover 2001's target of 300,000 RECs, and providing a head start for 2002's larger target of 1.1 million RECs.

The REC is traded on the Australian Electricity Industry developed Green Electricity Market (GEM), which was developed to provide electronic trading in green electricity rights. The "green nature" value is separated from the actual electricity, allowing the electricity to be sold to the wholesale market while the "green nature" value is traded on the GEM exchange. (There is a strong potential for this type of market to become global in the future.)

Following the launch of the Renewable Energy Action Agenda by Senators Minchin and Hill in 2000, the AGO has continued to work with industry and other government agencies to progress the implementation of its recommendations through the Leaders (CEOs) Meeting and the Implementation Group. One of the Action Agenda initiatives, which has involved extensive consultation with prac-

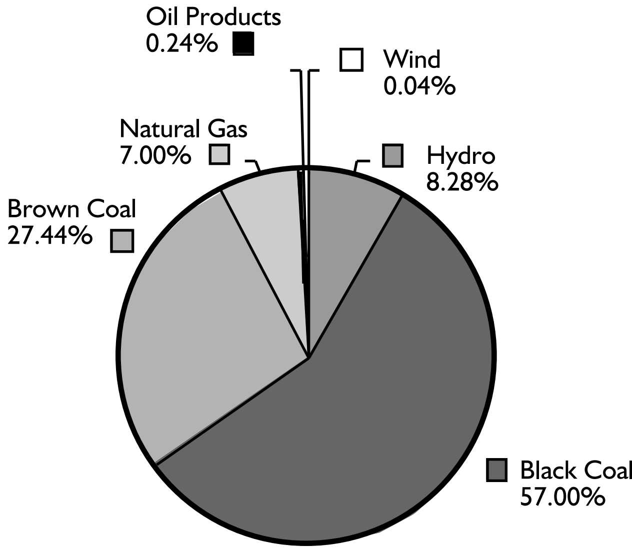

Figure 8.1 Contribution to the renewable generation target by source for Year 1

titioners and researchers in the industry, involved Australia-wide workshops for the development of a Renewable Energy Industry Roadmap.

A National Green Power Annual Audit performed by SEDA showed that total green energy sales reached 455 GWh in 2000 to 2001, up 50% from last year's sales. Over the four-year life of the GreenPower program, demand for genuine renewable energy has increased tenfold. Sales have climbed from 40 GWh in 1997, to 136 GWh in 1998 and 1999, to 300 GWh in 1999 and 2000. Green Power sales for 2001 and 2002 is likely to be more than 500 GWh. Solar and wind energy account for 12% of Green Power sales, up 4% from last year. Increased demand for renewable energy due to accredited Green Power products has lead to a growth in new installed capacity with over 100 new approved projects (200 MW) proceeding, including 20 installed in 2000 and 2001.

Australian targets relate to the renewables industry as a whole. In the absence of specific government targets for the wind industry, the Australian Wind Energy Association (AusWEA) and Greepeace have set their target as 5,000 MW of wind turbines by 2010. Australia's progress in the deployment of wind generation is shown in Figures 8.2 (a) and 8.2 (b).

SEDA has a set a target for new wind installations. In this state, the target is a total of 1,000 MW. The state achieved 16 MW by the end of 2001. No other states have established targets by the close of 2001.

8.3 COMMERCIAL IMPLEMENTATION

8.3.1 Installed Capacity

Installed capacity of wind turbines (less than 25 kW in size) reached more than 73 MW at end of 2001, an increase of 128% on 2000 totals. Approximately 69 MW are grid connected and the remainder is located in remote wind-diesel power systems.

Installed capacity is down 80 MW on what was expected at the end of last year due to delays in obtaining approvals (Toora) and delays in obtaining approvals and a connection agreement (Lake Bonney). Increases in wind installations

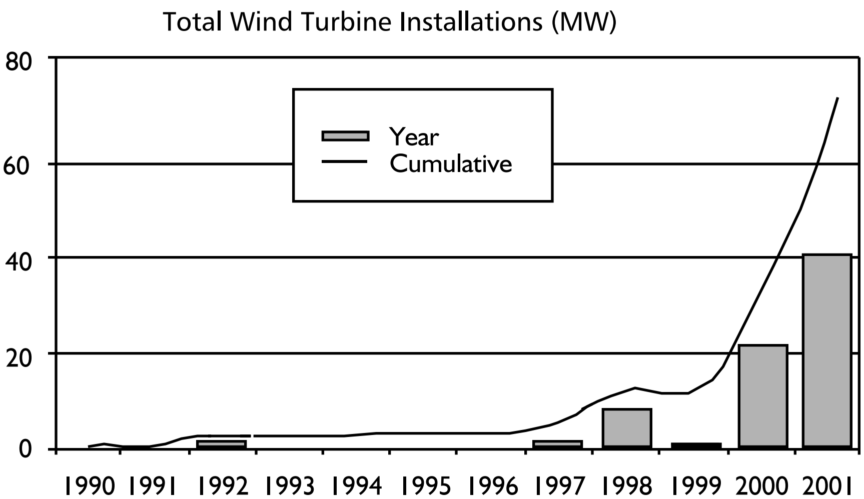

Figure 8.2 (a) Total wind turbine installations in Australia (MW)

were 41 MW from three grid-connected wind farms: Codrington, Hampton, and Albany (see Table 8.1).

Pacific Hydro's 18.2-MW Codrington Wind Farm, located on the coast near Port Fairy in southwest Victoria, began operation in June 2001 as Victoria's first large wind farm, with 14 1.3-MW AN Bonus turbines. Victorian Premier Steve Bracks officially opened the wind farm in July 2001. At a total project cost of $30 million, this is Australia's first privately funded wind farm. Electricity retailer Origin Energy purchases all the electricity generated. (See Figure 8.3)

Hampton Wind Park is the newest wind farm in NSW and is a two-hour drive from Sydney, past the Blue Mountains. Power from two Vestas 660-kW wind turbines enhances the quality of supply in the surrounding rural electrical grid. This wind farm supplies electricity to Integral Energy's Green Power customers.

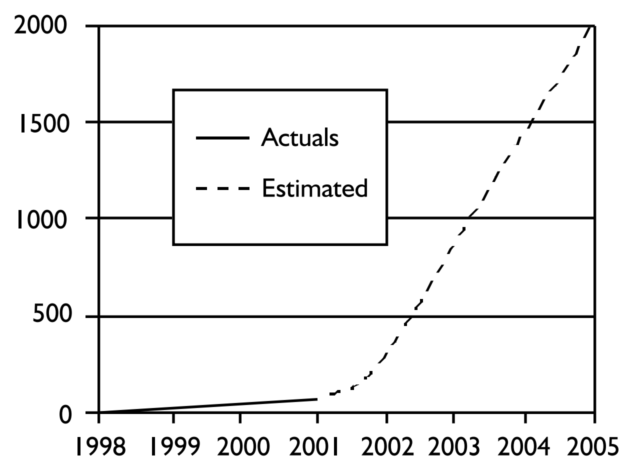

Figure 8.2 (b) Total wind turbine installations in Australia (MW)

Name or Location	State	Owner or Developer	Year	Total Capacity (MW)	No. of Turbines	Turbine Size (MW)	Manufacturer	Ownership	Application
Breamlea	VIC	NA	1987	0.06	1	0.06	Westwind	Private Co	Grid Connected
Flinders Is 1	TAS	NA	1988	0.055	1	0.055		Private Co	Wind Diesel
Salmon Beach	WA	Western Power	1988	0.36	6	0.06	Westwind	Gov. Utility	Wind Diesel
Coober Pedy	SA	Gov	1991	0.15	1	0.15	Nordex	Local Govt	Wind Diesel
Ten Mile Lagoon	WA	Western Power	1992	2.025	9	0.225	Vestas	Gov. Utility	Wind DieselWind Diesel
Flinders Is 2	TAS	NA	1996	0.025	1	0.025		Private Co	Wind Diesel
Armadale	WA	NA	1997	0.03	1	0.03	Westwind	Private Co	Grid Connected
Kooragang Island	NSW	Energy Australia	1997	0.6	1	0.6	Vestas	Gov. Retailer	Grid Connected
Thursday Island	QLD	Ergon Energy	1997	0.45	2	0.225	Vestas	Gov. GenCo	Wind Diesel
Crookwell	NSW	Eraring Energy	1998	4.8	8	0.6	Vestas	Gov. GenCo	Grid Connected
Huxley Hill	TAS	Hydro Tasmania	1998	0.75	3	0.25	Nordex	Gov. GenCo	Wind Diesel
Denham	WA	Western Power	1999	0.69	3	0.23	Enercon	Gov. Utility	Wind Diesel
Epenarra	NT	NA	1999	0.08	1	0.08	Lagerwey	Gov	Wind Diesel
Murdoch	WA	NA	1999	0.02	1	0.02	Westwind	Research	Research
Blayney	NSW	Eraring Energy	2000	9.9	15	0.66	Vestas	Gov. GenCo	Grid Connected
Windy Hill	QLD	Stanwell Corporation	2000	12	20	0.6	Enercon	Gov. GenCo	Grid Connected
Albany	WA	Western Power	2001	21.6	12	1.8	Enercon	Gov. Utility	Grid Connected
Codrington	VIC	Pacific Hydro	2001	18.2	14	1.3	An Bonus	Private Co	Grid Connected
Hampton	NSW	Hickory Hill Wind Energy	2001	1.32	2	0.66	Vestas	Private Co	Grid Connected
			Totals	73.115	102				

Table 8.1 Australian wind turbine installations at the end of 2001(more than 25 kW)

Figure 8.3 Pacific Hydro's 18.2-MW Codrington Wind Farm in Victoria

The Albany Wind Farm is Western Power's most ambitious renewable energy installation to date. Officially opened in October 2001 by the State's Energy Minister, the wind farm has 12 Enercon E66 1.8-MW wind turbines and is located at a site adjacent to cliffs along the coastline in an elevated position approximately 80 m above the Southern Ocean.

The outlook for large, grid-connected developments continue to be encouraging with the likely completion of up to 101.5 MW in 2002 (see Table 8.2).

Construction of Stanwell Corporation's 21-MW wind farm at Toora began in January 2002. The 12 Vestas 1.75-MW wind generators are due to be operating by June 2002.

Babcock and Brown appointed Pacific Power International as the engineer's for the Lake Bonney wind farm development in mid 2001. Lake Bonney is 16 km south of Millicent in South Australia. The first

Name or Location	State	Owner and/or Developer	Capacity (MW)
Toora	VIC	Stanwell Corporation	21
Lake Bonney Stage 1	SA	Babcock and Brown	70
Woolnorth Stage 1	TAS	Hydro Tasmania	10.5
		Total	101.5

Table 8.2 Planned grid-connected installations for 2002

Name or Location	State	Owner and/or Developer	Capacity (MW)
Bluff Point	TAS	Hydro Tasmania	54
Cape Bridgewater	VIC	Pacific Hydro	51
Cape Nelson	VIC	Pacific Hydro	66
Cape Sir Will. Grant	VIC	Pacific Hydro	12
Challicum Hills	VIC	Pacific Hydro	75
Coronation Beach	WA	Energy Visions	104
Emu Downs	WA	Stanwell Corporation	40
Fremantle	WA	Energy Visions	5.4
Granville Harbour	TAS	Hydro Tasmania	300
Green Point	SA	Wind Prospect & Primergy	44
Joanna Plains	WA	Stanwell Corporation	40
Kongorong	SA	Stanwell Corporation	30
Lake Bonney Stage 2+	SA	Babcock and Brown	140
Lake Hamilton	SA	Hydro Tasmania	110
Loch Well Beach	SA	Ausker Energies	54
Mumbida	WA	Wind Energy Corporation	30
Mussleroe	TAS	Hydro Tasmania	100
Nirranda	VIC	Stanwell Corporation	50
NSW Southern Highlands	NSW	Michelago Ltd PPI	30
Sellicks Beach	SA	Trust PowerT	122
Starfish Hill, Cape Jervis	SA	Tarong Energy	34.5
Tungetta Hill	SA	Ausker Energies	50
Uley Basin Stage 1	SA	Babcock & Brown	90
Windy Hill Stage 2	QLD	Stanwell Corporation	12
Woakwine Range	SA	Wind Prospect	NA
Woolnorth Stage 3+	TAS	Hydro Tasmania	73
Yabmana	SA	Wind Prospect	60
Yambuk	VIC	Pacific Hydro	25
		Total	1801.9

Table 8.3 Planned grid-connected installations for 2003 to 2005

stage of the development, for 40 1.75-MW machines, was awarded to Vestas, Australian Wind Technology, and Leighton Contractors in late 2001. It is proposed that the development will have two or three stages and total of 210 MW on completion. The planned commissioning date for the first stage of the development is the end of 2002.

Hydro Tasmania was granted environmental approval in late 2001 to build a 130-MW wind farm at Woolnorth in Tasmania. This was after more than a year's delay. The first stage of the Woolnorth project is to include six Vestas 1.75-MW wind turbines and is to be commissioned in late 2002.

Outlook for large, grid-connected developments, from 2003 to 2005, is extremely positive with announcements made on the planned completion of more than 1,800 MW during this period (see Table 8.3). However, success of these projects is dependent on obtaining satisfactory and timely environmental approvals, connection agreements, securing power purchase agreements, and funding.

Developers Primergy and Wind Prospect received provisional planning approval in December 2001 for 25 turbines generating 44 MW at Green Point, 15 km east of Port MacDonnell in southeast South Australia. In January 2002, the federal government agency Environment Australia declared that the project poses a risk to the endangered orange-bellied parrot as it migrates from Tasmania to coastal South Australia and Victoria for winter. Current activity focuses on securing Power Purchase Agreements, Connection Agreements, and financing. Commissioning is expected in 2003.

Wind farm developer Paul Hutchinson is working with Babcock and Brown to build up to 350 turbines between Port Lincoln and Elliston. The initial development near Coffin Bay and Shoal Point in the Uley Basin is proposed to be 90 MW and commissioned in 2003.

Hydro Tasmania is to build a 200 million AUD Lake Hamilton Wind Farm north of the coastal town of Sheringa on the Eyre Peninsula. Located on a coastal plateau approximately 45 km southeast of Elliston. The 110-MW development with 62 turbines (maximum of 95) is expected to begin in 2003.

Pacific Hydro continues to develop a major wind farm development in southwest Victoria. The development consists of four wind farm sites based around Portland, with a combined potential of more than 140 MW. Pacific Hydro started an 18-month Environment Effects Statement in 2000 for the projects – located at Yambuk, Cape Sir William Grant, Cape Nelson, and Cape Bridgewater – and ran into early opposition to its plans. Opponents have sited visual impact, endangered native birds, sensitive natural fauna, and Aboriginal sites as their concerns. The environmental effects statement was released for public exhibition in October 2001, closing in December. A panel begins its hearing into the development in February 2002, and a decision on the project is expected during May 2002.

The SA regulator SAIIR issued a discussion paper on a proposal by Tarong Energy and Global Intertrade for a 30-MW wind farm at Starfish Hill near Cape Jervis on the Fleurieu Peninsula in October 2001. Sinclair Knight Mertz was appointed as planning and environmental consultants to undertake the Development Assessment application, and Garrad Hassan Pacific was appointed to assist with the layout of the farm and tendering. Application has been made to ETSA Utilities for a connection to its 66-kV network and to NEMMCO for an exemption from registering as a scheduled generator if it has a capacity greater than 30 MW. Project commencement was expected by February 2002 – however, Global withdrew from the project in December and public concern has held up the development assessment.

The second stage of Hydro Tasmania's 130-MW Woolnorth wind farm in Tasmania, the 54 MW at Bluff Point development, will include 31 Vestas machines and is to come into service in 2003. Further stages will require an undersea DC link between Tasmania and Victoria (Basslink) and could total approximately 60 MW. Basslink is targeting 2003 to 2004 for start-up but is currently battling a range of environmental concerns.

New Zealand's TrustPower is planning to finance a 200 million AUD, 70 turbine, and 122-MW wind farm on 10 km of hills from Mt. Terrible to Mt. Jeffcott in South Australia, run by Wind Farm Developments. The proposal went to the South Australian Development Assessment Commission in late 2001 and, if approved, the project will be commissioned in 2003.

Franklin Harbour District Council gave approval in late 2001 for Wind Prospect to develop a 35-turbine, 60-MW wind farm at Yabmana, between Cowell and Cleve on the Eyre Peninsula. Current activity focuses on securing Power Purchase Agreements, Connection Agreements, and financing. The development is expected to be commissioned in 2003.

The Shire of Chapman Valley has approved Energy Visions' proposal for a 190 million AUD wind development at Coronation Beach, north of Geraldton. The 104-MW wind farm could be completed in 2003.

Wind Energy Corporation is conducting a feasibility study into a 50 million AUD wind farm on Mumbida, 40 km southeast of Geraldton. With an installed capacity of 30 MW, the proposed wind farm is due to be constructed in 2003. Wind Energy Corporation – a joint venture between Western Power, Enercon, and Powercorp – has referred the project to the Department of Environmental Protection to set the level of assessment. The wind farm will consist of 50 Enercon E40 600-kW wind turbines.

In October 2001, Pacific Hydro Limited received town planning approval from the Ararat Rural City Council to develop a 75-MW wind farm at Buangor in western Victoria. The proposed development is for up to 50 wind turbines on Challicum Hills, on the south side of the Western Highway near Mt. Langi Ghairan. The 110 million AUD development is contingent on a wind turbine manufacturing industry being established in Australia and, if successful, is expected to become operational by January 2004.

The prospects for wind-diesel power systems continue to be excellent with the incentives given by the Renewable Remote Power Generation Program established in late 1999. Some of the projects to benefit from the program that are being planned or under construction are King Island, Salmon Beach, and Rottnest.

Two more wind turbines are to be installed in Hydro Tasmania's Huxley Hill wind farm on King Island, Tasmania, in an project that will increase the proportion of wind generation in the wind diesel power system from 0.75 MW to nearly 2.45 MW. The project has a grant form the AGO to perform the R,D&D. The system modifications include a 200-kWh to 800-kWh battery and inverter system plus a new integrated control system. Commissioning is expected by 2003.

The German company Enercon will install three 300-kW wind generators in a wind/diesel application at Australia's Mawson Base in Antarctica. The modified E30 wind generators will need to withstand winds in excess of 300 km/h. A contract for the work was signed in August 2001 and erection is expected to begin in the summer of 2003.

Name or Location	State	Owner and/or Developer	Capacity (MW)
King Island	TAS	Hydro Tasmania	1.7
Exmouth	WA	Western Power	0.075
Mawson Base	TAS	Australian Antarctic Division	0.9
Lord Howe Island	NSW		0.3
Rottnest Island	WA		
		Total	2.975

Table 8.4 Planned wind diesel installations

Western Power is looking to replace the existing six 60-kW Westwind machines at Salmon Beach with six larger machines. The upgrade to the wind /diesel system is expected to be completed by 2003.

The Western Australian government announced a go-ahead in October 2001 for a single wind turbine to provide power to run a new water desalination plant at Rottnest Island off Perth. This announcement followed a public consultation during August. The wind/diesel system is expected to cost an estimated 1.6 million AUD to construct and will save over 330,000.00 AUD each year on diesel costs alone. Construction is expected during late 2002 or 2003. (See Table 8.4)

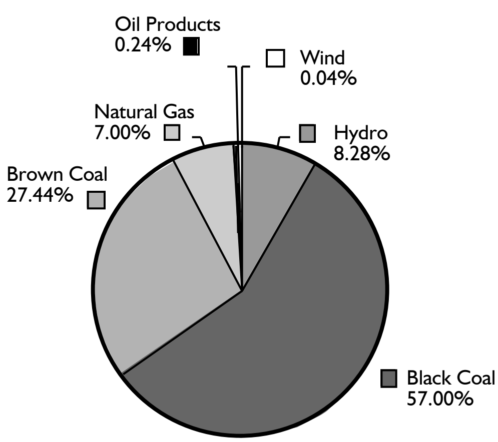

Figure 8.4 Contribution of wind to national energy demand

8.3.2 Rates and Trends in Deployment

Rate of development is expected to increase spectacularly over the next four years. See Figure 8.2 (a) for the current deployment and Figure 8.2 (b) for the forecast deployment in the period 2001 to 2005.

8.3.3 Contribution to National Energy Demand

As of June 2000, Australia had more than 40,975 MW of generation capacity that produced more than 192,000 GWh of electricity per annum (excluding Independent Power Producers), a 12% increase on the previous year. About 9% of Australia's electricity is from renewables sources, mostly hydro, and the remainder is from thermal sources, predominantly coal with some natural gas. Wind energy currently produces about 0.04% of total electricity generation, which is about double last year's total. The contribution by energy source is shown in Figure 8.4.

8.4 MARKET DEVELOPMENT AND STIMULATION

8.4.1 Support Initiatives and Market Stimulation Incentives

The most influential market stimulant in Australia continues to be the mandatory requirement for an increase of 2% in the use of electricity generated from renewable and specified waste sources by 2010. This is estimated to require investment of up to 5 billion AUD in renewable electricity generating capacity over the next ten years.

The Commonwealth Government and State Governments are also separately providing support for renewable energy industry development. The Commonwealth Government support for the renewable energy industry includes the following items listed below.

1. Renewable technology commercialization

The Renewable Energy Commercialisation Program with be supported with 5.6 million AUD over four years, commencing in 1999. These are grants to assist the commercialization of renewable technologies. One million AUD has been allocated to the development of the hybrid generation and storage power system on King Island, Tasmania, and 225,000.00 AUD has been allocated to the Exmouth Advanced mini wind farm in Western Australia.

2. Industry development activities

Beginning in 1999, 100,000.00 AUD over two years is being provided for the Sustainable Energy Industry Association of Australia (SEIAA) to support a range of industry development activities, including training and accreditation support for sustainable energy service providers and vendors, plus a survey of the sustainable energy industry.

3. Renewable energy companies

Since December 2000, 3.2 million AUD in funding has come from the government through REEF to provide specifically for the R&D and commercialization of renewable energy technologies of five renewable energy companies. The value of the fund invested rises to approximately 48 million AUD when matched by private-sector capital. The fund promotes better access to venture capital funding for commercializing R&D.

4. Rebates for renewable generation technologies

Beginning in 2000, 264 million AUD is available over four years to provide special-purpose payments to participating states and territories for the provision of rebates to install renewable generation technologies to reduce the use of diesel fuel for electricity generation. The Renewable Remote Power Generation Program (RRPGP) will provide support for the conversion of diesel-based electricity supplies to renewable energy technologies and increase the uptake of renewable energy technology in remote areas of Australia. The program is funded from excise paid on diesel consumed to generate electricity by public generators. Participating states and territories are allocated funding on the basis of the relevant diesel fuel excise paid in each jurisdiction.

5. Standards of design and installation for renewable energy systems

The AGO is working with industry to aid its establishment and to guide the development of appropriate standards of design and installation for renewable energy systems. Through this initiative, up to 6 million AUD is being made available over four years to address barriers to the uptake of renewable energy, quality issues, promotion, resource assessment, and consumer education. One of the projects supported includes the development of Best Practice Guidelines for the Implementation of Wind Energy Projects in Australia being conducted by the Australian Wind Energy Association. This grant of 88,000.00 AUD was awarded in the Industry Development - RECP Round 5.

National greenhouse strategies are being implemented through the Commonwealth Government agencies including AGO, AusIndustry, and the Australian Cooperative Research Centre for Renewable Energy (ACRE). A summary of these agencies is given below.

- AGO (established in 1998) is the key Commonwealth agency on greenhouse matters, responsible for both the coordination of domestic climate change policy and for managing the delivery of the National Greenhouse Strategy (NGS) programs.
- AusIndustry – within the Department of Industry, Science, and Resources, is the Government's principal agency for delivering information, programs, and services that support industry research and innovation. It administers a number of programs designed to encourage industry to become more innovative and entrepreneurial and to thus improve their competitive position. It also administers programs directed at helping specific industries, such as renewables, maintain their viability and enhance their competitiveness.
- ACRE was established in 1996 to facilitate the development and commercialization of renewable energy and greenhouse gas abatement technologies. ACRE seeks to create an internationally competitive renewable energy industry in Australia and operates by cooperative arrangements between universities, government organizations, and industry. ACRE currently has eight programs. Those programs that address the application of wind power cover Power Generation, Power Conditioners, and System Integration and Demonstration projects.

State governments and their agencies, including SEDA and the Sustainable Energy Authority of Victoria, are also providing support for renewable energy industries in their states, including the following.

- SEDA is promoting investment in the commercialization and use of sustainable energy technologies by awarding funding grants through the Renewable Investment Program to complying projects within NSW. A total of 3.6 million AUD was invested in 2001 to find new ways of generating clean green energy.
- SEDAis promoting the development of wind energy in NSW through the installation of a NSW Wind Monitoring Network incorporating 25 40-m monitoring towers across the state, production of a NSW Wind Atlas that is a low-resolution map of the state's wind resource based on data from SEDA's monitoring towers and other available data. This Atlas will be publicly available from March 2002 and will be updated each year. Production will be done of a NSW Wind Energy Handbook that provides comprehensive information on all aspects of wind energy development in NSW. Wind energy project support will also be provided.
- Victorian government departments and agencies are to use more renewable energy in a program aimed at fighting global warming and creating regional jobs through supporting the growth of viable renewable energy industry in regional Victoria. A minimum of 5% of their electricity will have to be sourced from renewable energy, primarily from wind farms.

SEDAwas created to bring about a reduction in the levels of greenhouse gas emissions and other adverse by-products of the production and use of energy in NSW. SEDA's Green Power scheme was widened in 1998 to encompass all of Australia. SEDAhas been instrumental in getting the wind farms projects of Crookwell and Blayney off the ground.

The Sustainable Energy Authority is a Victorian Government agency established to contribute to the reduction of greenhouse gases, and support and facilitate the development and use of sustainable energy options to achieve environmental and economic benefits for the Victorian community.

The Federal Government's approach to innovation support for the sustainable energy industry continues to include a tax concession at a rate of 125% on complying R&D.

8.5 DEPLOYMENT AND CONSTRAINTS

8.5.1 Wind Turbines Deployed

The majority of wind turbines of less than 25 kW are owned by government utilities and Generation Companies (GenCos) with 73% of all installations. The remainder are private installations, as shown in Tables 8.5 and 8.6.

NSW, Queensland (QLD), Western Australia (WA), and Victoria have been the most active in the installation of wind turbines this year.

8.5.2 Operational Experience

An estimated 154 GWh of energy was produced by wind generation in 2001 – this is well up from the 42 GWh produced in 2000. However, caution should be applied to the use of these estimates because actual production figures are not reported in Australia.

8.5.3 Main Constraints on Market Development

Market development constraints for wind development in Australia are mainly market price for electricity from renewable sources, access to the grid for export of power, and planning approval.

The market price for electricity from wind farms is set by a number of sources. The price categories are as follows.

- Spot price on the national or state electricity markets (varies because depends on market price)
- Value of the renewable energy certificate (varies because depends on market price)
- Green power component (premium set by retailers who sell the electricity product to consumers)
- Emission reduction rights (a premium that is starting to be provided in advance of the establishment of an international trading in carbon)

Over the last year, spot electricity prices in the national electricity market have typically averaged about 20.00 AUD/MWh to 40.00 AUD/MWh over a month. Higher-than-average prices in the early part of 2001 occurred when demand during warmer summer conditions and high air conditioner

Owner-ship	No. of Turbines	Capacity (MW)	Application
Private	18	19.61	Grid Connected
Gov. GenCo, Retailer or Utility	56	48.90	Grid Connected
Gov. GenCo, Retailer or Utility	25	4.51	Wind Diesel
Private	2	0.08	Wind Diesel
Research	1	0.02	NA

Table 8.5 - Deployment by ownership and application

State	No. of Turbines	Capacity (MW)
NSW	26	16.62
NT	1	0.08
QLD	22	12.45
SA	1	0.15
TAS	5	0.83
VIC	15	18.26
WA	32	24.73

Table 8.6 - Deployment by state

loads combined with restrictions in the electricity system to supply (see Figure 8.5). Indications are that prices will continue to rise in the long term as demand starts to reach the capacity to generate and distribute electricity.

Estimates of the value of certificates range from 20.00 AUD/MWh to the price cap of 40.00 AUD/MWh. The value of embedded generators to the distribution network operator may increase the return to a small wind farm through lower connection costs, lower line losses, and/or lower marginal factors. In the longer term, carbon trading credits may also increase the return, but that is well into the future at this stage.

Restrictions have emerged in the National Electricity Code that have delayed more than 1billion AUD worth of wind farm development in the states of South Australia and Victoria. The code stipulates that generators must provide power regardless of grid fluctuations, a feature that wind turbines currently are unable to do. Changes are proposed to the code and manufacturers are also considering modifications to overcome the restriction.

Proposed installations – located in some cases 25 km to 100 km from the extra-high voltage lines and requiring new dedicated or shared access transmission lines – are also, in some cases, being hampered by an inability to connect to the grid. The developments require planning and co-ordination between wind farm developers, electricity transmission companies, large electricity

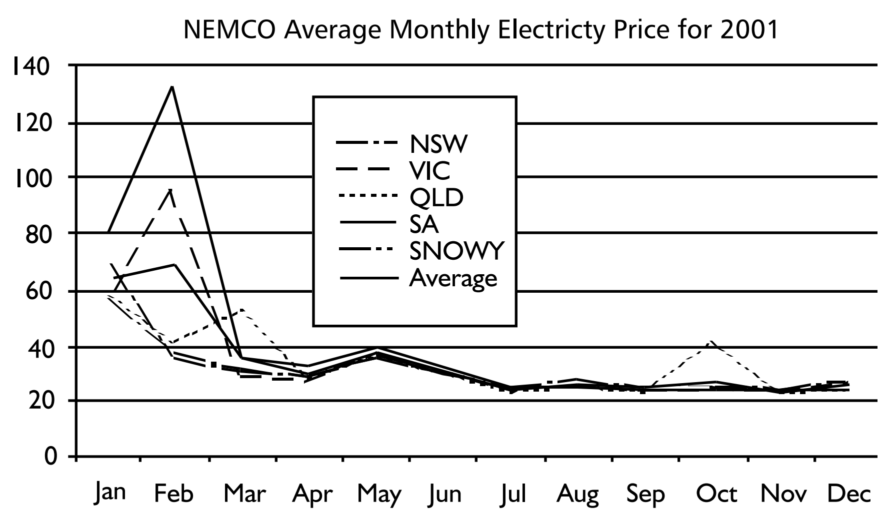

Figure 8.5 NEMCO average monthly electricity price for 2001

consumers, and state governments in the capital investment decision, timing of construction, and shared access provisions.

Australian EcoGeneration Association has an Industry Development - RECP Round 5 grant of 71,000.00 AUD to develop a Technical Guide To The Connection of Renewable Generators to the Local Electricity Network. The guide will cover the options and issues facing smaller generators when considering connecting and selling power through the NEM. It will also cover the process of negotiation of connection agreements with local distribution business as well as the negotiation of other local benefits.

Reporting in 2001 indicates a growing frustration in obtaining development approvals, according to the Renewable Energy Roundtable, with Australia's wind industry in danger of being weakened by the delays. Because wind is one of the fastest growing industries, there was uncoordinated local, state, and federal government planning and approval processes that caused some unacceptable delays for some projects. Some large wind farm projects are being called up for major project facilitation status to overcome some impasses in the state planning processes.

High growth plans being proposed by developers in 2001 have seen rising community concerns over the deployment of wind farms, particularly in coastal areas of states, such as Victoria where community leaders are calling for wind farm planning guidelines. The Sustainable Energy Authority in Victoria is to prepare guidelines to address this. The Australian Wind Energy Association Best Practice Guidelines for Wind Farm Development in Australia will form an excellent basis for the state guidelines.

Weighing up the loss of visual amenity perceived by the community against the huge economic and environmental benefits of the project, both to the local community and Australia, is one of the critical issues. Others issues are the impact on rare and endangered species, such as the migratory orange-bellied parrots that are protected by federal legislation; neighbors affected by noise and changes in land values; radiation; and interference with television reception. Of critical importance is the lack of a co-ordinated approach regarding where future wind farms will be located.

AGO is working with Australian Wind Energy Association to develop a comprehensive Best Practice Guidelines for the Implementation of Wind Energy Projects in Australia, an aid to appropriate installation of wind farms. The guidelines have been prepared in consultation with a large range of diverse stakeholder groups such as developers, local councils, consultants, environmental groups, state agencies, network operators, and retailers. Reference has been made to overseas guidelines with substantial revisions to tailor them to local industry conditions. The guidelines are expected to be completed in early 2002.

Standards Australia and the Australian Wind Energy Association are establishing a noise standard committee to address the absence of an agreed standard in Australia. This is also a crucial issue for the industry.

8.6 ECONOMICS

8.6.1 Trends in Investment

Growth of capital expenditure on wind farms has been rapid over the last two years and is forecast to continue at an extraordinary rate. Total expenditure of more than 3.5 billion AUD are expected by 2005 on current growth rates predictions. (See Figure 8.6)

8.6.2 Trends in Cost of Energy and Buy-Back Prices

Most of this information continues to be commercially sensitive and confidential in

State	Capacity (MW)
NSW	30
QLD	12
SA	805
TAS	540
VIC	300
WA	219
Total	1906

Table 8.7 Planned deployment by state

Australia for new and existing wind farms.

8.7 INDUSTRY

8.7.1 Manufacturing

There is a small but viable established industry in Australia that manufactures turbines in the battery charger sizes. There is a growing industry involving the manufacturing of 5-kW to 20-kW turbines for export as well as wind turbine towers for large wind turbine generators.

8.7.2 Industry Development and Structure

The wind industry in Australia principally consists of wind farm developers, owners, and regulators. There is little local manufacturing because most wind turbine components are imported. This excludes the steel towers for which there is excellent capability at many centers around Australia. Towers are being manufactured in Australia on a project-by-project basis and usually in the same region as the wind farm in order to increase the regional and local benefits of development.

Manufacturing in Australia of blades and assembly of nacelles has been the subject of feasibility studies by some of the world's largest manufacturers since the mandated target for new renewables measure was announced. The key impediment has been guaranteeing the demand for machines to justify the expense in establishing manufacturing facilities.

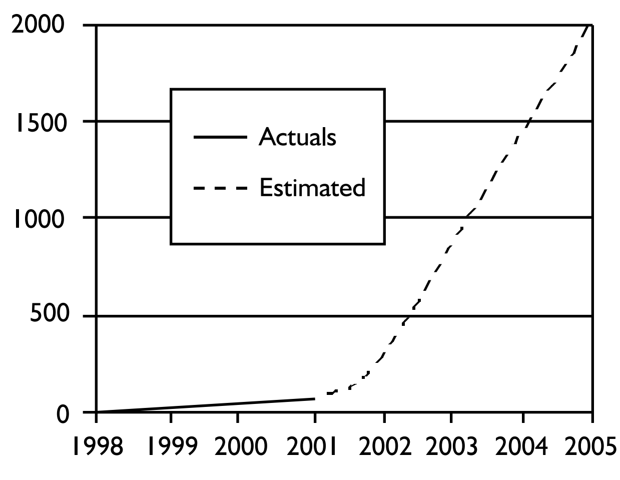

Figure 8.6 Estimated total expenditures on wind turbines installations since 1987

To overcome the demand impediment, Hydro Tasmania plans to sign a deal with Denmark's Vestas Wind Systems in 2002 for 128 MW of wind turbines as part of a 200 million AUD wind project development plan that will see part assembly and manufacture of the Vestas turbines in Tasmania. The deal could see the assembly of turbine nacelles and the manufacture of fibreglass components for turbines. Vestas and the state government also plan to investigate whether a blade manufacturing plant could be established in Tasmania once demand for the turbine is proven. Pacific Hydro Ltd. is also keen to facilitate the establishment of another wind turbine manufacturing industry near Portland, Victoria.

Any manufacturer that sets up in Australia has an opportunity to export to other countries in the Asia-Pacific region.

Developers are not taking an equity position in manufacturing but are instead focusing on guaranteeing the market for production.

8.8 GOVERNMENT-SPONSORED R,D&D

8.1 PRIORITIES

Funding for AGO programs are being allocated to renewable energy R,D&D projects that promise a significant contribution to increased local employment, have export potential, and contribute to a reduction in Australia's greenhouse emissions. Other government priorities include the development of viable wind turbine or component manufacturing capability, and improvement to the performance of wind diesel power or hybrid power systems. These priorities are evident by the funding allocation as previously indicated (see Section 8.4).

8.8.2 New R,D&D Developments

An inventory has been prepared by MURE of Western Australia in conjunction with AGO and ACRE. Results show there are over 250 possible diesel generator sites, of which many may be suited to conversion to hybrid wind diesel power systems.

The Denham wind diesel flywheel hybrid power system, constructed in 1999, completed its final optimization in 2001. The project consists of three Enercon E30, 230-kW turbines connected to the small, local, diesel-powered grid and energy storage performed by two 4-ton Enercon-designed flywheels that were installed and commissioned in 2000. The innovative flywheel system stores short-term energy and allows the wind turbine to maximize the renewable energy supplied to the grid. The energy stored in the flywheel is supplied to the grid for short-term periods to even out fluctuations in the wind. This then allows diesel generators to be kept offline, reducing fuel consumption and engine wear. This project was supported by a 1 million AUD grant from the AGO. Curtin University of Technology, Murdoch University, and Northern Territory University conducted research work into this system for PowerCorp and Western Power in conjunction with ACRE.

Another project being undertaken by Western Power, with a grant from the AGO, is the installation of three turbines designed and manufactured in Australia. Support from a 225,000.00 AUD Federal Government's Renewable Energy Commercialisation Program (RECP) grant has enabled the installation of three unique 20-kW and 25-kW Westwind wind turbines in Western Power's diesel-powered distribution network at Exmouth, Western Australia. The miniature wind farm is expected to generate 200 MWh of electricity each year. This will displace approximately 50,000 liters of diesel fuel.

As Exmouth is prone to cyclones, the new wind turbine design, developed through the ACRE, uses a tow-up type, guyed, steel tower that can be lowered ahead of an advancing storm event.

Another advantage of these turbines is their use of rare-earth super magnets to reduce the size and weight and improve the performance of the generator. This allows an increase in the power capacity of tow-up wind turbines, which have an upper weight limit for their practical use. The advanced design of the fixed aerofoil blades and generator has been undertaken jointly by members of ACRE.

The turbines for the Exmouth project are being developed separately for ACRE by a combined effort by Westwind (manufacturer); Murdoch University (monitor); University of Newcastle (blade designer); University of Technology, Sydney (generator designer); Northern Territory University (controller); and Western Power (customer). The turbines being developed range from 5 kW to 20 kW and use a unique, permanent magnet, low-speed, high-torque generator, blade pitching mechanism, tailfin arrangement, and power-electronic turbine controller interface.

ACRE, Curtin University of Technology, Industrial Research, PowerSearch, Power and Water Authority, and Western Power are developing a power conditioning and control system for high wind penetration, medium-scale wind diesel power systems. A prototype has been tested at Epenarra using a wind/photovoltaic/diesel/battery hybrid power system with an 80-kW Lagerwey wind turbine on a 30-m tower. The system is capable of reducing diesel use by up to 70%.

A 10-kW wind turbine continues to be commercialized by EnergyAustralia (in conjunction with University of Newcastle and Biomass Energy Services & Technology Pty Ltd.) for manufacture in Australia and under licence in China.

Hydro Tasmania has a grant of 1 million AUD from the AGO RECP program to design and build a system that makes better use of current and future wind energy generation on King Island, thereby reducing diesel consumption associated with existing power-generating facilities. The system comprises a number of components, including a battery and inverter system, demand-side load management systems, and an integrated renewable energy control system. Investigations during 2001 showed that the previous arrangement, incorporating a pumped storage mini-hydro, was not feasible at the island site and has been abandoned.

Monitoring towers at 22 sites across NSW currently obtain information on the wind resource necessary to assess wind generation potential in the state. This program, by SEDA, will provide a Wind Atlas for the state of NSW. The aim is to generate publicly available information and identify potential sites over a two-year period commencing in 2000.

8.8.3 Offshore Siting

There are no announced developments of offshore wind farms.

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Author: Robert Stewart, Australian Wind Energy Association and Hydro Tasmania, Australia.

CHAPTER 9

9.1 INTRODUCTION

Canada has tremendous wind energy potential and supports the development of this alternative energy source as part of its response to the climate change challenge and in order to achieve the goals of energy diversification, technology development, job creation, and increased trade. The main vehicle of technical support at the national level is the Wind Energy Research and Development (WERD) Program, at Natural Resources Canada, a department of the federal government of Canada.

9.2 NATIONAL POLICY

9.2.1 Strategy

The main elements of the Wind Energy R&D 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.

9.2.2 Progress Towards National Targets

There are no national wind energy deployment targets in Canada at this time. However, the development and expansion of the wind energy industry and wind turbine deployment is supported by all levels of government in varying degrees, and installed capacity is growing quickly (see Sections 9.3.2 and 9.4.1).

9.3 COMMERCIAL IMPLEMENTATION

9.3.1 Installed Wind Capacity

The total installed capacity in Canada at the end of 2001 was 198 MW. Some of Canada's specific installations are listed below. In addition to these systems, Canada has various other installations that total approximately 7 MW.

1) Canadian Hydro Developers

This is a 40.1-MW installation at Cowley Ridge, southern Alberta, comprised of US Windpower (Kenetech) and Nordex wind turbines. The first two stages, consisting of 18.7 MW of US Windpower 360-kW machines and 1.9 MW of US Windpower 375-kW turbines, were installed in 1993 and 2000, respectively. In 2001, 15 Nordex 1.3-MW machines were added.

2) Vision Quest Windelectric

This is a 42-MW installation in Southern Alberta. The operation consists of two sites comprising 600-kW and 660-kW Vestas turbines.

3) Sunbridge

This is a 4-MW system of Vestas 660-kW machines installed at Gull Lake, Saskatchewan, in September 2001.

4) AXOR Group

This is a 100-MW Le Nordais project. Officially opened in September 1999, this development consists of 133 750-kW NEG-Micon turbines located in the Gaspe area of Quebec.

5) Prince Edward Island Energy Corporation

This is a 5.3-MW system of Vestas 660-kW wind turbines installed at North Cape, PEI, in November 2001.

9.3.2 Rates and Trends in Deployment

Total installed wind power capacity in Canada has experienced an average annual growth of 56% over the past five years. Admittedly, the large block of capacity that was added in 1999, when the 100-MW Le Nordais project was commissioned, has skewed this figure. Nevertheless, the growth rate between 2000 and 2001 was 44%. These trends, in combination with a new production incentive for wind power developers that will become available in April 2002, set the stage for strong, continued growth into the future.

9.3.3 Contribution to National Energy Demand

The national electrical energy demand in Canada in 2001 was 550 TWh. Total installed generation capacity at the end of 2000, the most recent year for which statistics are available, was 111 GW, which includes hydro-power, coal, nuclear, natural gas, oil-fired, wood-fired, tidal, and wind plants. The installed wind capacity was 198 MW by the end of 2001, and an estimated 370 GWh of wind energy was produced that year.

9.4 MARKET DEVELOPMENT AND STIMULATION

9.4.1 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 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 that allows developers of wind turbines and other renewable energy sites to sell power, using power transmission lines, 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 consumers.

In its latest budget, introduced in December of 2001, the federal government announced a new, CAD 260-million, production-based incentive for wind power developers. This initiative will be for projects commissioned after 31 March 2002 and before 1 April 2007. Qualifying wind energy facilities will receive an initial incentive payment of 0.012 CAD/kWh of production, gradually declining to 0.008 CAD/kWh of production by the fifth year of the program. The incentive will be available for the first ten years of production and will help to provide a long-term, stable revenue source. The program is intended to help address climate change and improve air quality. Provincial and territorial governments are being encouraged to provide additional support.

9.4.2 Unit Cost Reduction

This item is not applicable.

9.5 DEPLOYMENT AND CONSTRAINTS

9.5.1 Wind Turbines Deployed

The following wind turbines are operational in Canada.

- 56 US Windpower (Keneteck) 360-kW and 375-kW wind turbines
- One NEG-Micon 900-kW and 136 NEG-Micon 750-kW machines

- 15 Nordex 1.3-MW wind turbines
- Five Vestas V44 600-kW, 74 Vestas V47 660-kW, and one Vestas V80 1.8-MW wind turbines
- One Tacke 600-kW unit
- Several turbines with capacities of 150 kW or less

9.5.2 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.

9.5.3 Main Constraints on Market Development

The two 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. For example, the recently announced production incentive for wind power developers will strongly encourage market development, particularly in those regions where the provincial governments choose to contribute.

9.6 ECONOMICS

9.6.1 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 1.8 million CAD has been accessed to leverage projects sponsored by WERD.

9.6.2 Trends in Unit Costs of Generation and Buy-Back Prices

Electricity deregulation in Alberta resulted in the restructuring of government-owned utilities into a free-market system. Full retail competition between power generators began on 1 January 2000. This process has allowed wind generators freer access to the electrical grid. In Ontario, a similarly deregulated system is scheduled to commence on 1 May 2002. In all other Canadian jurisdictions, the buy-back price is generally set by the local utility and based on avoided costs. Large wind farms, such as the Le Nordais project, have pre-negotiated special buy-back rates from the utility.

9.7 INDUSTRY

9.7.1 Manufacturing

Below is a list of some of the current manufacturing initiatives in Canada.

- Dutch Industries produces water pumping units in Regina, Saskatchewan
- Vergnet Canada of Guelph, Ontario, is developing 10-kW, 25-kW, and 60-kW single and three-phase wind turbines for grid connected, remote communities and stand alone applications
- Novelek Technology of New Brunswick has developed 10-kW and 25-kW inverters for the commercial wind turbine market
- Polymarin Huron Composites Inc, Huron Park, Ontario, is manufacturing blades for 10-kW to 1.5-MW wind turbines; the company produces rotor blades on specification for wind turbine manufacturers and has a new generic

blade design suitable for turbines in the 750-kW to 900-kW range

9.7.2 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.

9.8 GOVERNMENT-SPONSORED R,D&D

9.8.1 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 support 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.

9.8.2 New R,D&D Developments

The program supports new technology development activities related to the following items.

- Components for wind turbines in the 600-kW to 2-MW range
- Small- to medium-sized wind turbines (10 kW to 60 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

9.8.3 Offshore Siting

This item is not applicable.

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CHAPTER 10

10.1 INTRODUCTION

Denmark has a long tradition of implementing vigorous energy policies with broad political support and involving a broad range of actors, such as energy companies, industry, municipalities, research institutions, non-governmental organizations, and consumers. A continuous effort since the beginning of the 1980s has led to an installed wind energy capacity of approximately 2,500 MW by the end of the year 2001 and a wind energy production covering approximately 12.6% of Denmark's electricity demand. Any change in policy decided by the new government after November 27, 2001 will be described fully in the 2002 Annual Report.

10.2 NATIONAL POLICY

10.2.1 Strategy

Denmark has had several energy strategies over the last 20 to 25 years, and the goals of these strategies have shifted from securing the energy supplies after the crisis of 1973 and 1974, to plans pursuing a sustainable development of the energy sector. An energy strategy called Energy 21, which was created in 1996, is the fourth of the energy strategies and lays down the energy-policy agenda up to the year 2030.

Development and implementation of wind energy have been included in all Danish energy strategies. Both demand pull policy instruments (financial and other incentives) and technology push policy instruments

Demand pull instruments	Technology push instruments
Incentives	Incentives
• Taxation	• R&D programmes
• Production subsidies	• Test station for wind turbines
• Programs for developing countries	• International co-operation
Other regulation and policy instruments	**Other regulation and policy instruments**
• Resource assessment	• Approval and certification scheme
• Local ownership	• Standardisation
• Agreements with utilities	
• Regulation on grid connection	
• Buy-back arrangements	
• Information programmes	
• Spatial planning procedures	

Table 10.1 Policy instruments used in 2001 to promote wind turbine technology and installations.

(certification schemes and R,D&D programs) have been used as tools in the strategies. The policy instruments used in 2001 are shown in Table 10.1.

Energy 21 generally considers new, large wind turbines as one of the cheapest technologies for reducing carbon dioxide emission from power production. The most economical way is still to erect wind turbines on land, but area resources on land are limited when housing, nature, and landscape considerations are taken into account. Furthermore, wind conditions at sea are considerably better than at sites on land, and wind turbines erected offshore are expected to become competitive as technology develops.

For this reason, Energy 21 is based on the expectation that in the longer term, the main part of new development will take place offshore, while a significant part of the expansion until 2005 will take place on land. After 2005, new wind turbine capacity on land will be affected, among others, 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 the spring 1999, an electricity reform was introduced, and a number of new bills for the Danish electricity sector were approved by the parliament. The reform contributes to ensuring the fulfilment of the long-term, international environmental commitments for 2008 to 2012. The agreement covers the first four 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 years 2000 to 2003, a ceiling has been established for the total electricity sector's carbon dioxide emission of 23 million tons in 2000, 22 million tons in 2001, 21 million tons in 2002, and 20 million tons in 2003. The ceiling is to be expressed in carbon dioxide quotas, which will be split among the electricity production companies. The ceiling will make it possible to incorporate environmental commitments in the electricity companies' planning of future investments and operational dispositions. If the annual quota is exceeded, the production companies must pay to the state the sum of 40.00 DKK per ton of carbon dioxide.

In the future, a rising share of electricity consumption will be covered by electricity produced from renewable energy sources, and a more competition-based market mechanism that can ensure the cost-effective development of renewable energy production will be introduced. This results in certification of electricity from renewable energy sources, which creates a basis for the gradual development of a market for electricity from renewable energy sources. Also from now on, renewable energy quotas are to be announced by the government, and all consumers will be obligated to purchase an increasing share of electricity from renewable energy. In the first instance, a quota will be laid down, which requires 20% of electricity consumption to 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 the renewable energy is going to be wind power.

	Realistic capacity	Realistic production	% of annual electricity consumption
Onshore	2,600 MW	5.7 TWh	17 - 18 %
Offshore	12,000 MW	30 - 40 TWh	~ 100 %

Table 10.2 Estimated wind turbine capacity and production in Denmark.

10.2.2 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. Therefore, most of the 205 municipalities have prepared a wind turbine plan. The Danish Energy Agency has analyzed this local planning and estimates onshore wind energy potential to be between 1,500 MW and 2,600 MW.

Several investigations of the offshore wind resources have been prepared 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 as well as the ministry's Energy Agency and Environmental Protection Agency.

Year of instal-lation	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*	110	<100	900

Table 10.3. Installed wind turbine capacity and development in size.
(*Year 2001 estimated).
Source: E&M-Data for the Danish Energy Agency.

The plan of action includes eight areas available with water depths up to 15 m. The wind speeds in the areas allow 3,530 "net full load hours" per year at the North Sea (Horn's Reef) and between 3,000 and 3,300 hours in interior Danish waters. (A hub height of 55 m and a rotor diameter of 64 m is anticipated.) This can be compared to inland conditions of 2,000 to 2,500 hours. The total capacity for electricity production is estimated in Table 10.2.

In Energy 21, the targets for installed wind energy are 1,500 MW wind power by 2005 (12% of electricity consumption) and 5,500 MW wind power by 2030 (40% to 50% of electricity consumption), out of which 4,000 MW will be offshore. As shown later, the targets for onshore wind power have already been surpassed, while offshore development is just beginning.

10.3 COMMERCIAL IMPLEMENTATION

10.3.1 Installed Capacity

During 2000, new installed capacity reached a record of approximately 600 MW. By the end of 2000, the total installed capacity of wind turbines was approximately 2,417 MW. By February 2002, final statistics for the year 2001 were not yet available. However, it is estimated that less than 100 MW was installed in 2001, bringing the total installed capacity up to approximately 2,500 MW. The accumulated wind turbine capacity of private and utility wind turbine installations is shown in Figure 10.1.

10.3.2 Rates and Trends in Deployment

The deployment rate in Denmark in numbers and electrical capacity are shown in Table 10.3.

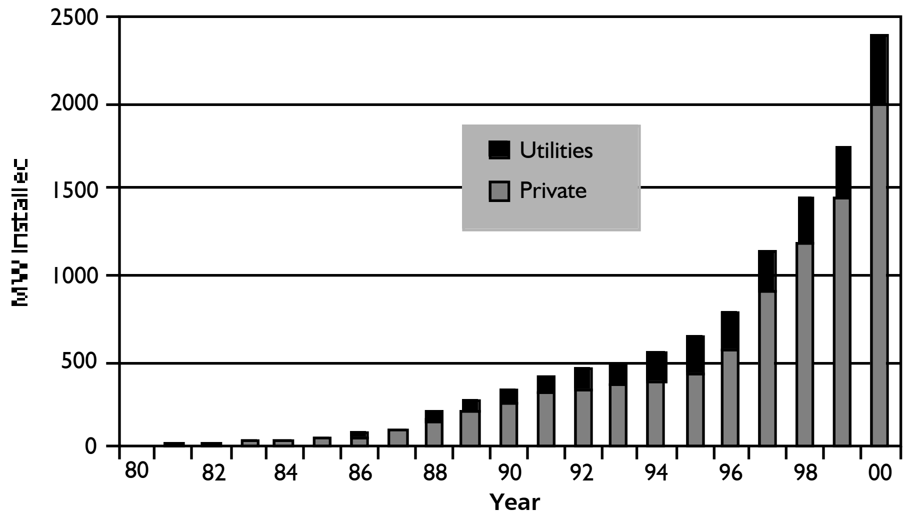

Figure 10.1 Accumulated wind turbine installations in Denmark 1980-2000.

Deployment has been almost constant since 1996, adding approximately 300 MW of wind power capacity onshore annually. However, in 2000, an extraordinarily high capacity of approximately 600 MW was installed, whereas a record low installation of less than 100 MW is anticipated for 2001. The average size of the installed wind turbines has grown gradually – 750 MW in 1999, 889 MW in 2000, and an expected 900 kW in 2001.

10.3.3. Contribution to National Energy Demand

The total electricity production in 2001 is estimated to be approximately 4,000 GWh, corresponding to about 12.6% of the total electricity demand in Denmark. The wind energy index in 2001, which describes the energy in the wind of a normal year, was relatively low (approximately 82%). Development in the wind energy index is shown in Figure 10.2.

10.4 MARKET DEVELOPMENT AND STIMULATION

10.4.1 Support Initiatives and Market Stimulation Incentives

Utilities are required by law to connect private 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' production and distribution costs (tariffs). Alaw has required power utilities to pay wind turbine owners a kilowatt-hour rate of 85% of the utility's production and distribution costs (85% of DKK; 0.37 DKK/kWh to 0.45 DKK/kWh in 1998). Up to now, the government has reimbursed wind turbine owners the 0.10 DKK/kWh carbon dioxide tax and added 0.17 DKK/kWh in direct subsidy. As a result, in 2001, the average selling price of electricity from private wind turbines was between 0.43 DKK/kWh and 0.58 DKK/kWh.

An electricity reform was introduced in spring 1999, and a number of bills were adopted by the parliament in the summer of 1999. The electricity supply bill (Act No. 375) includes new regulations, which significantly affect Danish wind power development. Renewable energy certificates have been introduced as a means to create a market for renewable energy, with a transitional period up to ten years, during which investors are guaranteed fixed tariffs for a defined electricity production.

The European Commission approved the electricity reform on 20 September 2000, except for the regulations guaranteeing a minimum price of 0.43 DKK/kWh for new installations during the transitional period. For existing or temporary wind turbines, the price will be reduced from 0.60 DKK/kWh to 0.43 DKK/kWh in the near future, depending on age and accumulated production. In additional regulations, limiting private wind developments has been withdrawn.

Favorable taxation schemes have been used to stimulate private wind turbine installations. The taxation schemes have changed over time. Today, income from wind turbines is generally taxed as any other income.

The Danish Energy Agency is responsible for administration of the approval scheme. On behalf of the Danish Energy Agency, a group at Risø National Laboratory acts as secretariat and information center for the approval scheme. The Danish approval scheme for wind turbines has been established to fulfil a common desire from wind turbine manufacturers, owners, and authorities for a coherent set of rules for approval of turbines installed in Denmark. An 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 ISO9000 quality assurance system.

Aset of rules has been developed and adopted in Teknisk Grundlag for Typegodkendelse og Certificering af vindmøller i Danmark (Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark), last revised in 2000. Several recommendations are affiliated to the Technical Criteria. Future recommendations are to be replaced by International Electrotechnical Commission or CENELEC standards, and the Technical Criteria are to be harmonized on a European level. All documents related to the approval scheme

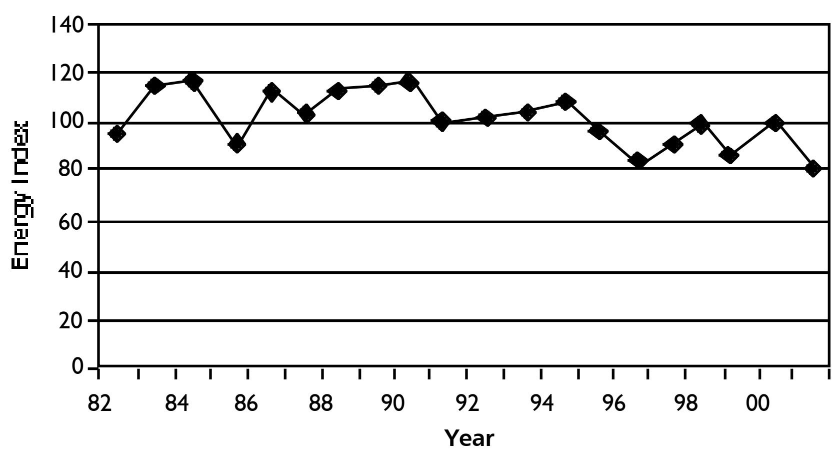

Figure 10.2 Energy in the wind, energy index in Denmark 1980-2001.

can be found on the Internet at www.vind-moellegodkendelse.dk.

Since 1979, Risø has been authorized by the Danish Energy Agency to issue licenses or type-approvals for wind turbines, including the test 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 10.4.

During recent years, large efforts have been made to establish a new test site for multi-megawatt wind turbines with heights up to 165 m. In order to have a reasonable number of high wind situations during a limited test period, a site at the northwest coast of Jutland has been preferred. In May 2000, the Minister of Environment and Energy issued a directive, allowing Risø to develop a test site at Høvsøre with five test stands. Purchase of land and planning of civil and electrical works, including connection to the grid, is ongoing. Risø will be responsible for the development and operation of the test site, which is planned to begin operation in 2002.

Service	Authorised body
Type approvals of wind turbines	Det Norske Veritas Germanischer Lloyds
Production and installation certification	Germanischer Lloyds Certification GmbH Det Norske Veritas Certification of Mgt. Systems Bureau Veritas Quality Insurance
Basic tests	Risø, Test & Measurements Tripod Consult Aps Ingenieurbüro für Windenergie
Power curve measurement	Risø, Test & Measurements DEWI, Wilhemshafen Tripod Consult Aps 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 DELTA Akustik & Vibration + bodies approved by DELTA

Table 10.4 Bodies authorised by the Danish Energy Agency to provide services under the Danish scheme for certification and type-approvals for wind turbines (Dec. 2001).

10.5. DEPLOYMENT AND CONSTRAINTS

10.5.1 Wind Turbines Deployed

Wind turbines are typically installed in clusters of three to seven machines. Local and regional planning authorities prefer clusters of wind turbines for spatial planning. Larger wind farms are allowed in some places. Denmark's largest capacity wind farm on land is Rejsby Hede with 42 600-kW machines. The largest offshore wind farm is the Middelgrunden wind farm outside Copenhagen harbor, with 20 2-MW wind turbines, installed in the year 2000 and put in full operation January 2001.

Different groups own wind turbines – private individuals, private co-operations, private industrial enterprises, municipalities, and power utilities.

During the 1980s and early 1990s, most new turbines were installed by co-operations. 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 opened up new possibilities for farmers.

Wind power contribution and total capacity for the 2000 are listed in Table 10.5. (Data for 2001 is not yet available.)

10.5.2. 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, Naturlig Energi.

Technical lifetime or design lifetime for modern Danish machines is typically 20 years. Individual components are to be replaced or renewed in a shorter interval. Consumables, such as oil in gearboxes and braking clutches, are often replaced with intervals of one to three years. Parts of the yaw system might be replaced in 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, which is dealt with as a re-investment.

Operation and maintenance costs include such items as service, consumables, repair, insurance, administration, and lease of site. 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 during 1991, 1994, and 1997. The model includes a large re-investment after the tenth operational year on 20% of the cost of the wind turbine. This re-investment is distributed over the operational years 10 to 20 (see Table 10.6).

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 kW, 150 kW, 225 kW, 300 kW, 500 kW, 600 kW, 660 kW, and 750 kW and is based on empirical data from a major questionnaire inquiry, which has been sent to approxi-

Owner type	Turbines added	MW added	Total number of turbines	MW reached
Private individuals	448	381	2943	1384
Private co-operations	159	139	2428	568
Power utilities	87	82	796	355
Municipalities, industries, others	6	1.7	120	27

Table 10.5 Status for wind turbines in Denmark for 2000.

mately 2,500 wind turbine owners in Denmark. The returned data has been merged with the database mentioned above. The first results on the operational experience are gathered in Table 10.7. The first part of this table shows the costs of reparation and maintenance, and the second part presents the total operation and maintenance costs – including costs from insurance, service, administration, and site rental.

It is normally expected that operation and maintenance costs increase over time. However, the empirical costs on the 55-kW machine are actually decreasing after ten years of operation, as observed in Table 10.7.

10.5.3 Main Constraints on Market Development

Since the mid 1990s, the Danish market has had significant size and remained remarkably constant. The main constraints are spatial planning, legislation in 1999 on electricity reform (which has caused uncertainty on future buy-back rates for private investors), and regulations on offshore wind power.

Up to 1999, permissions have been granted by the government based on existing regulations for the two, small, 5-MW, offshore demonstration wind farms at Vindeby and Tunø built by the utilities. Except for the offshore wind farm at Middelgrunden, installed in 2000 no applications have been granted with the argument that further investigations were needed in connection with large-scale demonstration projects before any other permissions could be granted.

The Danish government has supported several studies investigating the possibilities, and a governmental committee has been appointed to look at the regulatory conditions for offshore wind power installations. This committee has reported twice – in 1987 and 1995. Beyond selecting sites for small demonstration farms and new, large scale farms, all interest in Danish waters have been mapped. Aset of recommendations for future installations has also been given based on input from authorities and different surveys carried out over the past years.

The conditions for future offshore farms have now been laid down in the new electricity bill approved by the parliament in May 1999 as a result of the reformation of the Danish electricity sector. It is now laid down that the right to exploit energy from water and wind within territorial waters and the economical zone (up to 200 nautical miles) around Denmark belongs to the Danish government.

The bill outlines the procedures for approval of electricity production from water and wind and pre-investigation of such within national territorial waters and within the economical zone belonging to Denmark. Permission will be given for a

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 10.6 Annual operation and maintenance costs as percent of the investment in the wind turbine.

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 10.7 O&M cots in DKK/kW after machine size and year.

specific area, and if the constructions are expected to have environmental impact, an environmental assessment must be carried out.

10.6 ECONOMICS

10.6.1 Trends in Investment

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

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

Additional costs depend on local circumstances, such as soil condition, road conditions, and proximity to electrical grid sub-stations. Additional costs on typical sites can be estimated at 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 10.8.

10.6.2 Trends in Cost of Energy and Buy-Back Prices

The production cost for wind-generated electricity per kilowatt-hour has decreased rapidly over the last 18 years, and today the costs are getting close to the cost of electricity production from a new coal-fired power station based on condensation. The estimated cost is shown in Figure 10.3 below.

Average consumer (4,000 kWh per year) electricity price from power distribution utilities varies somewhat from west to east from 0.531 DKK/kWh to 0.535 DKK/kWh. These numbers comprise subscription, grid and PSO tariff, and commercial and prioritized power cost. For private consumers (connected to the 400/230-Volt distribution grid), a number of taxes are added to this price. A 25% Value Added Tax (VAT) is added on top. In 2000, the consumer price for Danish low-voltage customers was 1.44 DKK/kWh.

With new regulation beginning in 2000, the whole payment for wind-generated power will come from electricity consumers. The average selling price of electricity from private wind turbines was approximately 0.6 DKK/kWh in 2000. For 2001, the actual average selling price was between 0.43 DKK/kWh and 0.58 DKK/kWh. The price the distribution companies pay after a transition period will be the actual market price on conventional electricity. On top of that, producers of electricity from wind will receive green certificates that all consumers are obligated to buy. A special market for these certificates will be established, and the turbine owners are guaranteed a price between 0.10 DKK/kWh and 0.27 DKK/kWh.

At the same time, a transition period was introduced for existing turbines erected before the end of 1999 to ensure reasonable depreciation terms for investment already made. A settlement price of 0.33 DKK/kWh is laid down (corresponding to the present 85% rule) until a well-functioning market for renewable energy has been established or for a fixed period of ten years. In addition, wind turbines will continue to get the so-called "CO2 10-øre."

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 10.8 Cost of a 1,000-kW wind turbine project.

Depending on the size and age of the turbines, an additional price subsidy of 0.17 DKK/kWh is paid to wind turbines in the transition period. For turbines with a capacity up to 200 kW, a time period corresponding to 25,000 full-load hours has been given, and for turbines of 600 kW or more, 12,000 full-load hours have been given. Turbines between 200 kW and 600 kW receive 15,000 full-load hours.

Production from turbines owned by utilities and financed by allocations under present rules are not included and will not receive green certificates. New turbines erected before the end of 2002 will receive the settlement price of 0.33 DKK/kWh for a ten-year period, plus the value of certificates. Special rules will be established for owners of small-scale tech-

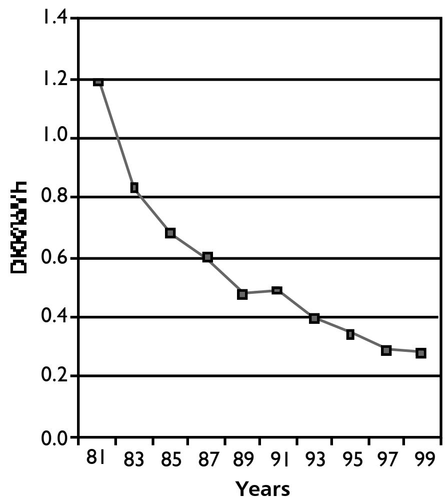

Figure 10.3 Estimated costs of wind generated electricity in Denmark.

nology and for owners of turbines that are decommissioned in favor of new wind turbines.

10.7 INDUSTRY

10.7.1 Manufacturing

Danish-based manufacturers of large, commercial wind turbines in the 150-kW to 2.5-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 biggest part of its manufacturing in Germany and is therefore no longer included in the statistics for sale from Danish manufacturers. In addition, Gaia Wind Energy A/S makes 11-kW machines for electricity to households. Calorius-Westrup A/S makes a 5-kW, heat-producing turbine.

A number of industrial enterprises have developed important businesses as suppliers of major components for wind turbines. LM Glasfiber A/S is a world-leading producer of fibreglass 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, and FAG – have developed businesses in the wind power industry.

10.7.2 Industry Development and Structure

Industrial development in 2001 focussed on refining the megawatt generation of turbines and adapting to the emerging offshore wind farms. This includes, among other things, upgrading the turbines with larger generators and larger rotor diameters. The wind turbine types from Danish manufacturers are shown in Table 10.9. For most types, a number of versions with different tower heights can be supplied.

Sales by Danish wind turbine manufacturers (except for Nordex Borsig) have increased from 1.922 MW in 2000 to between 3 MW and 3.1 MW in 2001, which is a growth of some 60%. This is significantly more than last year's growth of 10% to 15%. The global increase of wind power capacity in 2001 is estimated to be approximately 6,600 MW, which corresponds to a growth of about 47%. The cumulative global wind power capacity by the end of 2001 is in the range of 24,000 MW to 25,000 MW. In total, Danish wind turbine manufacturers have a world market share of approximately 45%, even though the Danish home market has decreased dramatically. It is worth noting that a significant part of Danish wind turbines and components are produced abroad by sub-suppliers and/or subsidiaries.

Service and maintenance of the more than 6,000 wind turbines in Denmark are carried out by the manufacturers' own service departments, but a handful of independent service companies have also been established. These are companies such as DWP Mølleservice A/S and DanService A/S. Some 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; transport of turbines, towers, and blades domestically and for export; and insurance. The major Danish consultancies in wind energy utilization are BTM Consult Aps, E&M Data, Tech-wise A/S, WEA ApS, and Tripod ApS. There is one major, independent developer of wind farms in Denmark, Jysk Vindkraft A/S, which sells turnkey projects to farmers and co-operatives.

10.8 GOVERNMENT-SPONSORED R,D&D

10.8.1 Priorities

The Danish governmental-sponsored programs consist of two programs, the Ministry of Environment and Energy's Energy Research Programme (EFP) and Development, Demonstration, and Information of Renewable Energy Programme (UVE).

The Energy Agency is responsible for the administration of the EFP, which covers both conventional energy and renewable energy. Practically, all projects are initiated through the annual call for proposals issued for each area of energy, where wind energy is an important issue. The deadline for project proposals is normally in the beginning of September. Projects normally run over two or three years, and funding is given by the end of each year. In almost all projects, several partners participate, and industrial participation and co-financing is encouraged. The Danish Energy Agency typically finances 50% to 85% of the total costs. In the 2001 round (processed in 2000), five wind energy projects, with a total budget of 20.78 million DKK, were supported, with a total amount of 11.98 million DKK. In total, 21 projects were proposed, asking for 49.3 million DKK in support of individual projects and a total budget of 79 million DKK. The situation is still not clear for 2002 because a change in government in November 2001 put the process on hold. The total budget for EFP for all programs has also been cut to 40 million DKK – almost one-third of the previous year's budget.

The Energy Agency makes the administration of the UVE program. So far, the program has been renewed every three years. In the present period, projects are initiated through a standing call for proposals. There is no deadline for project proposals, but they are debated at regular meetings of the Technical Advisory Committee. Projects are always shorter than three years. In 2000, wind energy projects were supported by the Danish Energy Agency, with a total of 9.6 million DKK. The figures for 2001 are not available because the process was put on hold in December 2001 due to financial cuts by the new government.

For the program areas of wind energy, biomass, and solar energy, the ministry and the Energy Agency are advised by Technical Advisory Committees. The Technical Advisory Committee on wind power is identical to the Research Committee in the EFP. This ensures a good co-ordination of the activities within the two programs.

As a part of this program, the Danish Energy Agency operates test stations for different renewable energy technologies. One is the Test Station for Wind Turbines at Risø National Laboratory. The activities

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
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	250	52.0	Stall
NEG MICON	NM1000/60	1000	250	60.0	Stall
NEG MICON	NM1500C/64	1500	375	64.0	Stall
NEG MICON	NM2000/72	2000	500	72.0	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
NORDEX	N80/2500	2,500	0	80.0	Stall
NORWIN	N46-ASR	599	125	46.0	Ac stall
NORWIN	N47-ASR	599	125	47.0	Ac stall
NORWIN	N46-ISR	750	180	46.0	Ac stall
VESTAS	V47	660	200	47.0	Stall
VESTAS	V52	850	0	52.0	Stall
VESTAS	V66	1,750	0	66.0	Stall
VESTAS	V80	2,000	0	80.0	Stall
WINCON	W250/29	250	0	29.0	Stall
WINCON	W600/45	600	0	45.0	Ac stall
WINCON	W755/48	755	200	48.0	Ac stall

Table 10.9 Wind turbines (> 100 kW) on the Danish market.

of the Test Station for Wind Turbines are negotiated each year. The budget for the Test Station task at Risø was 5.8 million DKK in 2000 and close to 7 million DKK for 2001.

In addition to 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 wind turbines as well as regulation and forecasting of production, environmental impact, and maintenance. Call for proposals have been issued with 15 September as the deadline, and a number of 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 Agency.

International co-operation on wind energy R&D is emphasized by the Danish Energy Agency. Denmark has participated in the international co-operation in International Energy Agency (IEA) R&D Wind since its establishment. Danish universities, research centers, power utilities, and manufacturing industries participate in the European Union's RTD programs. No quantitative data are available.

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

10.8.2 New R,D&D Developments

In the year 2000, the Danish Energy Agency issued a new strategy and action plan for the energy research and the development program for wind. The new plan is a development of the previous, but places more emphasis on long-term R&D. The key areas for future R&D projects are as follows.

- Wind turbine technology
- Wind resources and climate
- Integration of wind turbines in the electrical power system
- Environmental effects from wind turbines

The overall aims of the energy research program are the following.

- Contribute to realization of the goals of the energy policy through short-term research activities
- Support long-term and strategic research, which can significantly improve the Danish energy situation in a long-term perspective and establish the basis for new political initiatives
- Contribute to achieving other political goals than those affiliated with energy issues, such as the country's economical development, environmental improvements, industrial development, employment, and export
- Contribute to a global, sustainable development through dissemination of Danish-developed technology and knowledge adapted for the conditions in developing counties and countries in East Europe

In recent years, the Danish energy research program has emphasized the uncertainties and challenges associated with offshore wind development. In 1999, new R&D projects included wind resources and forecasting offshore; integration of the large, offshore wind farms in 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 call 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 Agency's web pages located at www.ens.dk.

The overall aims of the renewable energy development program's wind part are as follows.

- Promote the technical possibilities for utilization of wind power in Denmark through research, development, and demonstration of new and better wind power technology
- Support the optimal utilization of available sites
- Participate in removing barriers for sustainable utilization of wind energy
- Strengthen the Danish contribution in international co-operation
- Stimulate Danish industrial development and export

The list of project titles is very long and contains very different projects – such as development projects; demonstration projects of small, household turbines; information activities; economy surveys; and co-financing of some European Union projects.

The Test Station for Wind Turbines activities for 2001 comprised the following.

- 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 break-downs of turbines
- Danish and international standardization
- Development of test methods for wind turbines
- Preparatory tests for a new test station at Høvsøre

For 2002, the entire UVE has been cut out of the financial order by the new government. Hence, financing of the Danish approval scheme for wind turbines and other activities covered by the previous UVE program will have to be covered from other sources and probably structured in another way.

10.8.3 Offshore Wind Energy

In the future, utilization of Danish offshore wind resources will have a high priority in Danish energy research and development programs. Today, two demonstration farms are in operation at Vindeby (4.95 MW) and Tunø Knob (5 MW), and a commercial, 40-MW wind farm exists that is jointly owned by the utility in Copenhagen and a private co-operative at Middelgrunden.

The 40-MW project at Middelgrunden 2 km outside the Copenhagen harbour in shallow water (3 m to 5 m) was put into operation at the beginning of 2001. The farm comprises 20 Bonus wind turbines, each of 2 MW, which are installed in a row with a distance of 2.5 rotor diameters between them. 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 according to owners' reports, the production has been slightly higher than anticipated for 2001. The wind farm and the construction phase are shown in Figures 10.4 and 10.5.

Studies financed by power utilities, the Danish Energy Agency, and EU/JOULE indicate a substantial cost reduction for new, 100-MW to 200-MW, offshore projects – a 56% reduction compared to Vindeby. More accurate assessment of the offshore wind climate and prediction of wind loads are important research issues.

Several investigations of the offshore wind resources have been conducted since 1977, resulting in the finalization of the two demonstration projects. In July 1997, a plan of action for offshore wind farms was submitted to the Minister of Environment and Energy. The plan was drawn up by the two electricity utility associations, Elkraft and Elsam, together with the Danish Energy Agency and the National Forest and Nature Agency. The plan of action 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 could realistically be utilized in four major areas. These areas 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 Østersen, the Baltic Sea). The 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 12 TWh to 14 TWh. For comparison, the total Danish electricity consumption in 2000 was 35 TWh.

The main conclusion of the action plan was that the technology for a commercial offshore development could be expected to be available after the year 2000. Also, the economical prospects looked good in comparison with onshore installations. It was recommended that steps be taken for a first face of development, meaning that a 150-MW demonstration offshore wind farm should be erected in each of the selected areas. After that, approximately 150 MW would have to be built each year over the next 25 years to fulfil the above mentioned offshore action plan.

The Danish Energy Agency has continued the implementation of the first phase of the Plan of Action for Offshore Wind Power in Danish Waters, which started in 1998. According to the agreement, 750 MW in five large, offshore farms will 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 are planned to consist of 80 wind turbines and a capacity of approximately 150 MW. The Horns Rev farm is planned to become operational in 2002. The farm is located 14 km from the coast at Blåvandshuk. The turbines are 2-

Figure 10.4 The Middelgrunden wind farm. ***Photo by Jens H. Larsen and Mads Eskesen. Published with the permission of Københavns Miljø og Energikontor***

Figure 10.5 The Middelgrunden wind farm under construction. Photo by Jens H. Larsen and Mads Eskesen. Published with the permission of Københavns Miljø og Energikontor.

MW Vestas tubines, with a total height of 100 m to 110 m, and the farm will occupy an area of 20 km2. The wind turbines for the farm at Rødsand will be 2-MW Bonus turbines. Rødsand is expected to be taken into operation in 2003.

The other Danish offshore wind farms mentioned above have at present been put on hold by the new government.

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CHAPTER 11

11.1 INTRODUCTION

The first grid-connected wind turbine designed and manufactured in Finland was erected and took operation in 2001. However, as a result of low electricity prices and lower investment subsidies, there were no other new investments. New plans have been initiated, and investments in 2002 are anticipated.

11.2 NATIONAL POLICY

11.2.1 Strategy

The national energy strategy from 1997 mentions renewable energy to have a significant role and wind energy to have a recognized role by 2025. The Action Plan for Renewable Energy Sources elaborated this – while recognizing 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 a targets for renewable energy deployment.

The target is to increase the use of renewable energy sources by at least 50% (3 Mtoe/a) by the year 2010 from the level of the year 1995. Ninety percent of this increase is expected to originate from of 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 TWh (2,010 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 a vision to 2,000 MW in 2025. Thus, wind energy production would reach 5 TWh/a in 2025, which is about 5% of the projected gross power consumption.

11.2.2 Progress Towards National Targets

The Action Plan for Renewable Energy endorsed by the Ministry of Trade and Industry has been adopted by the government as part of the national program to reach the targets of greenhouse gas emission reductions. There are not yet any new instruments in place to promote the investments in renewable energy sources. In the present level of electricity prices, the funds for the main instrument, investment subsidy, will not alone be adequate to reach the goals.

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

11.3 COMMERCIAL IMPLEMENTATION

As already stated, only one new installation was made in the year 2001. The total installed capacity is now 38 MW. The gross wind energy production amounted to 76 GWh. This is slightly less than the production in 2000 and is mainly due to a less windy year. The development in capacity and gross production is presented in Figure 11.1.

There is a drive in Finland toward offshore siting. Some gravel, semi-offshore installations at "artificial" islands in low water are already built. The new projects planned will be located either just on the shore line or on small rock cliffs and islands that are just above sea level. There are no plans for new investments on fjell areas at the moment.

The gross power consumption in 2001 is expected to reach 80 Twh. Wind energy stands for about 0.1% of the national consumption.

11.4 MARKET DEVELOPMENT AND STIMULATION

11.4.1 Support Initiatives and Market Stimulation Incentives

The Action Plan for Renewable Energy Sources states that the investment subsidy will remain the primary support mechanism. For wind energy installation, an investment subsidy of up to 30% can be awarded, depending on the rate of novelty in the project. Due to a budget cut, the projects proposed in 2000 were only given an investment support of 25%, and those projects were not realized. Projects that applied for subsidy in 2001 and are to be realized in 2002 have received an investment subsidy of approximately 30%.

In addition to the investment subsidy, a price premium of 42.00 FIM/MWh (7.00 Euros/MWh) is awarded. This corresponds to the tax on electricity that is paid by household consumers.

The Information Centre for Energy Efficiency (Motiva) is also promoting wind energy by publishing best-practice guides and handbooks. The Finnish Wind Energy Association is also actively promoting wind energy through seminars and political lobbying.

In the CLIMTECH-Programme, financed by the National Technology Agency (TEKES), the possibility of various technologies used in greenhouse gas emission reduction and the possibility of new business opportunities

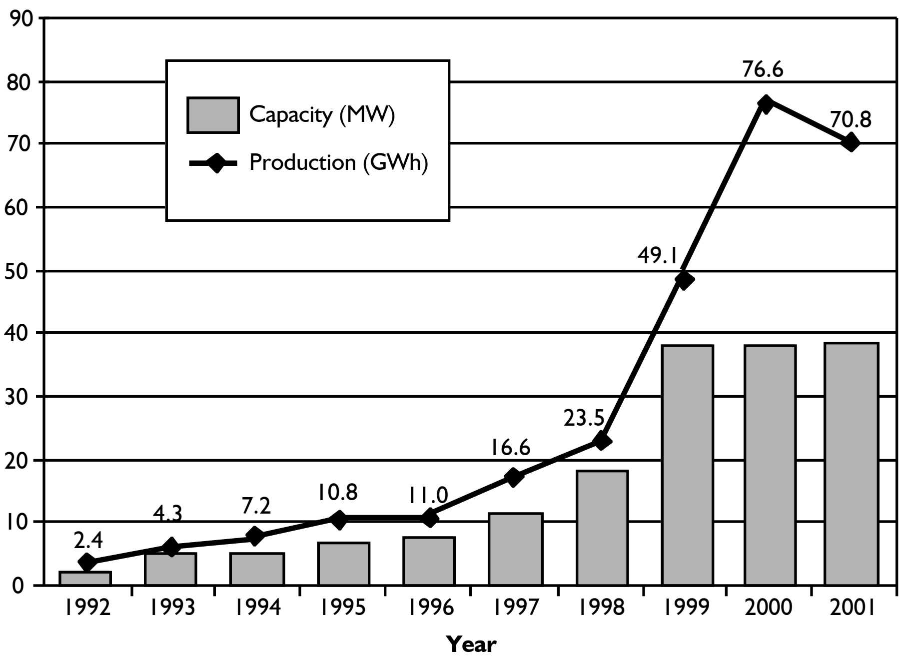

Figure 11.1 Development of wind energy production and installed capacity in Finland from 1992 to 2000

are investigated in order to have guidelines to further support different technologies.

11.4.2 Unit Cost

When introduced in 1991, the investment subsidy covered 40% of the installation costs. During the next ten years, it gradually decreased to today's level of 30%. Two projects were given a 25% subsidy in 2000, but both projects were withdrawn.

The cost trends in wind investments will be analyzed as part of the production and failure statistics in 2002.

11.5 DEPLOYMENT AND CONSTRAINTS

11.5.1 Wind Turbines Deployed

The turbines now in operation in Finland are from Denmark and Germany with and one from Finland. Large wind turbines have for a long time been preferred, mainly due to difficult siting in the complex coastal landscape. The projects planned to be constructed in 2002 and 2003 use turbines with a power rating from 1 MW to 2.5 MW.

The 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, which have a public safety concern due to occasional icing. Experience shows that the higher the tower and the closer to sea the turbines are, the more prone they are to occasional icing.

11.5.2 Operational Experience

In general, there is great satisfaction in turbine operation. There are incidents of breakage in seals and bearings, but overall availability among the reporting turbines is high. However, turbines operating at extreme climates report higher down times.

11.5.3 Main Constraints on Market Development

The electricity market has been fully liberalized, down to 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 quite substantial support, wind 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 across the country and are so high in some areas that they prevent local generation.

Wind energy deployment is slow in Finland, 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.

11.6 ECONOMICS

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

As stated above, all wind energy installation are "merchant" power plants and have to find their customers in a free-power market. In most cases an agreement with a local utility is made, providing 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 current household price. However, the market success for these initiatives has been modest – only a few percent of the household consumers have changed electricity suppliers since the liberalization.

11.7 INDUSTRY

In spring 2001, a new Finnish manufacturer, WinWinD, presented its first prototype, which is now in operation in Oulu. The turbine has a rated power of 1 MW and will operate at variable speeds. 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 expected to be installed in 2002.

For some time, the Finnish industry has been able to produce main components, such as gearboxes and induction generators, as well as materials like steel plates and glass-fiber for the main wind turbine manufacturers. The total turnover of this "sale of components" is estimated to pass one billion FIM in 2001. The industry has been successful in supplying components to medium-sized wind turbines up to 1 MW, and the industry is developing its product range to also fit large-scale turbines. This has required some investments in new production facilities.

Figure 11.2 WinWinD's 1-MW prototype in operation in Oulu

Ablade-heating system for wind turbines operating under icy conditions was released as a commercial product in 1998. It has been developed mainly for the domestic market but also for export, of which the first delivery was made in 1998 to Sweden.

11.8 GOVERNMENT-SPONSORED R,D&D

Since 1999, there has not been a national research program for wind energy. Individual projects can, however, receive funding from TEKES according to the general priorities and requirements for technical R&D. Benefit to the industry and the industry's direct financial contribution to individual research projects are stressed. Priority is given to product development and the introduction of new products.

New development mainly comprises the new domestic turbine mentioned above. The actual performance of 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.

There is a drive toward offshore locations of turbines. Careful design of the support structure is required for the foundation and installation of turbines in icy waters. A project to develop foundation and installation technology suitable for Finnish offshore conditions has bee initiated in a co-operation between research bodies and industry.

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CHAPTER 12

12.1 GOVERNMENT PROGRAMS

12.1.1 Aims and Objectives

The development of wind power (Research and Technology, 250-MW Wind Program) is part of the 4th Program for Energy Research and Technology. This program has been in force since 1996 and is carried out now by the Federal Ministry for Economics and Technology (BMWi). Other technologies and their demonstrations supported by this program are photovoltaics, fuel cells, advanced storage of electric power, and saving of energy in buildings.

In addition, in 2001 the Investment Program for the Future (ZIP) of the government was set in force. Under the responsibility of BWWi, R&D projects of environment-saving energy technologies will be supported for a limited period of three years by annual budgets of 41 million Euros. Part of this new program is a fundamental measuring program for the implementation of offshore wind energy utilization in Germany by measuring platforms. Other program items are fuel cells for block type thermal power stations PTTB and vehicles, special drive technologies like high-power batteries with renewable fuel substances (such as methanol and hydrogen), demonstration projects for electric heat generation from geothermal power plants, and additional model projects for the energy saving renovation of old buildings. Under the responsibility of the Ministry of Environment, Nature Conservation and Reactor Safety (BMU), solar thermal and geothermal R&D projects and ecological accompanying R&D of renewable energies are supported by ZIP with a total budget 30 million Euros in a three-year period.

The programs aim to conserve limited resources, to improve the security of the German energy supply, and to protect the environment and the climate. The two general objectives emphasized in the programs are creation of the necessary prerequisites and contribution to the modernization of the national economy, which includes maintaining the German technology position and improving exports.

Research and technology policy should set boundary conditions that allow the development of a sufficiently broad spectrum of technical options.

12.1.2 Strategy

The strategy of the 4th Program follows three aims and is supported by the ZIP Program. These aims are listed below.

- Improvement of the performance and reliability of existing techniques
- Development and demonstration of technological concepts for the future
- Support of basic research for the above items by financing projects with industry and research

In the short and medium term, the main contribution to decrease energy consumption and to reduce carbon dioxide emission is expected from the improvement of thermal power stations and additional use of rational energy.

In the medium or long term, renewable energies are expected to contribute significantly to the German energy supply and to reduce carbon dioxide emission. The use of heat (solar thermal, heat pumps, and biomass) and electricity (wind power, waste combustion, biomass, and photovoltaic) is technically rather advanced but not in all cases economically competitive. Hydro-power contributes 4.2% to the

German electricity generation, and wind power is expected to reach 4% in the near future.

The full range of strategy measures covers various technologies. For this report, renewable energies (with wind energy as a part) is of special interest.

An important strategy element is continued governmental support since 1973. BMWi's budget for energy research in 2001 was approximately 144 million Euros, including 41 million Euros for the new ZIP Program. Additional support by other ministries and the German federal states should be mentioned. In many cases, R&D is financed jointly by public money and industrial money. From 1998 to 2001, the government spent 489 million Euros for project R&D of renewable energies and rational use of energy; the corresponding budget for institutional R&D was 208 million Euros.

12.1.3 Renewable Energies Act

The Renewable Energies Act, or Erneuerbare Energien Gesetz (EEG), which has been in force since 1 April 2000, supports the development of renewable energies by law. The preamble says that the aim of the act is to enable a sustained development of the energy supply and to increase the contribution of renewable energies to the electricity supply. This is considered to protect the climate and the environment. In accordance with the goals of the European Union (EU) and Germany, the share of the renewable energies of Germany's primary energy consumption should be at least doubled until the year 2010.

In 2001, according to the association of German utilities (VDEW), renewable energies (including large hydro-power) shared 2.2% of the total primary energy consumption and 7.6% of the electricity consumption. (In the year 2000, these percentages were 2.1% and 7.2%, respectively.) Approximately 55% of the renewable electricity was generated by hydro-power, and the share of wind power electricity reached approximately 30%.

12.1.3 Targets

The 4th Program for Energy Research and Energy Technology was related to the political target of the German government to reduce carbon dioxide emission from 1990 levels by 25% by the year 2005. Sustained implementation of the program will contribute to reach this target, together with measures taken in other fields such as traffic. German industry will contribute to the government obligation, as declared on March 1996, by reducing its specific carbon dioxide emission from 1990 levels by 20% by the year 2005.

In the EEG, general targets are fixed but not explicitly worked out. In governmental publications, an annual wind electricity production of up to several percent of total electricity production is considered to be possible.

Two German federal states published specific targets several years ago. Lower Saxony targeted 1,000 MW by the year 2000, and Schleswig-Holstein targeted 1,200 MW by the year 2010. At the end of 2001, Lower Saxony had 2,427 MW and Schleswig-Holstein had 1,555 MW.

12.1.4 New Offshore Wind Energy Targets

The offshore utilization of wind energy was discussed by representatives of German wind energy associations, research institutes, and ministries intensively in 2001. Important limiting factors of offshore utilization include: the special situation of German offshore waters in the North and Baltic Sea, technical and economic reasons, already existing use, nature conservation, and public acceptance. It seemed to be difficult to realize wind power installations less than approximately 30 km from the shore where water depth may reach more than 40 m.

Legally, the favored regions are located outside the German territorial waters with the 12 nautical miles distance seawards from the base lines used to demarcate territorial waters. This is the German exclusive economic zone. In this zone, the Federal Maritime and Hydrographic Agency has to approve an installation proposal. The Renewable Energies Act covers the zone.

Up to 15,000 MW of offshore wind power were considered to be installed without major conflicts with other use. This target would cover approximately 10% of Germany's actual electricity consumption, with a corresponding 50 TWh/a of electricity. One important open issue is that the connection of some dozen terawatts to the existing grid on land near the shore is not possible because current grid capacity is not sufficient. Large offshore installations of the 1,000-MW class should be connected to the 400-kV grid. Grid connections of this kind to the strong grid are possible in Brunsbuettel, Bremerhaven, Wilhelmshaven, and Leer (all four in the North Sea) as well as Greifswald and Rostock (in the Baltic Sea). But the enlargement of the grid on land is considered to be extremely difficult due to legal, planning, and public acceptance reasons.

One result of the discussion is a report by BMU published in June 2001. The report was written by BMU, the Federal Environmental Agency (UBA), and the Federal Office for Nature Conservation. The report recommended a phased construction of offshore wind energy installations as follows.

- Preparatory Phase: 2001 to 2003
- Start-up Phase: 2003 to 2007; 500 MW
- Expansion Phase One: 2007 to 2010; 2,000 MW to 3,000 MW
- Expansion Phase Two: 2010 to 2030; 20,000 MW to 25,000 MW

On 29 January 2002 and 4 February 2002, the target of 25,000 MW wind power offshore by 2030 was again published by BMU as an element to reduce national carbon dioxide emissions in Germany by 10% from 1998 levels. The target stated is to reach a share of renewable electricity production of at least 12.5% of the total electricity production in 2010, especially by wind energy offshore. This would mean that the part of renewable energy of the primary energy should increase to at least 4.2% in 2010.

12.2 COMMERCIAL IMPLANTATION OF WIND POWER

12.2.1 Installed Wind Capacity

By 31 December 2001, the number of installed wind turbines was 11,438, with a total rated power of 8,754 MW. The number of turbines installed in 2001 was 2,079 with a total of 2,659 MW.

The total number of turbines by 31 December 2001 within the 250-MW Wind Program was 1,479 (13% of all systems), corresponding to a total of 366 MW (4.1% of the total rated power). The development of wind power in Germany is shown in Table 12.1. The total rated power of wind turbines by the end of 2001 in the three coastal Federal States Lower Saxony, Schleswig-Holstein and Mecklenburg-Vorpommern was 4,664 MW (53% [last year 56%] of the total installed wind power in Germany) corresponding to 6,271 wind systems (55% of all wind systems in Germany).

12.2.2 Comparison with Conventional Public Electricity Consumption

The total public electricity consumption including grid losses in Germany for 2001 was published by VDEW as 477 TWh (474

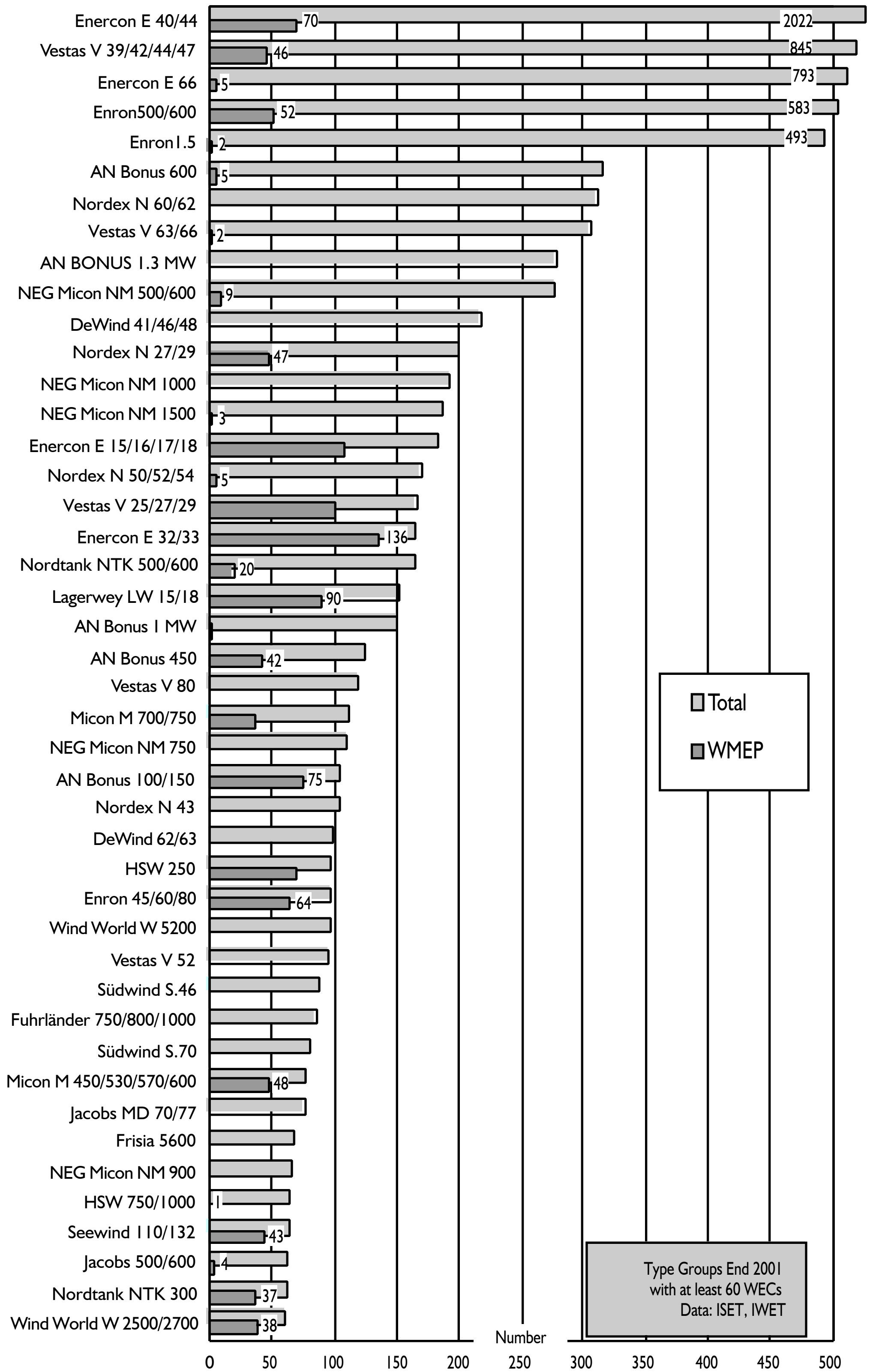
DATE	NUMBER OF WECs		RATED POWER [MW]		WIND ELECTRICITY PRODUCTION [10^9kWh]	
	250 MW WIND	TOTAL	250 MW WIND	TOTAL	250 MW WIND	TOTAL
31.12.1989	15	256	1.4	20	0.0003	------
31.12.1990	187	506	30.8	60	0.016	0.043
31.12.1991	439	806	72.2	111	0.089	0.13
31.12.1992	738	1211	121.3	183	0.201	0.28
31.12.1993	1058	1797	183.9	334	0.302	0.5
31.12.1994	1317	2617	225.5	643	0.462	0.9
31.12.1995	1466	3528	311	1120	0.543	1.5
31.12.1996	1521	4326	335	1546	0.523	2.0
31.12.1997	1511	5102	343.8	2033	0.580	3.0
31.12.1998	1510	6205	345	2874	0.70	4.5
31.12.1999	1493	7874	347	4430	0.6	6.1
31.12.2000	1484	9369	348	6095	0.6	8.6
31.12 2001	1479	11438	356	8754	0.6	10.7

Table 12.1 Development of wind power in Germany at the end of 2001

TWh in 2000). Wind power electricity production is given in Table 12.1. In 2001, wind power contributed about 2.2% to the German public electricity consumption (1.8% in 2000). The reasons for the relatively low increase of the share were low wind speed, especially in coastal regions, at the beginning of 2001 and that almost half of the new capacity went into operation the last quarter of the year.

Regionally, the wind power contribution to the electricity consumption shows considerable deviations from the mean values in Germany. Wind power electricity shares for 2001were 20% for Schleswig-Holstein, 13% for Mecklenburg-Vorpommern, and 7% for Lower-Saxony (values for 2000 were 17%, 11%, and 6% for these regions, respecitvely). These are the three German coastal states that are not densely populated. However, in North Rhine-Westphalia, with almost a third of Germany's electricity consumption, the wind power electricity share in 2001 was 0.7% (0.5% in 2000).

Figure 12.1 Wind energy system types currently installed in Germany


Enercon E 40/44
70
2022
Vestas V 39/42/44/47
46
845
Enercon E 66
5
793
Enron500/600
52
583
Enron1.5
2
493
AN Bonus 600
5
Nordex N 60/62
Vestas V 63/66
2
AN BONUS 1.3 MW
NEG Micon NM 500/600
9
DeWind 41/46/48
Nordex N 27/29
47
NEG Micon NM 1000
NEG Micon NM 1500
3
Enercon E 15/16/17/18
Nordex N 50/52/54
5
Vestas V 25/27/29
Enercon E 32/33
136
Nordtank NTK 500/600
20
Lagerwey LW 15/18
90
AN Bonus 1 MW
AN Bonus 450
42
Vestas V 80
Micon M 700/750
NEG Micon NM 750
AN Bonus 100/150
75
Nordex N 43
DeWind 62/63
HSW 250
Enron 45/60/80
64
Wind World W 5200
Vestas V 52
Südwind S.46
Fuhrländer 750/800/1000
Südwind S.70
Micon M 450/530/570/600
48
Jacobs MD 70/77
Frisia 5600
NEG Micon NM 900
HSW 750/1000
1
Seewind 110/132
43
Jacobs 500/600
4
Nordtank NTK 300
37
Wind World W 2500/2700
38
Total
WMEP
Type Groups End 2001
with at least 60 WECs
Data: ISET, IWET
Number
0
50
100
150
200
250
300
350
400
450
500

12.2.3 Wind Turbines Deployed

The statistics for different wind system types built in Germany are shown in Figure 12.1, which includes wind systems of the 250-MW Wind Program from the beginning of the program in 1990 through 2001. In 1990, many smaller turbines came into operation that are no longer on the market. Due to the 250-MW Wind Program, the statistics of ownership of these nearly 1,500 systems is known. If private individuals, commercial operators, and operator groups are considered to be private operators, then 83% of all wind systems (80% of the rated power) are financed with private capital.

As of November 2001, actual development consists of 336 turbines corresponding to a total of 450 MW of rated power erected as single units, farms, or phases in farms under construction. Note that the 450 MW corresponds to the total power reached during 1994 in Germany (see Table 12.1). From these, 336 turbines (56%) had a rated power from 1 MW to 1.5 MW, 22% had a rated power below 1 MW (but greater than 599 kW), and 22% exceeded 1.5 MW. Types of wind energy systems with more than 1.5 MW were AN-Bonus 2MW/76, Enercon E66, Nordex N80/2500 (one unit in Neubukow, Mecklenburg-Vorpommern), Vestas V66/1.65, and Vestas V80/2.0. Six Nordex N80/2500 were installed in September 2001 at an inland site near Bitburg with an estimated production of 4.2 million kWh per year and unit.

12.2.4 Performance and Operational Experience

Performance and operational experience for the turbines in the 250-MW Wind Program have been under investigation in the Scientific Measurement and Evaluation Program (WMEP) with the contractor ISET for more than ten years (see Section 12.6.3). The average technical availability for 2001 was approximately 98.3% with an average stand-still time of approximately 144 hours or six days per unit. The average time of operation of the wind systems in the program is at present approximately eight years. So far, no considerable increase of failures with the total operation time of the systems has been found. The failure rate in the first operational years had decreased continuously.

Failure statistics and statistics of repaired and exchanged parts are documented in the WMEP. More than 50% of the causes of failure are identified with component failure and control system of the systems; about a quarter of the causes are identified with external influences (high wind, grid failure, lightning, and icing).

The contract of the running Phase IV of the WMEP is extended to investigate the operation of modern turbines that do not participate in the 250-MW Wind Program. Various results are published in WMEP's 2001 annual report.

12.2.5 First Offshore Wind Energy Plant

Halfway through 2001, 17 proposals for commercial offshore wind energy farms were introduced – corresponding to a total of 8,249 MW. The total investment is estimated to be 12 to 14 billion Euros. By November 2001, the Federal Maritime and Hydrographic Agency approved the pilot phase of the offshore wind farm, Borkum West of Prokon-Nord. About 60 MW – with an annual wind electricity production of 200 GWh – will be installed 45 km north of the island Borkum in the North Sea. Wind energy systems of 3.5 MW to 5 MW of rated power will be erected on 800 tons of three-legged steel foundations in water 30 m deep. By the end of 2003, the farm will be connected via a high voltage sea cable at the transformer station, Emden/Borssum, to the existing grid. The total investment of the pilot phase is calculated as 128 million Euros. The final installation is planned to be installed with 1,000 MW and 3,500 GWh/a by 2010, with an estimated investment of 1.5 billion Euros. These 1,000 MW are not included in the previously mentioned 8,249 MW – nor are another company's planned 1,800 MW.

12.3 MANUFACTURING INDUSTRY

12.3.1 Market Shares

The five manufactures on the German market in 2001 with more than a 10% share of the total rated power are Enercon with 28.5%, Vestas with 19.5%, NEG Micon with 11.4%, Enron Wind with 10.9%, and Nordex with 10.4%. The others shares are covered by German companies.

12.3.2 New Products and Technical Developments

There are a large number of wind energy system installations in Germany with a technical availability of at least 98%. The average size of yearly erected turbines increased from 1.1 MW in 2000 to 1.3 MW in 2001. This indicates a rapid technical development of wind power that is not limited to German manufactures. The Nordex N80/2500 is equipped with a doubly-fed asynchronous generator. This type of generator was first tested successfully with the 3-MW GROWIAN about 20 years ago. The Enron 1.5 uses this type of generator as well. The concept of the large Enercon wind systems is based on a multipole ring generator without a gear box.

12.3.3 Business Developments

The number of direct and indirect employees in the German wind power industry was 35,000 at the end of 2001. The total commerce connected with wind energy systems in Germany in 2001 amounted to 3.5 billion Euros.

12.4 MARKET DEVELOPMENT AND CONSTRAINTS

12.4.1 Market Development

The rated power of the installed turbines has increased significantly over the years. In 1989 and 1990, the market offered wind energy systems with a maximum power of 250 kW. Nevertheless, the majority of plants still had a rated nominal power of 100 kW or less at that time. The typical operator was assumed to be a farmer who produced electricity for farm needs and fed the surplus electricity into the grid. This situation has rapidly changed due to the technical and price development of wind systems. In addition, the boundary conditions to finance wind power projects were improved drastically by different measures (see Section 12.5). This created confidence for investors in wind power technology and opened a rapidly growing market for European wind turbine manufactures in Germany.

Most of the wind systems erected in 1998 and 1999 had a rated power of 500 kW or more. In 1997, the introduction of the 1,500-kW class started very successfully. By the end of 1999, the first commercial, 2-MW system Type N80 by Borsig Energy GmbH with a rotor diameter of 80 m was erected, followed soon by commercial units of this type. In 2001, the commercial Nordex N80/2500 with 2,500 kW was the leader of rated power. Research and development for a 3-MW to 4-MW turbine is on the way (see Section 12.6.2). The realization of wind power offshore projects was again discussed during 2001 and was considered as the wind power market in the near future. Offshore governmental targets were set and the first offshore installation was approved (see Section 12.2.5). Most German company production is still sold inland, but export is considered as a further option.

12.4.2 Main Constraints on Market Development

Constraints on market development, starting in the German coastal areas, include complaints that wind turbine installations are destroying the landscape and disturbing wildlife and birds. Neighbors of wind systems complain of noise and shadow effects. Germany has a high population density and is short of good wind sites compared with international criteria. At the good sites, different users are often competing. Due to the necessity of noise-emission reduction, a distance of at least 500 m to the next resident is recommended for large-scale systems. Although the corresponding land around a wind system can still be used as farmland, there are a lot of complaints. Over the past few years, it has become more and more difficult to get a construction permit for wind energy systems.

12.5 ECONOMICS

12.5.1 Trends in Investment

The rapid market development in the late 1980s and 1990s was driven by the favorable financing conditions during that period. BMWi's 250-MW Wind Program, at that time the 100-MW Wind Program, led the way.

The Electricity Feed Law (EFL) became effective 1 January 1991. Since then, utilities have been obliged to pay the same 90% of the average tariffs per kilowatt-hour that private consumers had to pay with taxes of 15% excluded. In 1998 and 1999, this amounted to 0.1679 DEM/kWh (0.0858 Euros/kWh) and 0.1652 DEM/kWh (0.0845 Euros/kWh), respectively. The EFLand the 250-MW Wind Program were cumulative.

In April 1998, a modification of the EFL came into force. The changes in the EFL do not affect refunding but specify the financial charges of the different utilities of the German grid and set a date for reconsideration. But in 1999, a completely new renewable energy law was prepared by the German government. The law, called Erneuerbare-Energien-Gesetz (EEG), came into force on 1 April 2000. The general contents of this law are as follows.

- An obligation on electricity grid operators to give priority access to all renewable electricity
- Afixed tariff for each renewable
- Rules on grid connection and grid reinforcement
- Amechanism to spread the tariff costs equally across all grid operators (renewable quota arrangement).

Operators of wind turbines should receive at least 0.178 DEM/kWh (0.0910 Euros/kWh) for the first five years of operation. From the sixth year, the tariff for turbines that have generated 150% more power than a defined standard reference turbine will drop to at least 0.121 DEM/kWh (0.0612 Euros/kWh). For wind turbines that produce less than the theoretical 150% reference-turbine limit, the period of maximum payment is extended by two months for every 0.75 percentage point by which production fails to reach 150% of the standard turbine's output. An annual decrease in the two tariff rates of 1.5% per year starting from 1 January 2002 is foreseen for wind systems taken into operation from this date. The rates for 2002 are 0.175 DEM/kWh (0.0895 Euros/kWh) and 0.119 DEM/kWh (0.0608 Euros/kWh).

Offshore wind power is covered by the act in German territorial waters and the German zone outside of the 12 nautical miles zone, or the German exclusive economic zone. A premium support for first installations sited in water more than three nautical miles from a baseline near the coast is given if the systems are installed before the end of 2006. In this case, the tariff of at least 0.178 DEM/kWh (0.0910 Euros/kWh) must be paid for nine years.

For wind turbines online before 1 April 2000, the maximum payment period is calculated as five years minus half the number of years the turbine has been in operation. Turbines that no longer qualify – due to their age – for the higher rate of 0.178 DEM/kWh (0.0910 Euros/kWh) are guaranteed for at least four years.

The defined standard turbine or reference turbine is, in practice, a series of turbine types operating at an average wind speed of 5.5 m/s at a height of 30 m with a logarithmic height profile and a roughness length of 0.1 m in specific conditions, averaged over a period of five years using an internationally recognized and EU-approved power curve model. The output of the actual turbines will be compared with the equivalent reference model.

In addition to the reimbursement according to the EFL, a wind turbine operator might get soft loans. The Deutsche Ausgleichsbank offers soft loans for wind systems, while some other states, especially in the German inland, still conduct programs with direct funding (e.g., Nordrhein-Westfalia).

12.5.2 Influence of Parameters

Over the last ten years, a market for wind turbines has been established in Germany that does not depend on direct funding. This market instead depends on the conditions for reimbursement regulated today by the EEG, the development of key-turn prices of wind systems, and the interest rate for loans and mortgages with a pay-back time of ten years. The interest rate was approximately 10% in April 1991 and was followed by a fluctuating decrease to about 5% to 6%.

The economics of wind systems is determined by electricity production, which can be expressed by hours of operation per year at rated power, and the special investment model using the advantage of the EEG with guaranteed high tariffs and long-term security about the tariffs for wind power electricity fed into the grid. Under German meteorological and financial conditions, it is generally accepted that wind energy systems erected in 2000 or later provide an option for investors to receive a positive balance in the near future. Of course, details depend on the special project. An additional, simple economic estimate is to forecast the balance of yearly income and expenditure.

At good sites, close to the German or the Baltic Sea – where the mean wind velocity at a height of 10 m high is between 5.5 m/s and 6 m/s – the majority of wind systems already have lower financing costs than the compensation provided by the EEG.

At inland sites, it takes longer to reach a positive balance. The actual megawatt-sized turbines with 80-m towers, or higher, use the higher wind speeds at the nacelle-level compared to surface wind. Already in the early 1990s, governmental support of investment within the 250-MW Program as an option for special owner groups depended on tower height. This stimulated techniques relatively early, especially for inland sites. In addition to high towers (additional costs are tolerable) for inland wind systems, the meteorological site analysis made considerable progress. Financing of systems is often managed with low equity. Even on inland sites, the projects are sometimes financed completely by loans. Nevertheless, the inland situation in Germany, where typical wind velocities of 4 m/s at 10-m heights dominate, is significantly different from coastal sites. Investors take a longer period of time into account before a positive balance is reached, which builds up a considerable share of Germany's wind power in inland states. It is obvious that the break-even point could exceed ten years. Nevertheless, Germany's inland wind power is expanding considerably (see Section 12.2.1).

Reducing the taxable income of certain investors is an additional driving force for the German wind power market. A depreciation time for wind systems of ten years was not possible until mid-1997. Since 1 July 1997, the depreciation time has been 12 years. Since 1 January 2000, the depreciation time 16 years.

12.5.3 Results of the WMEP

From various measurements and operational reports, a generalized diagram reflecting the distribution of electricity production for nearly 1,500 turbines installed in the 1990s in Germany was elaborated. Figure 12.2 shows the distribution of full load hours for the coast, the northern German lowlands, and the low mountains by 31 December 2001. The broad curves again support the necessity for an investor to plan a project carefully.

12.5.4 Offshore Installations

The costs of future German offshore wind farms obviously depend on the special site conditions, with water depths of more than 20 m and distances from the coast of more than 30 km. A simplified model calculation demonstrates influences of important economic parameters.

Typical investment costs of an offshore project are set at 1,800.00 Euros/kW (wind systsms price without the value added tax of 900.00 Euros/kW plus 100% additional costs for extras such as foundations, grid connection, and sea transport). Operation and maintenance costs over an operation period of 20 years are set to 6% of system costs, or 54.00 Euros/kW. Major repairs are not considered. A medium interest rate of 7.6%, or an annual financing cost of 263.00 Euros/kW, is obtained by financing total investment costs with 70% loans (and an interest rate of 5.5%) and with 30% equity capital (risk capital with 12.5% interest) for a pay-back time

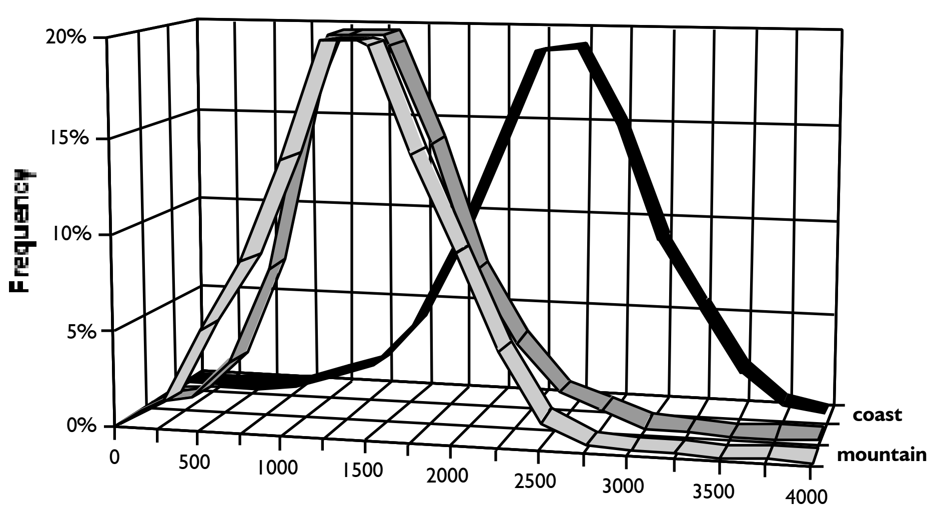


Figure 12.2 Full load hours of the 250-MW Wind Program for 2001

of ten years. In this case, the total annual expenditure is 317.00 Euros/kW during the pay-back time and 54.00 Euros/kW the last ten years of operation. With a typical 3,500 kWh/kW per year (with 8.8 m/s to 9 m/s annual mean wind speed at hub height), the compensation to be paid by the EEG (using 1.8-MW Enercon as the reference system) is 308.00 Euros/kW for years one through nine and 206.00 Euros/kW for years ten through 20.

Despite excellent wind conditions and EEG compensation, the economics of German offshore wind farms is determined by the burden of the high investment. For wind turbines installed in 2001 at good land-based sites near the North Sea coast, the accumulated balance of expenditure minus revenues reach the 100% mark after 16.5 years. For offshore wind turbines accumulated expenditures minus revenues reach 100% only after 24 years. This development of economics of offshore systems over the time scale is similar for a German inland site with 2,000 full load hours/a but with losses the first 11 years. In the considered case, the corresponding offshore electricity production costs for the 20-year period are 0.053 Euros/kWh. Compared to other published calculations, which take into account more risks, this is a relatively low value. At a coastal land site with 3,000 full load hours, typical production costs are significantly lower, at 0.041 Euros/kWh.

A sensitivity analysis shows that a 10% decrease of investment costs yields a 10% decrease in production costs (0.048 Euros/kWh). To reach the mentioned 0.0417 Euros/kWh for a good German coastal site on land, an investment decrease of 23% is necessary. An increase raises production costs by 3% if the medium interest rate is 1%. An operation and maintenance cost increase of 1% yields an increase of 5% of the production costs.

The technical challenge hidden in these numbers is obvious.

The electricity production costs of the first approved offshore wind power farm in its pilot phase (see Section 12.2.5), were not published and are estimated by the model calculation as 0.055 Euros/kWh for a period of 20 years (and 0.039 Euros/kWh for the final 1,000-MW installation in 2010 without inflation).

12.6 GOVERNMENT-SPONSORED PROGRAMS

12.6.1 Funding

BMWi 2001 funding levels of wind power are shown below.

R +D:	Euro	4.8 (3.1, 2.2) million
"250 MW Wind":	Euro	7.6 (11.9, 16.4) million
ZIP:	Euro	0.68 (- , -) million
Total:	Euro	13.08 (15.0, 18.6) million

The decrease of funding for the 250-MW Wind Program results from the fact that more and more projects are reaching the upper funding level. The BMU part of the ZIP program is not included. By 20 February 2002, approximately 50 proposals were considered to be supported and some of these where already approved. They include wind energy ecological accompanying R&D.

12.6.2 R&D

Recent R&D projects by BMWi are shown in Table 12.2. The projects include the engineering of a 3-MW to 4-MW, 110-m turbine to be erected near Magdeburg in spring 2002. The WMEP, Phase IV involves a 5.85 million Euros contract for the period of July 2000 to June 2004.

In autumn 1998, experts reviewed the future of R&D for the wind energy technology on behalf of the company, BMBF. These experts found that despite the facts that this technology has made a rapid technical development in the last ten years and that a market for wind power has opened world wide, there is still much work left to be done to fulfil the potential of wind power as a key renewables contributor to the world wide energy supply. The conclusions are consistent with a recent strategy document of the International Energy Agency (IEA) Wind Energy Agreement. Some recommendations are being realised by R&D projects, including now sustainable offshore research.

12.6.3 The250-MW Wind Program

The current subsidy for operators in the 250-MW Wind Program is either 0.06 DEM/kWh (0.0307 Euros/kWh) or 0.08 DEM/kWh (0.0409 Euros/kWh), depending on whether the energy is fed into the grid or is being used by the wind system owner. The latter can apply to a farm, a factory, a private household, or a utility as a system owner. The grants are now limited to a maximum of 25% of total investment costs. In certain cases (private individuals and farmers), a subsidy of the investment, limited to 90,000.00 DEM, was possible. It is expected that total support will reach 160 million Euros. The costs of the measuring program phases are not included in this sum and could reach an additional 30 to 36 million Euros for the period of 1990 to approximately 2007.

12.6.4 Offshore Measuring Platforms

The aim of the project, 3-4 Platforms in the North and Baltic Sea, is to collect offshore data for the certification of offshore wind systems and operators. These are the necessary data for the technical and environmental assessment of the offshore wind energy utilization. Part Aof the project covers the technical and meteorological measurements (i.e., wind direction and velocity, wind SODAR 20 m mast, option 80 m to 100 m mast, tide and sea currents, waves water temperature, ice, ship movements, and sound as background and as propagating in water and ground). Part B of the project covers biological investigations (i.e., sensors to receive signals of the common porpoise, phoecoena phoecoena; soil investigations during construction of platforms; bird migration investments; detection of bats; vegetation settling on foundation, benthos, and fish; and water extinction). The fist platform will be built near Borkum West offshore wind farm (see Section 12.2.5), in the North Sea in spring 2002. The two other platforms are planned 70 km west of the island of Sylt (in the North Sea) and 40 km north of the island of Ruegen (in the Baltic Sea).

References:

[1] BMWi 2001 Annual Report Energieforschung und Energietechnologien, available by Fachinformationszentrum Karlsruhe, D76344 Eggenstein-Leopoldshafen, telefax: 49/07247/808-135, e-mail: library@fiz-karlsruhe.de.

[2] ISET Annual Report 2001 and other publications; Koenigstor 59, D34119 Kassel, telefax: 49/561/7294/100 (see also: www.iset.uni-kassel.de/reisi).

[3] DEWI-Magazin, February 2002, Deutsches Windenergie-Institut GmbH, Ebertstraße 96, D26382 Wilhelmshaven, telefax: 49/4421/48084, Internet: www.dewi.de.

[4] Further information and links by the home page of Projektraeger Juelich (PTJ) of BMBF and BMWi, Forschungszentrum Juelich GmbH, Internet: www.fz-juelich.de/beo/beo.htm, e-mail: beo41.beo@fz-juelich.de.

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SUBJECT	PERIOD	COSTS (Euro million)	BMWi (%)
Special wind data and programs for complex terrain (German Weather Service)	07.93-06.97	0.840	100.0
Early recognition of turbine failure (ISET/Industry)	01.94-12.97	0.732	50.0
Fatigue Loads WECS (VDMA/DEWI)	07.95-06.97	0.227	50.0
MW WECS inland (RWE Energie)	06.95-09.99	2.502	20.43
Control LS WECS (ISET/Industry)	07.95-06.99	0.610	40
Active stall rotor blade (A&R Rotec)	08.96-07.98	1.281	50
Lightning protection WECS (Fördergesellschaft Windenergie)	10.96-09.99	0.307	50
Development of a 3-4 MW WECS (Enercon)	08.98-06.02	5.113	35
Decentralized electrical power plants for grids : voltage fluctuations (Windtest K-W.Koog)	08.99-01.02	0.416	50
Integration of decentralized electrical power plants for grids (Engineering high school Wilhelmshaven)	08.99-01.02	0.445	100
Phase IV , WMEP (ISET)	07.00-06.04	5.85	100.0
Forecast wind electricity for medium and large utility regions (Fördergesellschaft Windenergie)	05.00-10.01	0.332	94.31
Aspects of construction and environment of offshore-WECS (University Hannover)	10.00-09.03	0.854	100
Advanced drive train for LS-WECs (Fr. Flender AG)	01.01-12.03	0.941	40
Advanced life time analysis of WECs (Germanischer Lloyd Windenergie)	12.99-11.02	0.481	50
Advanced small WEC 1: System technology (SMA-Regelsysteme)	10.01-03.04	0.84	50
Advanced small WEC 2: Mechanics and hardware (Aerodyn)	10.01-03.04	0.41	50
Drive train for offshore WECs (MULTIBRID entwicklungsgesellschaft mbh)	05.01-04.05	16.617	25
3-4 offshore wind power measurement platforms (Germanischer Lloyd Windenergie)	04.01-09.03	15.33	100

Table 12.2 Selected wind power R&D projects

CHAPTER 13

13.1 NATIONAL POLICY

13.1.1 Strategy

The Greek electricity market is currently under deregulation processes. Law 2773/99, Liberalization of the Electricity Market – Regulation of Energy Policy Issues and Other Provisions, was issued in 1999, and liberalization of the electricity market came into force on 19 February 2001.

According to the above Law, two bodies were established, the Regulatory Authority for Energy (RAE) and the Hellenic Transmission System Operator (HTSO). The main tasks of the RAE are to ensure the operation of the liberalized electricity market, according to certain rules, and to make recommendations to the Ministry of Development for the issue of Authorization for Generation and Supply. HTSO operates, utilizes, and plans the development of the system in order to ensure reliable and efficient operation.

During 2001, the RAE approved an important number of applications for power production from wind energy, totaling 1,111 MW of total installed capacity. More specifically, 748 MW have been approved for the interconnecting system on the mainland, and 146 MW have been approved for autonomous power plants on the islands

In addition, RAE provided permission for the installation of 217 MW for the area of Thraki, in North Greece, which is characterized by high-wind potential. The installation of the 217-MW wind parks will be combined with the construction of a new, high-voltage grid.

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

Greece is one of the European countries possessing high wind-energy potential. 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.

13.1.2 Progress Towards National Targets

In 1995, the Ministry for Development set a target of 350 MW of installed wind energy capacity by the year 2005. As soon as Law 2244/94 was issued in early 1995, a great interest was shown by the private sector in developing wind-power projects, bringing installations up to 298 MW at the end of 2001 from 29 MW installed in 1995.

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

13.2 COMMERCIAL IMPLEMENTATION

13.2.1 Installed Capacity

In total, 134 wind systems – having an installed capacity of approximately 84

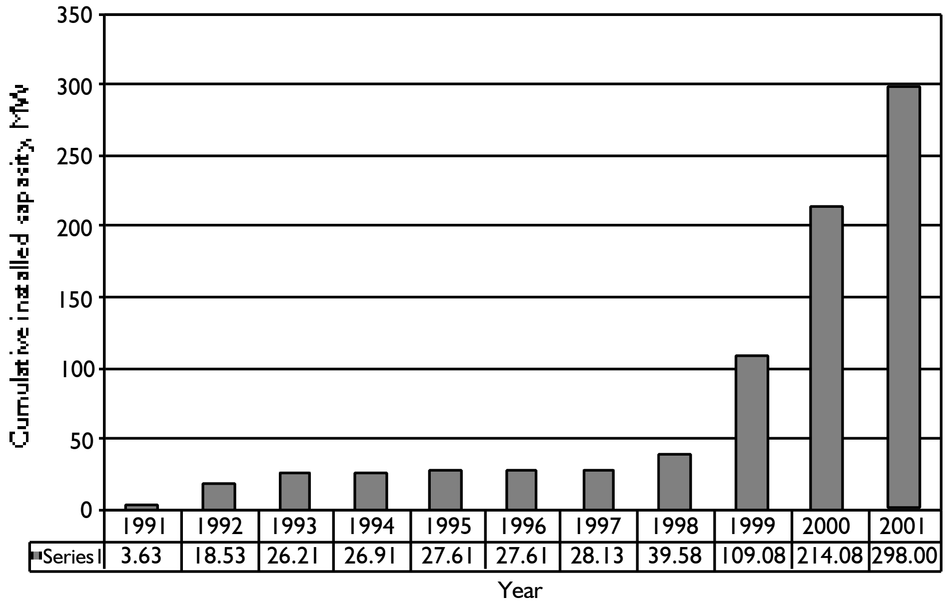


Figure 13.1 Cumulative installed wind capacity in Greece

MW, concerning 13 separate projects – have been connected to the electricity supply network during 2001, bringing up the total installed wind energy capacity to 298 MW (615 machines). In addition, 43 wind systems of 29 MW are under the connection procedure.

13.2.2 Rates and Trends in Deployment

The development of wind energy within the last ten years is shown in Figure 13.1, where the total installed capacity per year is depicted.

13.2.3 Contribution to National Energy Demand

The energy produced from wind turbines during 2001 was approximately 756 GWh, while the energy production from the years from 1997 to 2000 was 38 GWh, 71 GWh, 160 GWh, 460 GWh, for each year respectively. The total energy consumption in the country is on the order of 50,000 GWh, so the energy produced from wind turbines accounts for about 1.5% of the total energy demand. Figure 13.2 shows the electricity produced from wind turbines for the last ten years and the corresponding capacity factors.

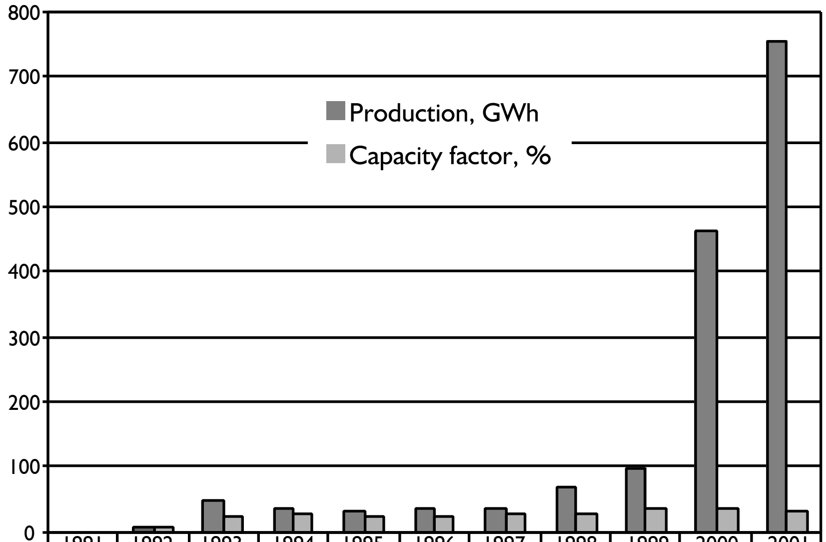
13.3 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

13.3.1 Main Support Initiatives and Market Stimulation Incentives

Support for the development of wind energy projects was provided under Law 2601/98, Law for the Economical Development, of the Ministry for National Economy. This law has been implemented within a continuous program according to which wind projects may be subsidized by 40% of the cost and receive up to a 40% reduced soft loan.

13.3.2 Unit Cost

No data is available.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Production	1.00	8.00	46.00	37.00	33.40	37.20	38.10	71.00	98.00	460.00	756.00
Capacity factor	0	7	21.4	24.8	21.8	24.3	25.6	26.8	34.9	37.1	33.5

Year

Figure 13.2 Electricity produced and capacity factor for wind turbines in Greece

13.4 DEPLOYMENT AND CONSTRAINTS

13.4.1 Wind Turbines Deployed

The average capacity of the wind turbines installed in 2001 was 595 kW, while the average capacity of all the wind turbines operating in the country was 485 kW. The market share per manufacturer is depicted in Figures 13.3 and 13.4.

13.4.2 Operational Experience

No serious malfunctions have been reported since the commissioning of Greece's wind energy projects, due to the relatively short period of operation of most projects. Due to the rapid increase of

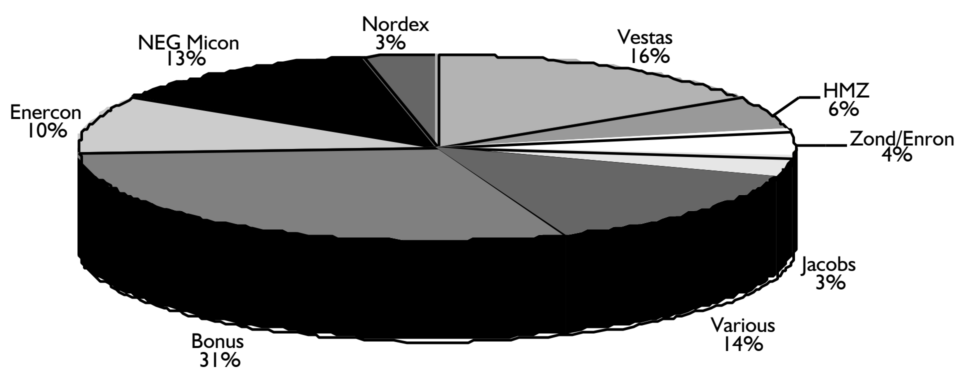


Figure 13.3 Market share of wind turbine manufacturers (as a percentage of the total installed wind turbines)

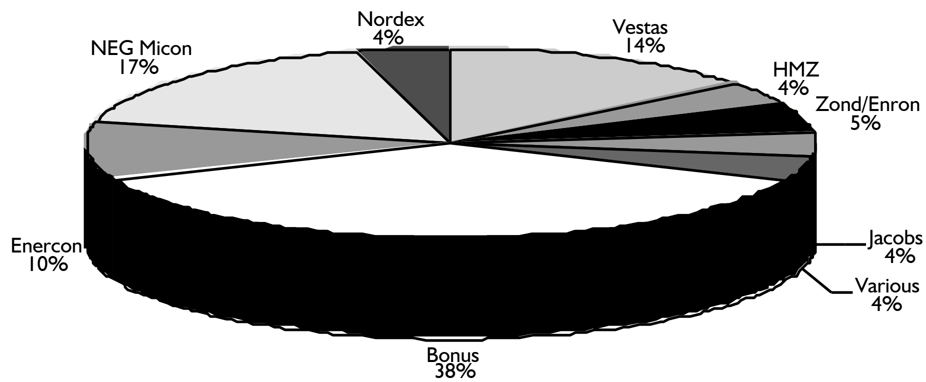


Figure 13.4 Market share of wind turbine manufacturers (as a percentage of the total installed capacity of wind turbines

installations and the need for better knowledge on the operation and performance of each wind park, the Center for Renewable Energy Sources (CRES) is preparing a database with related information for all of the wind parks around Greece.

13.4.3 Main Constraints on Market Development

There are two main constraints for the optimal exploitation of the high-wind energy regime and the great interest of private investors to built wind farms. One constraint is the existence of complicated procedures for the acquisition of generation authorization. The second constraint is the inability of the electrical network infrastructure to absorb the energy produced, given that the sites with high-wind potential are in remote areas, at the end of transmission lines.

13.4.4 Trends in Investment

The total cost of wind power projects ranges from 970.00 Euro/kW to 1,170.00 Euro/kW and depends on the type, size, and accessibility of the wind turbine used. The generated wind power cost can be assumed to be between 0.026 Euro/kWh and 0.047 Euro/kWh, depending on the site and project cost. The typical interest rate for financing any project without subsidies is on the order of 8%. However, many investments – including wind projects – may profit from a reduced soft loan according to Law 2601/98.

13.4.5 Trends in Unit Costs of Generation

The system of power generation in Greece is divided into two categories: the interconnected system of the mainland and the autonomous power plants of the islands. In the liberalized electricity market (as well as before its existence), a single charging price is used in both systems, depending on the identity of the consumer and the voltage class. As of July 2001, low-voltage systems have had a selling tarriff of 0.08322 Euro/kWh, and medium-voltage systems have had a selling tarriff of 0.06733 Euro/kWh and 3.1107 Euro/kW (peak power value).

The purchase prices defined by HTSO for renewable energies are based on the actual selling price. For an 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., 0.06059 Euro/kWh), and the power component is set at 50% of the respective power production company's power charge (i.e., 1.5554 Euro/kW times 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., 0.07489 Euro/kWh). The Ministry of Development has the right to ask the producers for discounts on these prices.

13.5 INDUSTRY

13.5.1 Manufacturing

Except for a couple of small wind turbine manufacturers (manufacturing wind turbines ranging from 1 kW to 5 kW), there is no wind turbine manufacturing industry in Greece in a classic manner. However, the steel industry is quite developed in the country and is able to support wind turbine manufacturing. As a result, most tubular towers of the installed wind turbines have been constructed in Greece. Furthermore, a Greek company has been successfully involved in blade manufacturing and has produced blades up to 19 m.

13.5.2 Certification

A certificate is required in order to operate a wind turbine in Greece with a rating more than 20 kW. CRES is, by law, the certifying authority for wind turbines in Greece. CRES currently accepts approval certificates issued by authorized institutions, but it is working on certification procedures and standards to be followed nationwide, taking into account the individual climate characteristics of Greece.

13.6 GOVERNMENT-SPONSORED R,D&D

13.6.1 Priorities

The Ministry for Development promotes all R,D&D activities in the country. Government-sponsored R,D&D activities include applied and basic R&D as well as demonstration projects. Basic R&D on wind energy is mainly performed at the country's technical universities. Key areas of R&D in the field of wind energy in the country 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 megawatt-sized wind turbines or offshore deployment.

In 1995, a project for the development of a 450-kW wind turbine was initiated within the framework of the EPET-II National Programme. The project is aiming at both the development of a 450-kW, variable speed, stall-regulated wind turbine and the development of blade manufacturing technology. Prototype assembly concluded in 2000, and installation at the test site was completed at the beginning of May 2001. Commissioning tests are planned to take place during 2002.

CRES is the national organization for the promotion of the renewable energies in Greece and, by law, the certifying authority for wind turbines. CRES is mainly involved in applied R&D and is active in the field of aerodynamics, structural loads, noise, power quality, variable speed, wind desalination, standards and certification, wind assessment, and integration.

The development of a national certification system for wind turbines is considered as a crucial parameter for the successful implementation of new strategic plans for extensive use of wind energy in the country. CRES's Wind Energy Department is continuing the development of the National Certification System, as well as participating in the standardization work carried out by the Hellenic Organisation for Standardisation (ELOT) in the framework of European and international organizations, regarding wind energy matters. In 2001, active involvement continued in the activities of IEC TC-88, CLC/BTTF83-2, and their working groups.

CRES's blade-testing facility is going to be used as an integral part of the certification system underway. The blade-testing facility – which is one of the most advanced testing facilities in the world – is used for static, dynamic, or fatigue testing of blades up to 25 m long.

CRES's 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.

13.6.2 New R,D&D Developments

A number of research projects were running or initiated at CRES during 2001, co-funded by DGXII and the Greek Secretariat for Research and Technology (GSRT). These research projects were aimed at achieving the following.

- Characterizing the main features of complex or mountainous sites because this type of topography is the most favorable for wind energy development sites
- Identifying the crucial parameters that affect both the power performance and the loading of different types of wind turbines operating in complex or mountainous environments (new techniques are under development for power-curve measurement of wind turbines operating in complex terrain)
- Developing wind turbines for installation in hostile environments of 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

The National Technical University of Athens (NTUA) is actively involved in two research areas concerning wind energy: 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 field of wind modeling, rotor aerodynamics, load calculation, fatigue analysis, noise, and wind farm design. The work conducted during 2001 concerned applied research on rotor aerodynamics for wind turbines. More specifically, this work included the following elements.

- NTUA participated in a European Commission (EC)-funded benchmark exercise concerning the verification of design tools for wind turbines. Within this activity, NTUA upgraded the in-house developed free-wake model GENUVP into a complete aeroelastic tool. In particular, a new hybrid wake model was implemented that allows 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 validat-

ed against wind tunnel measurements in cases of light as well as deep stall for pitching airfoils.

- NTUA further developed the computational procedures concerning the optimum design of airfoil sections and complete blades for stall-regulated machines. The family of airfoils designed has improved polars, especially in regard to roughness sensitivity and stall behavior. Application of this procedure was carried out for megawatt-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, large, offshore machines.

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

In 2001, the Electric Power Division of NTUA continued its research activities on issues related to the technical constraints and problems in the integration of wind power into electrical grids, management and control of isolated power systems with increased wind power penetration, and power quality of wind turbines and wind parks as well as with the design of electrical components for variable speed machines.

The technical constraints and problems in the integration of wind power into electrical grids have been investigated in various regions of Greece where the transmission system is weak and there is high interest in related wind projects because of favorable wind conditions. Steady-state voltages, voltage variations, and power quality issues have been investigated. Particular emphasis has been placed on the secure integration of increased shares of wind energy in larger island systems, like Crete. Work continues on CARE, which is an advanced control system installed in Crete that is comprised of load and wind power forecasting, unit commitment, and economic dispatch and on-line dynamic security assessment modules integrated within a friendly Man-Machine Interface.

The MORE CARE phase comprises enhancement with improved wind power forecasting modules for a short-term and medium-term time horizon, Unit Commitment and Economic Dispatch modules that take into account the availability of hydro-storage, liberalized market conditions and increased security conditions, and online security modules to provide both preventive and corrective advice in case of predetermined disturbances. The Crete control system will be respectively updated. 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 been continued, focusing mostly on technical issues related with the integration and control of such units, the units' impact on the operation of distribution grids, and the planning of distribution networks in areas with high, dispersed generation potential.

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

Simulation codes are being developed in collaboration with the Fluids Division of NTUA and CRES. These codes are used for studying the dynamics of wind turbines with various configurations of the electrical part and the control system. 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 to the grid-connected operation of wind turbines (slow and fast voltage variations, flicker, and harmonics) are a central research area, and a great deal of work has been performed on the elaboration of connection guidelines.

Since 1990, the applied mechanics section of the Department of Mechanical Engineering and Aeronautics, University of Patras (UP), has focused on educational and R&D activities involving composite materials and structures. Emphasis is given on anisotropic material property characterization, structural design, and dynamics of composite rotor blades of wind turbines. Experience has been acquired by participating in several research projects funded nationally or by the EC.

UP has successfully completed structural designs for 4.5-m, 5.5-m, 8-m, 10-m, 14-m, and 19-m GRP blades. Verification of these blades was performed by full-scale static, fatigue, and modal tests at the CRES blade testing laboratory.

As part of the JOULE-III program, UP is participating in the project, AEGIS-Acoustic Emission Proof Testing and Damage Assessment of W/T Blades, which contributes to the design of small blades and failure characterization of composite materials using advanced numerical techniques for pattern recognition and analysis of NDT signals. As a subcontractor to CRES, UP is also participating in a project called ADAPTURB-Adaptation of Existing Wind Turbines for Operation on High Wind Speed Complex Terrain Sites; kWh Cost Reduction. For this project, UP is mainly contributing to information on numerical prediction of blade structural integrity under prescribed static and fatigue loading.

During 2001, UP contributed in two new research projects, funded by EC: Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites (DAMPBLADE) and Development of a Megawatt Scale Wind Turbine for High Wind Complex Terrain Sites (MEGAWIND). 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 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 that will be verified by full-scale testing at CRES with a prototype under development by Geobiologiki SA.

The other research activities of the applied mechanics section involve (a) fatigue failure prediction of multidirectional laminates under combined stress state and variable amplitude loading; (b) probabilistic methods in the design of composite structures; (c) fatigue characterization of composite materials using non-destructive testing; (d) smart composites and structures; (e) structural damping, passive and active vibration control; and (f) development of numerical tools FEM, BEM.

13.7 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. There were two main ongoing demonstration projects in 2001, a wind/diesel/battery power supply system in Kythnos and a wind farm in Lavrio.

The project involving a large, advanced, autonomous wind/diesel/battery power supply system in Kythnos is called the THERMIE program. The aim of this project is to demonstrate the technical feasibility of the integration of a high penetration of wind energy in large supply systems. This large, modular system on 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 – due to this, the diesel generators can be totally stopped when the power output of the wind turbines is sufficient. The already-existing photovoltaic 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 by the power production company and SMA. The wind turbine was erected in mid-1998, and the commissioning was completed during 2000. High-wind penetration reaching 100% was achieved while the system was still in trial operation. The most important advantages achieved during the system's operation are listed as follows.

- Demand under specific conditions can be covered totally by RES
- System has high reliability
- Improvement of the grid stability and, consequently, the quality of the power supply
- Decrease of the operational cost of the diesel gensets

The wind farm project in Lavrio is the 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 (see Figure 13.5). The purpose of the project is to study the effects of the complex topography on the performance of the wind turbines as well as of the overall wind farm. The wind

Figure 13.5 CRES's 3.1-MW wind farm located in Lavrio

farm consists of five different medium-sized wind turbines with distinguished design aspects: a 500-kW, gearless, synchronous, mutlipole 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 in progress.

No offshore wind farms are installed.

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

CHAPTER 14

14.1 INTRODUCTION

The year 2001 was another very good year for the dissemination of wind energy in Italy. In fact, total wind power capacity reached approximately 700 MW at the end of the year, which is better than the general trend of the last five years. This represented a growth rate of 60%. This result is ascribable mainly to the measures introduced by the government to stimulate a larger use of renewable sources in the country.

Several wind farms were completed by the first months of 2002, the last to be built in accordance with the previous instrument of buy-back prices (CIP Provision 6). As a result, the role played by the introduction of a new system based on green certificates (foreseen by the Legislative Decree 79/99), will be of fundamental importance for wind energy exploitation in the coming years.

In this framework, Italian and foreign developers are showing a keen interest in looking for new potential wind sites in the regions of Central and Southern Italy. Most developers are showing quite a different approach to wind energy exploitation in these windy Italian regions, and, consequently, have to deal with more difficulties in the planning of new projects, even in the early stage.

14.2 NATIONAL POLICY

14.2.1 Strategy

In Italy, renewable energy sources are considered very important for the energy sector in the future. This is because of the contribution they provide to the guaranteeing of greater security of the energy supply system, the reduction of the relative environmental impact, and the opportunities for protecting the territory and fostering social development.

In 1992, the Interministerial Committee for Prices (CIP) issued CIP Provision 6, which introduced an incentive system for renewable energy sources based on buy-back prices. Until now, this provision has been the principal instrument for the development of renewable power plants in Italy. Since 1998, some legislative initiatives have been taken to increase the penetration of renewables in Italy.

In November 1998, Resolution 137 of the Interministerial Committee for Economic Planning (CIPE) indicated the national measures for the reduction of greenhouse emissions, in accordance with the Kyoto Protocol objectives. In August 1999, the CIPE approved the Italian White Paper for the exploitation of renewable energy, which fixed two goals: the reduction of greenhouse emissions by 24 Mt CO2 through renewables by 2008 to 2012, and the doubling of the share of renewables by 2010.

In March 1999, according to European Union Directive 96/92 EU, on the liberalization of the electricity market, Legislative Decree 79/99 was issued, fixing new rules in the national electricity sector. An important aspect of this decree is the introduction of a percentage of electrical energy produced or imported from conventional sources (starting at 2%), to be generated from renewable sources. In addition, the decree foresees a change to the system of stimulation and exploitation of renewable energy sources. On 11 November 1999, a following specific decree introduced the new support system based on the green certificate mechanism. This new system, in force since the beginning of 2002, should provide a satisfactory replacement to the previous system. Electricity produced by renewable energy sources is labeled with green certificates issued by the transmission system operator (GRTN); the green certificates are tradable.

14.2.2 Progress Towards National Targets

Most developers, in accordance with the transitory rules for renewables, established by the Legislative Decree 79/99, have completed the major wind plants entitled to obtain the premium tariff fixed by CIP Provision 6/92. With these installations, the first target as indicated in the Italian White Paper, 700 MW by 2002, was achieved at the end of 2001.

The other subsequent targets are 1,500 MW by 2006 and 2,500 MW from 2008 to 2012. The achievement of these targets is linked significantly to the effect that the introduction of the green certificate mechanism will produce in the market.

14.3 COMMERCIAL IMPLEMENTATION

14.3.1 Installed Capacity

A good wind, from the point of view of new installations, blew again in Italy in 2001. In fact, during this year, approximately 270 MW of new wind energy capacity were added to the capacity of 427 MW reached at the end of 2000, bringing total wind power to 697 MW.

Most of these new plants were installed by IVPC and Edison Energie Speciali in Southern Italian regions, extending the area of wind farms to the north and south of the Apulia and Campania regions, where approximately two-thirds of the national wind energy capacity is located. In addition, Enel GreenPower – a subsidiary company of the ENEL group, involved in the production of renewable energy – put into operation its first two wind farms in Sicily, totaling 15 MW. Another 7.5-MW wind plant was built by Enel GreenPower in Western Sicily and will be connected to the grid shortly. All these plants will be enlarged in 2002.

In Sardinia, a wind farm of approximately 40 MW was completed. This is the first commercial wind farm in the island after the installation of several prototype and demonstrative plants.

Overcoming some difficulties that have arisen in the Basilicata region, IVPC and Edison Energie Speciali are expected to complete their last two wind farms by the

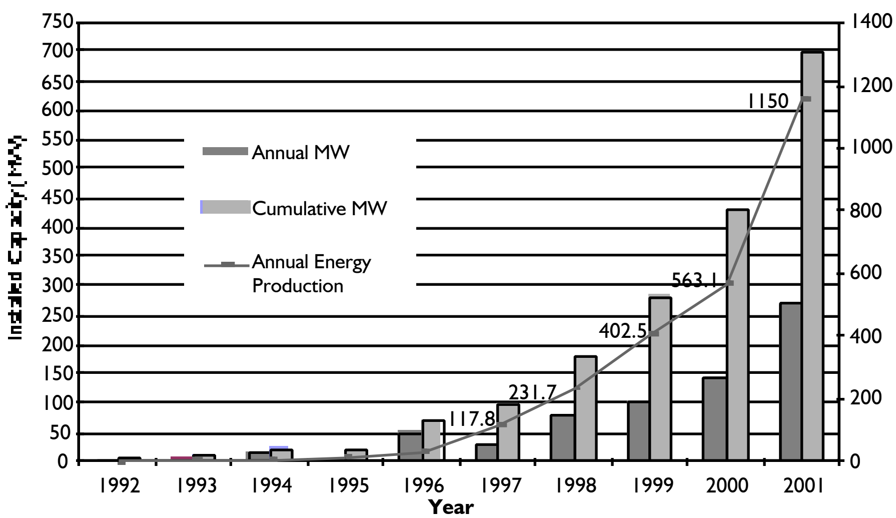


Figure 14.1 Installed capacity (annual and cumulative) and annual energy production

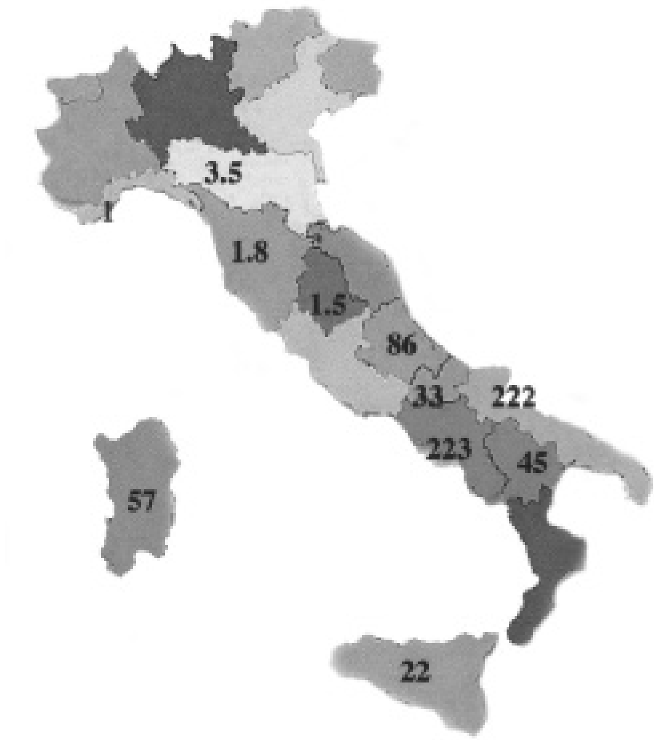


Figure 14.2 Wind capacity in Italian regions

beginning of 2002, under CIP Provision 6/92 that allows a premium tariff. With these installations, almost all wind plants authorized to be erected under this provision will be completed.

14.3.2 Rates and Trends in Deployment

Italy's good deployment rate for wind plants was fully confirmed and improved on 2001. With approximately 270 MW of wind farms installed, the expected rate of 200 MW per year was surpassed, adding 60% of new capacity to the 2000 total. At the moment, it is very hard to estimate the amount of new wind power for the coming years – particularly for 2002, which is the first year of green certificates and the beginning of a completely different system of incentives.

14.3.3 Contribution to National Energy Demand

Electrical energy demand was 298.5 TWh (including transmission and distribution losses) in 2000, an increase of 4.4% from 1999. Of this amount, 44.8 TWh, 5.6% more than in 1999, were imported from foreign countries. In 2000, the net electric energy produced in Italy was 263.3 TWh, 4.2% more than the previous year.

Thermal plant production increased by 5.6% compared to 1999, with a total net production of approximately 208 TWh, and the contribution of renewable sources, including large and small hydro, was 50.1 TWh. The total net production of hydro-power was 44.2 TWh, decreasing by 1.8% from 1999.

In 2000, the contribution of wind energy to electricity generation was 563 GWh, approximately 40% more than 1999. In 2000, this contribution increased to approximately 1,150 GWh. Despite this achievement, the share in terms of percent of wind energy to satisfying the country's energy demand remains very small – similar to the contribution of biomass.

14.4. MARKET DEVELOPMENT AND STIMULATION

After the results achieved – in terms of wind energy dissemination, with the premium tariff granted by CIP Provision 6/92 – the relevant support provided by the government is Legislative Decree 79/99 and the associated green certificates. Another form of support, for Southern Italian regions only, is represented by the 2000 to 2006 Piani Operativi Regionali (PORs).

14.4.1 Support Initiatives and Market Stimulation Incentives

In order to avoid a crisis in the sector and with the aim of doubling the share of renewables by 2010, new incentives for renewable plant construction have been conceived by the Italian government. Decree 79/99 has been in force since 1999 on the liberalization of the electricity market. This decree was followed by a specific decree issued in the same year regarding renewable energy sources, and in particular, the emission of green certificates, which should adequately replace the previous system starting at the beginning of 2002. This new mechanism for supporting clean energy sources is based on the rules of market competition.

Electricity produced by renewable energy sources is labeled with green certificates issued by the transmission system operator (GRTN). Green certificates are tradable, and one green certificate corresponds to 100 MWh of electricity generated by a renewable source.

In this market, the demand is defined by the obligation for producers and importers of energy to put into the system in the year 2002 a quota of energy produced by renewables corresponding to 2% of the conventional energy produced or imported in the year 2001. Supply is constituted by the green certificates issued by GRTN for private renewable plants that have obtained the qualification, and for renewable plants, built under the CIP Provision 6/92, that have entered into operation after 1 April 1999. GRTN is the owner of the certificates granted to the latter category of plants.

1. Green certificate demand
   (See Table 14.1)

2. Green certificate supply

As stated above, there are two types of green certificates. The first type of green certificate, owned by GRTN, relates to renewable plants built under CIP Provision 6/92. The estimated energy values for these plants, updated after two

	2001	2002	2003	2004
Energy from conventional sources (TWh)	243	256	265	274
Green certificate demand (TWh)	/ /	4.9	5.1	5.3

Table 14.1 Maximum estimated values of conventional energy for each reference year and the corresponding values for demand

	2002	2003	2004	2005
A) CIP 6 plants authorised by resolutions AEGG No. 175/00 and 144/01 (TWh)	3.6	4.7	4.9	5.5
B) Producer-distributor plants authorised by resolution AEEG No.144/01 (TWh)	3.2	3.5	3.5	3.5

Table 14.2 Estimated energy values for renewable plants built under CIP Provision 6/92

D) Qualified	0.6 TWh
E) Suspended for technical evaluation	0.4 TWh
Total	1.0 TWh

Table 14.3 Available energy for the year 2002

resolutions of the Authority for Electrical Energy and Gas (AEEG), are shown in Table 14.2. The second type of green certificate is owned by private investors. The available energy based on demand is shown in Table 14.3.

3. Reference price for 2002

The average price paid by GRTN for the electricity generated from renewable plants under CIP Provision 6/92, that have entered into operation after 1 April 1999, is estimated to be approximately 0.134 Euros/kWh. In particular, approximately 0.124 Euros/kWh from wind generation. Assuming that sales of electricity in 2002 will be made according to the current rules and with an average price of 0.067 Euros/kWh, according to the decree of 11 November 1999, the supply price of GRTN's green certificates should be approximately 0.067 Euros/kWh (the difference between 0.134 Euros/kWh and 0.067 Euros/kWh).

4. Piani Operativi Regionali

A completely different approach is followed by some Southern Italian regions. In particular, the Sicily, Campania, and Apulia regions are allocating financial resources to complement European structural funds in order to finance various renewable projects at different percentages of eligible cost. It is in this context that a number of wind projects, including offshore ones in Sicily, will be implemented from 2002 to 2006.

5. Other financing opportunities

The other financing opportunities that exist for wind projects are listed below.

a) Value-Added Tax (TAX) reduction can be used on the purchases of various components of Renewable Energy Source (RES) power plants under the law regulating VAT application D.P.R. 633/72 and successive modifications and updating. The percentage applied for the RES components and materials is 10%, while the full percentage is 20%.

b) Tax credit exists for RES investments in favor of the enterprises in their declaration of the corporate income tax or on VAT payments. This opportunity is given by the last finance Law 388 of 23 December 2000. In fact, Article 8 provides for a grant of a tax credit according to the following modalities.

- Interested subjects: Enterprises, particularly Small and Medium-sized Enterprises (SME), for new investments
- 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
- Tax credit amounts: Up to 50% for the SME, 35% for other enterprises
- 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
- Application period: From 14 March 2001 to 31 December 2006
- Restriction: Grant is not compatible with other types of financial support

c) Public aid from direct subsidies assists RES investments, included in important laws such as the ones listed below.

- The already well-known Law 10/91 for the promotion of RES technology. At present, subsidies are granted by the regions mainly from the 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, reconversion, renovation, and updating of exiting plants; rehabilitation of decommissioned productive plants; transfers of production plants; and restructuring of the organization of enterprises.

The 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.

d) Other opportunities include supporting measures to green electricity production provided within the national sector programs – such as the national program for scientific research, technological development and training of specialised experts, as provided by Legislative Decree 297/99 and implementation Decree of the Ministry of Scientific and Technological Research 593/00. The measures included in this legislative package are addressed to the enterprises that invest in the research and development field, including the energy sector.

14.4.2 Unit Cost

The cost of turbines is continuously decreasing, but not as much in 2001 as in the previous years. In fact, in 2001, the cost of a medium-sized turbine (600 kW to 900 kW) decreased from 740,000.00 Euros/MW to a range of 650,000.00 Euros/MW to 700,000.00 Euros/MW, while that of a large-sized turbine (1,500 kW to 2,000 kW) ranges from 750,000.00 Euros/kW to 800,000.00 Euros/kW. To these costs must be added the balance-of-system cost, around 30%, bringing the total cost per megawatt installed into the million-Euros range.

14.5 DEPLOYMENT AND CONSTRAINTS

14.5.1 Wind Turbines Deployed

There were approximately 30 Italian communes in which there were new wind farm installations, which contributed to the achievement of the first target of 700 MW by 2002. In 2001, the number of new wind

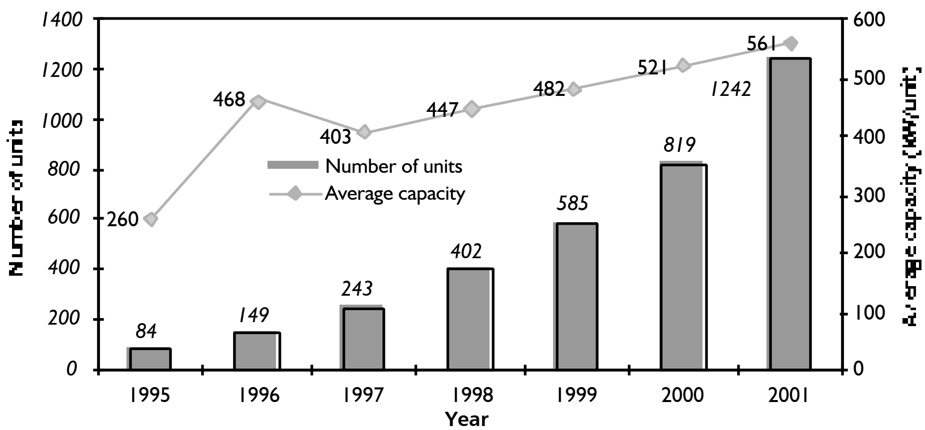


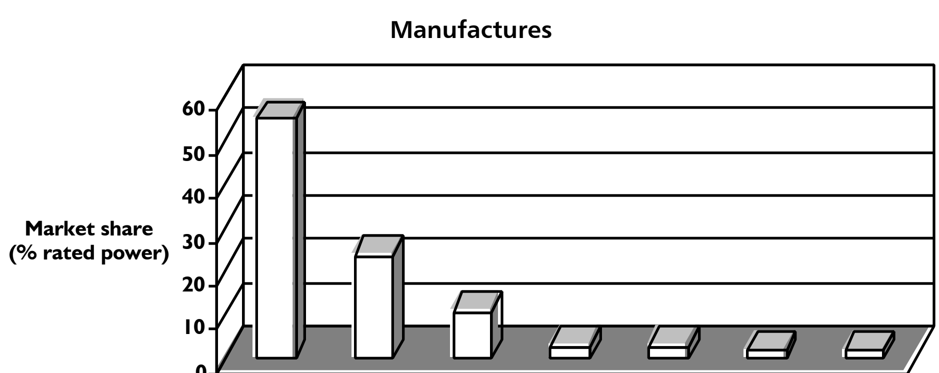
Figure 14.3 Number of units and average capacity

turbines installed was 423 with an average capacity of 638 kW – this brought the total number of wind turbines in Italy to 1,242, and the average turbine size rose to 561 kW (see Figure 14.3).

All new wind farms have medium-sized machines – 600 kW, 660 kW, and 750 kW – supplied by Enercon, Italian Wind Technology (IWT), and Neg Micon and installed by IVPC, Edison Energie Speciali.

Market shares for wind turbine manufacturers at the end of 2001 is shown in Figure 14.4, and the contribution by electricity producers from wind at the same date is shown in Figure 14.5.

IWT has been improving its position, and now more than 55% of wind capacity installed in Italy has been produced in IWT's factory. Enercon is also increasing its significant presence in Italy, particularly in the Abruzzo region, where in 2001 more than 150 E-40 wind turbines, totalling 90 MW, were put into operation.



	IWT	Enercon	Vestas	Bonus	RWT	WEST	NegMicon
%	55	24	11	3	3	2	2

Figure 14.4 Market shares of wind turbine manufacturers at the end of 2001 (as a percentage of total on-line capacity

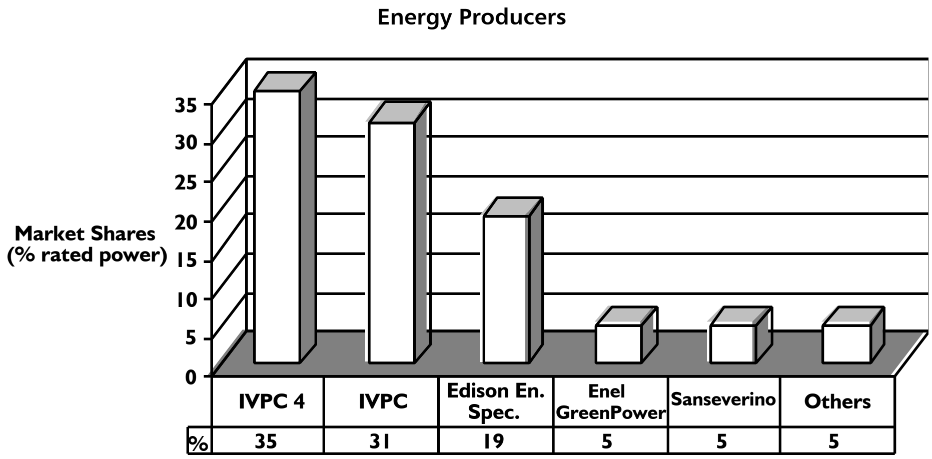


Figure 14.5 Contribution by electricity producers from wind at the end of 2001 (as a percentage of the total on-line capacity]

The main producers of energy from wind – IVPC, Edison Energie Speciali, and Enel GreenPower – are confirming their positions in the Italian market. In particular, during 2001, IVPC and Edison Energie Speciali with approximately 140 MW and 90 MW, respectively, gave the largest contribution in the country to wind energy growth.

14.5.2 Operational Experience

Good availability continued in 2001 with percentages of 98% and 99% and a load factor of approximately 0.31 in the Apulia and Campania regions. In particular, a wind farm located in the province of Benevento achieved a load factor of 0.36.

14.5.3 Main Constraints on Market Development

Central and Southern Italy, because of their geographical position and morphological structure, are characterized by a large number of interesting areas for potential wind energy plant installations. However, one of the main drawbacks to market development is finding good wind sites in complex orography areas. In fact, in these regions it is quite difficult to obtain accurate information on the wind regime. In these conditions developers are looking for good wind sites using both a large number of anemometer installations and computer model systems.

Other constraints encountered by wind investors are visual impact, weakness of grid, and difficult authorization procedures. Most Italian coastal areas, due to their high environmental value, seem unsuitable for exploitation for wind plant installations. In some marginal areas, objections from citizens and environmental associations arise, in particular where many wind plants have already been installed.

14.6 ECONOMICS

14.6.1 Trends in Investment

Total invested capital in 2001 on wind energy plants in Italy was 250 million Euros to 270 million Euros.

14.6.2 Trends in Cost of Energy and Buy-Back Prices

In 2001, buy-back prices established by CIP 6/92 for electricity generated from wind were 0.124 Euros/kWh for the first eight years of plant operation, and 0.069 Euros/kWh for the remaining lifetime. With the introduction of the new support mechanism based on green certificates, wind energy buy-back prices, according to GRTN, are estimated to be approximately 0.135 Euros/kWh for 2002.

14.7 INDUSTRY

14.7.1 Manufacturing

Only IWT is manufacturing medium-sized wind turbines in Italy. In fact, Wind Power Service (WPS), in replacement of RWT, and WEST are no longer involved in the production sector but only in operating and maintenance of the their medium-sized turbines (WPS has 350 kW installed and WEST has 320 KW installed).

IWT launched its activity of production and installation of wind turbines in June 1998, with the aim of building a product with Vestas' technology reliability and quality, together with a high Italian material and component content (see Figures 14.6 and 14.7). Turn-over has increased rapidly – 35 million Euros in 1998, 52 million Euros in 1999, 118 million Euros in 2000, and 160 million Euros in 2001. Employees in IWT's factory in Taranto have similarly risen from 101 in 1998 to 349 in 2001.

IWT is now in the position to build about 400 medium-sized turbines (660 kW to 850 kW) per year, while bigger installations (1,750 MW to 2,000 MW) will be made, for the time being, with Vestas turbines. Steel towers are built in Italy for IWT according to Vestas specifications.

Energy production from wind power has provided new job opportunities and now, in plant manufacturing along, there are more than 1,000 people working. The main Italian wind component suppliers are as follows.

Figure 14.6 View of the 7.3 MW wind farm, with 11 IWT V47 units of 660 kW, which has been built by Enel GreenPower at a hill site near Carlentini in Sicily (photo Carmine La Fratta).

Figure 14.7 IWT facility-Taranto V-47 blades production (photo Carmine La Fratta).

- 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-Pugliese-Leucci for towers

14.7.2 Industry Development and Structure

Following the general market trend of increase in commercial size and capacity of wind turbines, IWT is ready to launch a new, 850-kW, V-52 production line. The first units, coming from Denmark, will be installed in Campania at the beginning of 2002.

14.8 GOVERNMENT-SPONSORED R,D&D

14.8.1 Priorities

Since the end of the government-sponsored programs for the development of medium and large wind turbine prototypes in 1996, public support has been significantly cut back. For the time being, only ENEA, CESI, Enel GreenPower of the Enel Group, and a few universities are in some way involved in R&D wind programs.

The most active universities in wind energy are those in Genoa, Bologna, and Rome. These universities are working on aerodynamics, local wind maps, offshore applications, and innovative generators and converters for small wind turbines. In particular, blade profile performance analysis in different conditions like erosion and icing is being carried out by the University of Rome, which is also involved in studying the environmental impact of wind turbines.

ENEA and the Enel Group, through its companies CESI and Enel GreenPower, are less involved than in past years in R&D programs and do only some work on small wind turbines; elaboration of an Italian wind map and siting is in progress. In this framework, the development of small wind turbines by Jonica Impianti can also be included.

At the moment ENEAhas a very limited involvement in wind R&D, through its participation in a European project and testing of a small aerogenerator in Antarctica. This 5-kW wind turbine was tested for one year at ENEA's Casaccia test field and was finally installed at Dome-C, Italian-French inner Antarctica station, during the 1999-2000 expedition (see Figure 14.8).

In winter some problems occurred, caused by a bearing failure with a subsequent wind turbine shut-down. In the last expedition, the main shaft bearings were replaced and another kind of grease was used. Other failures were found in the active converter, making some repair work necessary on this component, too. Finally, the turbine was put into operation, but some proposals were suggested in order to improve its performance. These proposed initiatives take into account the limited amount of wind in inner Antarctica and are listed below (as a result, the turbine survived winter operation at -75 degrees Celsius).

- Lowering the turbine cut-in
- Simplifying the electrical system
- Evaluating the opportunity of installing a data transmission system in order to monitor aerogenerator performance when no one is present

The Departments of Physics and Structural and Geotechnical Engineering of the University of Genoa are involved, mainly through their participation in the Meteo-Hydrological Center of the Liguria Region (MHCLR), in several tasks related to meteorology. These tasks are as follows.

- Running a Limited Area Model (LILAM)
- Collecting and processing meteorological data
- Collecting, checking, and correcting the historical meteorological data that are available in order to produce homogeneous databases

Figure 14.8 The 5-kW direct drive turbine with P.M. generator especially developed for Antarctic environment. Photo at Dome C., Courtesy of National Research Project in Antarctica.

- Using wind models to construct three-dimensional wind fields from point measurement
- Statistically analyzing historical data sets in order to produce territorial maps for various purposes

14.8.2 New R,D&D Developments

CESI S.p.A., a company whose majority shareholder is the Enel group, has continued working on wind energy during 2001, both by providing plant developers with technical services on a commercial basis and by carrying out research on behalf of the Ministry of Production Activities (formerly Ministry of Industry) under the supervision of the Authority for Electricity and Gas. In the latter sphere (government-sponsored work), funding was about 700,000.00 Euros in 2000 and 850,000.00 Euros in 2001. The main activities are listed below.

1. Drawing a general map of Italy's wind resources

This activity is the follow-up of former surveys made by Enel and is being conducted in co-operation with the Department of Physics of the University of Genoa with a view to drawing general wind maps of all regions of Italy (including the main islands) by up-to-date wind flow models and relevant software tools using geostrophic wind data.

At present, work is also in progress to develop methods and tools for comparing the maps with measured wind data provided by historical or new met stations located all over Italy, and then adjusting them accordingly. The first validated maps should hopefully be issued in the course of 2002, thus providing intending wind farm developers with a framework they could use as a reference for site selection.

2. Assessment of exploitable wind potential in high-altitude and off-shore areas

Since 2000, CESI has been enquiring into the feasibility of wind plants in some areas of Italy that have not yet been exploited, namely mountain areas above 1,000 m in altitude and offshore areas. In 2001, a possible general trend of unit energy cost as a function of altitude was searched for, using a statistical approach. A preliminary sample of ten areas gave encouraging results – energy yield appeared to grow with height to such an extent that it could well offset the estimated increase in such costs as access roads, grid connecting lines, and plant construction. The same method is now being fine-tuned to provide overall figures of exploitable high-altitude potential all over Italy.

As to offshore siting, CESI at first embarked on a survey in co-operation with Enel Hydro (an Enel subsidiary) to pinpoint sea areas with suitable depth and offing, and to gather information on elements such as coastal wind resources and environmental constraints. This work continued in 2001 and also included an analysis of technical and cost issues for offshore plant construction, with reference to the different site features that can be found in the seas surrounding Italy. Estimates of unit energy costs from offshore wind plants, combined with information on likely available areas, will make it possible to get a preliminary insight of exploitable offshore potential in Italy.

3. Testing of a wind turbine at a high-altitude site

To complete the assessment of feasibility of high-altitude wind plants, tests have also been planned on a commercial, 660-kW wind turbine to be installed by mid-2002 at a site over 1800 m above sea level in the Apennines of northern Italy. The unit will be monitored to check how far wind turbines with today's technology can work profitably under the harsh conditions (especially heavy ice accretion) that can occur on the highest ridges of the Apennines during the winter time.

14.8.3 Offshore Siting

ENEA has completed its participation in the Offshore Wind Energy in Europe (OWEE) contract of the European Commssion for developing state-of-the-art R&D activities in the field. ENEAis also engaged in a European project (WEMSAR) with Denmark and Norway (co-ordinated by the Nansen Institute). WEMSAR is supported by the EU's Fifth Framework Program with the aim of investigating, validating, and demonstrating the potential of synthetic aperture radar and other satellite data to map wind energy in offshore and coastal regions.

The data that is collected, analyzed, and validated will be used to ascertain the wind characteristics of selected test sites in Norway, Denmark, and Italy. Then a study will be carried out to assess the usefulness of using satellite data for offshore wind siting purposes. Afirst offshore feasibility study was committed by the province of Ragusa to the consultant group Garrad&Hassan with the aim of evaluating the energy production of a 10-MW to 15-MW offshore plant off the extreme South of Sicily. This study, encompassing the environmental and social impact as well as the local sea characteristics, was carried out in summer 2001.

14.9 NEW INTERNATIONAL DEVELOPMENTS

Within the Enel group (as is known, the utility Enel S.p.A. has been restructured into a holding company that controls several companies), the renewable energy company Erga grew further in 2001 through the taking over of foreign companies such as Chi Energy (United States) and Egi (South America), thus giving rise to Enel GreenPower. This new company is currently the world's largest electricity producer, exploiting only renewable energy sources.

The company's installed capacity totals 2,500 MW of geothermal, mini-hydro, wind, photovoltaic, and biogas power plants located in Italy, the United States, Canada, and Latin America. Its staff totals 2,400 people with the mission of developing, setting up, and running renewable energy plants. The company is endowed with engineering capabilities, laboratories, and workshops that enable it to provide technical services to third parties as well.

In the wind energy field, the 2001 highlights of Enel GreenPower can be summarized as follows.

- Total wind plant capacity reached 140 MW, including wind farms in Italy (Sicily, Sardinia, Abruzzo, and Molise), the United States, and Costa Rica
- Planning was created for the construction of 400-MW wind farms in Italy in the next two years

Figure 14.9 The new "Miniwind"15-kW wind turbine developed by Enel WindPower. It features a 3-bladed, 8-m-diameter, variable-speed rotor and a permanent-magnet synchronous generator connected to the network through an a.c./d.c./a.c. converter. Cut-in wind speed is 3 m/s, rated speed 10.5 m/s, cut-out speed 25 m/s.

- Wind farm investments worth 800 million Euros were planned for Italy over the next five years
- A contract was awarded for building a 25-MW wind farm in Newfoundland (Canada) starting in early 2003
- Development plans and further plant projects were defined for America and other countries

In addition, Enel GreenPower has developed on its own and manufactured a small-sized, innovative wind turbine: the 15-kW Miniwind model designed for grid-connected operation as well as for feeding hybrid generating systems and stand-alone customers. The first four units are already operating, and series production of this machine will start with an additional 20 units in 2002 (see Figure 14.9).

Authors: L. Pirazzi and A. Arena, ENEA, Italy; C. Casale, CESI, Italy.

CHAPTER 15

15.1 INTRODUCTION

After the installation of a 20-MW wind farm in December 1999, Japan entered an age of commercial wind farms. Although the total wind power capacity in Japan was officially recorded as 162 MW in September 2001, actual capacity was estimated to be around 250 MW at the end of 2001 (if plants under construction are included). Based on recent developments in wind power, the government has changed the 2010 national target for wind power from 300 MW to 3,000 MW.

15.2 NATIONAL POLICY

15.2.1 Strategy

At the United Nations 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. Changing the government's 2010 national target for wind power from 300 MW to 3,000 MW in the latest Primary Energy Supply Plan will help to achieve this.

15.2.2 Progress Towards National Targets

In 1995, the government and the National Institute of Advanced Industrial Science and Technology (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 two yeas.

15.3 COMMERCIAL IMPLEMENTATION

15.3.1 Installed Capacity

Japan's cumulative wind power capacity was recorded as 161.7 MW with 286 units

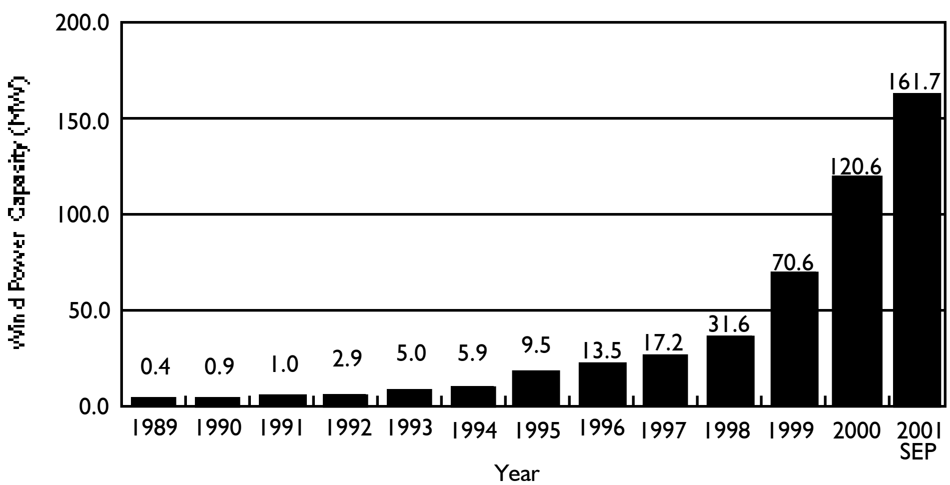


Figure 15.1 History of installed capacity of wind systems in Japan

in September 2001 (data source: NEDO). If the many projects under construction are included, the total wind power capacity is estimated at more than 250 MW. Figure 15.1 shows the history of wind turbine development in Japan.

15.3.2 Rates and Trends in Deployment

The increase in cumulative wind power capacity during last three yeas is 130.1 MW, which provides a mean increasing ratio of 43 MW per year. Governmental promotional subsidy programs, such as the New Energy Business Support Program introduced in1997, support this trend. The private Long-term Electricity Purchase Contract Menu for new energies, offered by utilities in 1998, has also stimulated wind power business.

15.3.3 Contribution to National Energy Demand

The contribution of wind power to national energy demand was 163.3 GWh (from April 2000 to March 2001), which is 0.02 % of national electric power generation. The national target of 3,000 MW is equivalently evaluated as 1,340 ML of oil, the contribution of which to the national primary energy resources will be 0.22%. (Wind Energy/New Energy = 1,340ML/19,100ML and New Energy/Total Primary Energy = 3.1%.)

15.4 MARKET DEVELOPMENT AND STIMULATION

15.4.1 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' introduction of wind turbine generating systems, and motivating the development of large-scale wind farms.

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 since1998. 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 facility design and construction. As is shown in Figure 15.1, the wind farm market has recently been stimulated, due to the above initiatives.

15.4.2 Unit Cost

Approximately 90% of installed wind turbines in Japan are imported from Europe. Therefore, unit cost is considered to be the same as in Europe. However, other factors – such as transportation cost and the additional apparatus cost required to stabilize power for grid connection – still require high plant cost. However, the Cost of Energy (COE) is coming below Yen/kWh at most of the large-scale wind farms. Even with these lower costs, wind power plants in Japan are still not competitive with traditional generation without national subsidy programs.

15.5 DEPLOYMENT AND CONSTRAINTS

15.5.1 Wind Turbines Deployed

Commercial wind farms are increasing recently. Locations for large wind farms are concentrated in the northern part of Japan, which has some grid problems. Approximately 90% of wind turbines employed in Japan are European 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.

15.5.2 Operational Experience

At good wind sites, the annual mean capacity factor is more than 20%. However, it is very important to watch individual wind turbines in a wind farm. For example, at Tappi Wind Park, owned by Tohoku Electric Power Co., the capacity factors among individual turbines vary by 15% to 33% due to the complex terrain effect. In addition to power quality issues, this issue is one of the most important to be solved in the Japanese environment. It is commonly understood that the technical items to be solved in Japan are that of power quality, typhoon attacks, high-turbulent intensity at hilly sites, and lightning strikes. All of these issues increase cost.

15.5.3 Main Constraints on Market Development

Power quality is an important issue because most of the promising wind sites are located in weak grid regions, and electric power companies, such as the one in Hokkaido, limit commercial wind power development. NEDO conducts two demonstration programs on power stabilization techniques and battery-back-up systems. The problem of complex terrain also affects mechanical strength and electrical quality due to gusty and turbulent wind. This increases the cost of transportation, erection, and grid-connection.

Some constraints were reported on the issue of birds. Sometimes complicated negotiations delay wind power development. As wind power development expands, more forums for interactions among developers, public utilities, and authorities are needed.

15.6 ECONOMICS

As large-scale commercial wind power plants ranging from 20 MW to 30 MW are developed, the economics are getting more and more competitive. The COE comes below 10 Yen/kWh; however, it is still high if compared with Europe or the United States.

15.6.1 Trends in Investment

After the 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, including the cost for grid-connection, currently ranges from 130,000.00 Yen to 200,000.00 Yen.

15.6.2 Trends in Cost of Energy and Buy-Back Prices

The average electricity purchase price is about 18.00 Yen/kWh. The current wind-generated electricity purchase price is equal to or less than 11.5 Yen/kWh.

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

Table 15.1 National activities on wind energy

15.7 INDUSTRY

15.7.1 Manufacturing

MHI is the only national manufacturer that supplies mid- to large-sized wind turbines. MHI has recently developed variable speed synchronous wind turbines of 300 kW, 600 kW, and 2,000 kW. Recently, many of MHI's wind turbines have been constructed in the United States. FHI is a new wind turbine manufacturer. Starting with 20-kW class rotor development in cooperation with the Mechanical Engineering Laboratory (MEL), FHI developed a 40-kW Subaru wind turbine and a 100-kW wind turbine under a national project.

15.7.2 Industry Development and Structure

The major wind turbine manufacturers in Japan are Neg-Micon, Vestas, Bonus, Enercon, MHI, and Lagerway. Approximately 90% of wind turbines are imported from Europe.

15.7.3 Export Potential

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.

15.8 GOVERNMENT-SPONSORED R,D&D

15.8.1 Priorities

Since 1978, the government – formerly the Ministry of International Trade and Industry (MITI), now METI – aims its wind energy R&D program at energy security after the oil crises. This is one part of the general R&D program for renewable 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 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 became an independent research institute. The national wind energy activities in Japan are shown in Table 15.1. Electric Power Companies (EPC) have participated in some of the projects. Table 15.2 shows the history of the budget of METI for various wind energy activities.

15.8.2 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 environmental conditions – typhoon attacks, high turbulence intensity, weak grid in remote areas and islands, poor accessibility at hilly sites and islands. Other research topics such as power quality are also being explored. Two demonstration programs on power stabilization were conducted.

1. R&D project of advanced wind turbine generating systems for remote islands

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 design features are shown in Table 15.3.

As shown in Table 15.4, the program comes to the final stage during the fiscal year 2002, when two units of this prototype will be erected on Izena Island among the Okinawa Islands. Because there are no big cranes, the turbines are designed to use a gin pole system for construction.

The annual wind speed at the site is approximately 6 m/s, which is not unusual for Japan – however, the island is located under the main pass of typhoons, so and the turbine must be designed to withstand extreme wind speeds up to 80 m/s. The island is supplied with electric power from five diesel generators with 3,800 kW of total capacity.

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
NSS Project (R&D&D)	540	981	978	744	634	606	554	477	414	516	739
NEDO Subsidies (Field Test)	-	-	-	-	80	320	460	1529	1739	1620	1389
NEDO Subsidies (Business Support)	-	-	-	-	-	-	430	1670	3320	5490	14040*
NEDO Power Stabilization Dem.	-	-	-	-	-	-	-	-	-	1730	917
Total	540	981	978	744	714	926	1444	3676	5473	9356	-
(R&D)	540	981	978	744	634	606	554	477	414	516	739
(Subsidy)					80	320	890	3199	5059	8840	-

Table15.2 Budget for national wind energy projects in millions (Yen)

Design Items	Spec
Rated power	100 kW
Rotor diameter	22 m
Hub height	24 m
Cut-in wind speed	3.0 m/s (10-min.-ave.)
Rated wind speed	10.5 m/s
Cut-out wind speed	25.0 m/s (10-min.-ave.)
Extreme wind speed	80 m/s (instant.)
Power control	Variable pitch
Operation	Variable speed
Yaw control	Active yaw
Main brake	Blade feather
Protection system	Feather
Generator	Multipole permanent magnet synchronous
Construction	Gin pole type
Life time	20 years

Table 15.3 Technical specifications for a 100-kW wind turbine for remote islands

By separating the connected feeders in the grid, grid-connected operation will be demonstrated until 40% penetration from the wind is achieved. In the fiscal year 2001, the components will be manufactured and blade tests will be performed, as shown in Figures 15.2 and 15.3, respectively. By April 2002, the plant will be erected.

2. R&D project of a local-area, wind energy prediction model

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

Table 15.4 Testing schedules for advanced wind turbine generating systems for remote islands

Figure 15.2 Nacelle components of a 100-kW wind turbine for remote islands

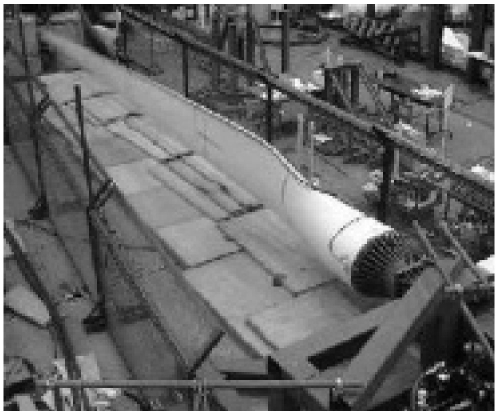


Figure 15.3 Blade testing for a 100-kW wind turbine for remote islands

This Computational Fluid Dynamics (CFD) model is being developed especially for Japanese complex terrains to accurately predict local wind flows. Figure 15.4 shows the nesting structure employed in the CFD model. Wind tunnel testing was also conducted to develop a "plant model" in the boundary layer (see Figure 15.5).

3. Field test and wind measurements of WINDMEL-III at a hilly and gusty site

Hill sites are promising wind plant sites in Japan. However, the wind characteristics are usually gusty, and higher technology is considered necessary to be developed. Under the Sunshine Program, the Wind Energy Team of the National Institute of Advanced Industrial Science and Technology (AIST) conducts field testing of a 15-kW, variable-speed research turbine with a 15-m diameter, teetering rotor at Mt. Nonobor. The site (see Figure 15.6) is quite gusty and extraordinary winds have been measured.

4. Demonstration of leveling effects of multiple wind turbines

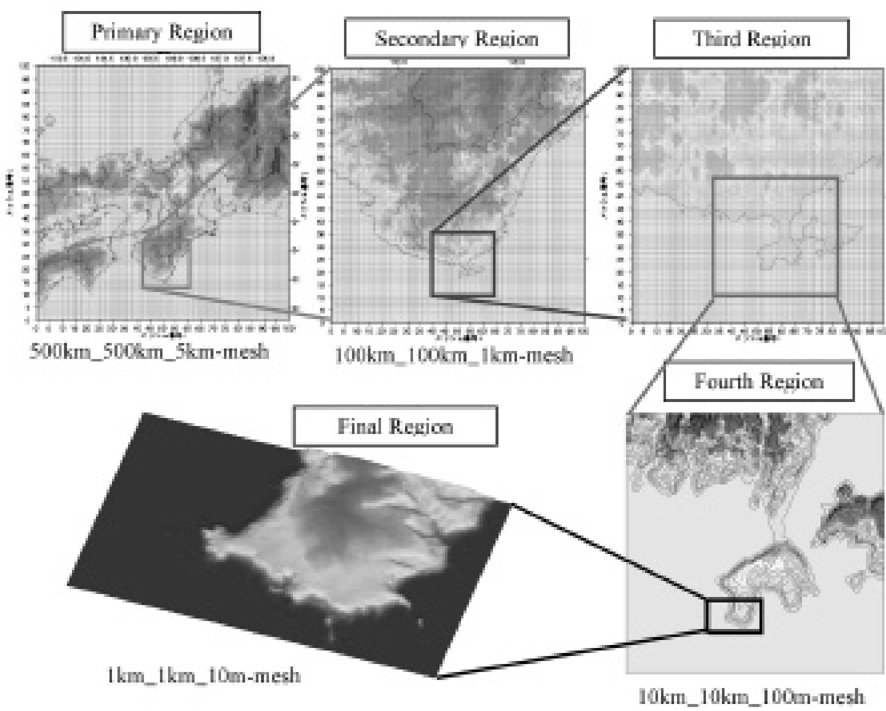


Figure 15.4 Nesting structure of the CFD model

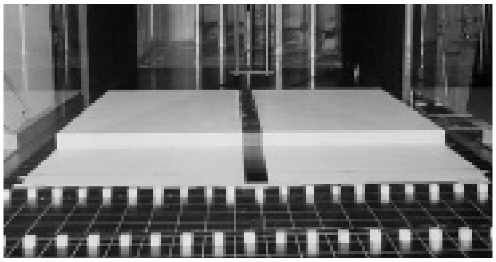


Figure 15.5 Wind tunnel testing for "plant model" simulation

Figure 15.6 Field testing of WINDMEL-III at Mt. Nonobori

This program studies the state-of-the-art technology of the leveling effect of multiple wind turbines and collects practical data on power quality in relation to fluctuating wind conditions at actual sites. During 2001 and 2002, much wind speed and operational data were collected in the Hokkaido area.

5. Demonstration of the stabilization effect of a storage-battery-supported wind turbine

This program has demonstrated the stabilization effect at three wind turbines ranging in capacity from 275 kW to 500 kW of rated power, each supported by a different battery type – NAS, Redox flow, and Lead Acid ranging from 170 kW to 400 kW (AC) rated power.

6. International Energy Agency (IEA) Task XV, XVII, and XVIII

The wind energy researchers in AIST and Mie University have joined in some IEA R&D Wind Tasks to develop databases on statistics in wind development, rotor aerodynamics, and wind measurements.

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CHAPTER 16

16.1 INTRODUCTION

Estimates indicate that Mexico's most viable wind resources would be sufficient for the installation of 3,000 MW to 5,000 MW of wind power. These figures are based on rough regional estimates – detailed evaluations of wind resources have yet to be carried out. Other sources indicate that there are many areas in the country with moderate wind resources that could eventually be efficiently tapped using improved wind turbine technologies. Based on the experiences of other countries, it is reasonable to expect that extensive exploration and improved wind speed measurements throughout the country will result in higher estimates of Mexico's wind energy potential.

Mexico's strongest wind energy resource is found in a sizeable region (approximately 3,000 km2) known as La Ventosa, located on the Isthmus of Tehuantepec in the State of Oaxaca (see Figure 16.1). Average annual wind speeds in this region range from 7 m/s to 10 m/s, measured at 30 m above the ground. It is estimated 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 1.5-MW pilot plant, located in one of the best windy sites in the region (La Venta), has operated at a 5.5 years average capacity factor of 38%, 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 is incipient and inconsequential in view of the fact that a number of barriers exist. Jointly, a number of individuals from the public and private sectors are carrying out some actions to remove the major barriers. Negotiations are in progress for 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.

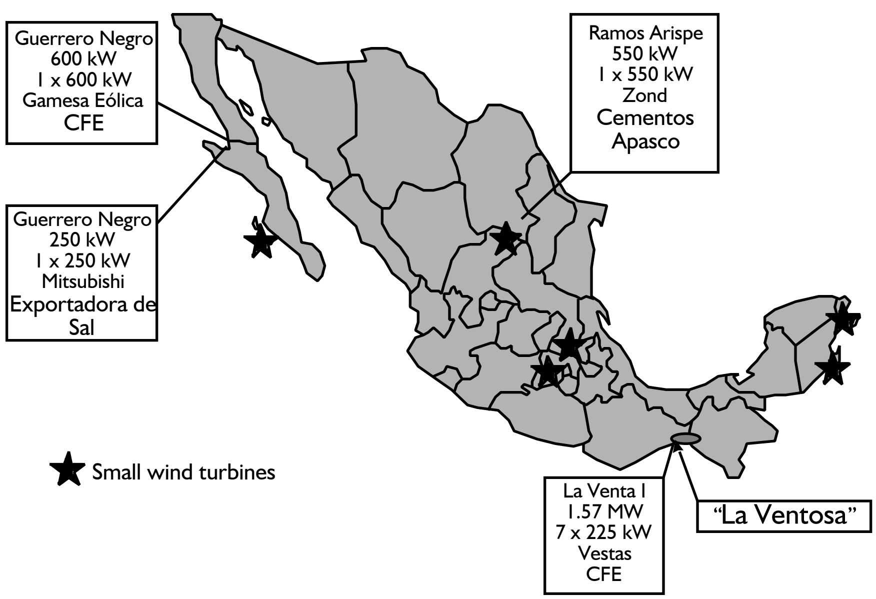

Figure 16.1 Distribution of wind turbine installations in Mexico

16.2 NATIONAL POLICY

In August 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 the policy is to coordinate common objectives and establish a shared vision concerning 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 also be aligned and co-ordinated to ensure fulfilment 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 follow 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 6.6% over the next decade. This growth translates into a projected requirement of 342.8 TWh in 2009 for total electricity generation, which represents an increase of 161.9 TWh and an estimated required new capacity of 30 GW. Of this, 12 GW is already under construction or planned, the majority using combined-cycle, gas-turbine technology in addition to several new hydro and geothermal plants. The remaining 18.5 GW will be supplied through new projects, with an expected 4.3 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 18.5 GW of new capacity using Mexico's wind energy resource. Nevertheless, it has been recognized by energy authorities that the current regulatory framework does not favor commercial development of wind power in Mexico.

16.2.1 Strategy

An action plan for removing barriers to the commercial implementation of wind power in Mexico will be launched by mid 2002. Phase 1 of the project will launch a comprehensive and systematic effort to reduce identified barriers to wind energy development, beginning with a co-ordinated initiative aimed at revising the institutional, legal, and regulatory frameworks of the electricity sector so that they provide a more level playing field for wind energy. 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 toward raising awareness among government officials of 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 also 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 of which will be geared toward the formulation of business-demonstration wind power plants.

Phase 2 of the project, will begin by launching a competitive bidding process for three pilot 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 and suitable financial mechanisms will be established. Finally, lessons learned, best practices, and specialized human resources will be the base of a national campaign aimed at consolidating a sound wind power market.

16.2.2 Progress Towards National Targets

Until now, the federal government has not stated any specific national target regarding wind power capacity to be installed. The government of the state of Oaxaca is very active in promoting the development of wind power in La Ventosa on the basis of economic and social development. In October 2001, the meeting called the Second 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 Mexico, Germany, Spain, Finland, and the United States.

This meeting is quickly becoming the country's most important wind energy event. At the meeting, several figures were mentioned regarding expectations of wind power development in Mexico over the next few years. From the general feeling of some foreign attendees, enthusiastic but unrealistic figures were stated overseas – to the point that a note published in January 2002 by a prestigious international magazine brought about false expectations. The major target is to remove the existing barriers for the commercial implementation of wind power. After that, it has been outlined that at least 2,000 MW of wind power capacity could be installed over the next ten years.

16.3 COMMERCIAL IMPLEMENTATION

During 2001, additional wind power capacity was not installed. The total installed capacity of wind turbines in Mexico remains at approximately 3 MW (see Table 16.1 and Figure 16.1). Therefore, rate in wind power development was 0%, while contribution to national energy demand from wind power installed capacity is negligible. Trends are unpredictable since a number of wind project developers are trying to go forward, but various barriers hold back some initiatives.

16.4 SUPPORT INITIATIVES AND MARKET STIMULATION INCENTIVES

In September 2001, the federal government, through the Regulatory Energy Commission, issued the first incentive for renewable energy. Embedded in the existent legal and regulatory frameworks, this new incentive consists in a "Contract model 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.,

Location	Manufacturer	Wind turbines (kW)	Capacity (MW)	Commissioning date	Owner
Guerrero Negro, B.C.S.	Mitsubishi	1 x 250	0.25	1985	(1)
La Venta, Oax.	Vestas	7 x 225	1.57	1994	CFE
Ramos Arispe, Coah.	Zond	1 x 550	0.55	1997	(2)
Guerrero Negro, B.C.S.	Gamesa Eolica	1 x 600	0.60	1998	CFE
TOTAL		10	2.97		

Table 16.1 Wind turbine installations in Mexico at the end of 2001

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 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 contract model is expected to facilitate some self-supply wind power projects that have been waiting for better regulatory conditions for years. Hopefully one or two of these projects will begin construction during 2002.

16.5 DEPLOYMENT AND CONSTRAINTS

16.5.1 Wind Turbines Deployed

Additional wind turbines were not installed during 2001. The number of wind turbines installed in Mexico remains at ten (see Table 16.1).

16.5.2 Operational Experience

During 2000, electricity production from La Venta wind power station was 6.77 GWh. The facility operated with an annual capacity factor of 49%, and its overall availability was 94.5%. Unfortunately, during 2001 these excellent records were cut down because during more than one month local peasants stopped the operation of the plant. The facility is located in an ejido, a sort of communal property. From the time when the plant was commissioned in 1994, there had not been any problem with local people. Six years later, peasants blocked access to the grid in order to demand some benefits for the community. The problem was not linked to public acceptance of wind power technology or to any environmental impact. As a matter of fact, the local people like wind power, and they expect to become beneficiaries of a promising wind energy industry to be developed over the region. The government of the state of Oaxaca, as well as the local authorities, is working to develop best practices in order to anticipate solutions for potential problems in this direction.

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. Performance data was not released from the 550-kW wind turbine installed at Ramos Arizpe, and the 250-kW machine installed at Guerrero Negro.

Sector	Average price (Mexican Pesos)
Industrial	0.5720
Agriculture	0.3040
Domestic	0.6730
Commercial	1.3030
Public service	1.1090

Table 16.2 Electricity prices in Mexico, January 2001 (1MXP= 0.103627 USD)

16.5.3 Main Constraints on Market Development

Main constraints on wind power market development in Mexico are as follows.

- Current regulatory framework does not favor the 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 national and international financial institutions on the viability and profitability of wind power projects
- Anational program on wind power implementation does not exist
- Specialized human resources on the subject do not exist

16.6 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 along the day. Table 16.2 shows the average price for electricity in different sectors.

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.

16.7 INDUSTRY

A 5-kW turbine of Mexican design is currently manufactured in Mexico, primarily for export markets. Since 1999, a Mexican company has been manufacturing 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 be manufactured in Mexico using existing infrastructure. Over 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.

16.8 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 2001, the Mexican government did not sponsor the construction of any additional wind power facility for demonstration or local capacity building.

Under the auspices of the Ministry of Energy, the Electrical Research Institute is in charge of 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
- Ameans 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 R&D institutions.

Furthermore, a major concern exists because wind data currently available in Mexico is scarce, except for a few sites, and therefore wind energy resource in several promising areas has not been evaluated. In addition, planning the adequate deployment of wind power at the national level is considered as 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 17

17.1 INTRODUCTION

In 2001, a total of 63 turbines were installed in the Netherlands with a capacity of 42.3 MW. The national target for wind in 2020 was increased to 7,500 MW. Selection of consortia began for the demonstration of the 100-MW Near Shore Wind (NSW) farm, and in the North Sea an area was designated on the Dutch continental shelf for 6,000 MW of wind capacity.

17.2 NATIONAL POLICY

During the discussion in Parliament in October 2001 for the budget year 2002, the government announced a new policy and targets for renewable energy. The targets were revised after a review of the previous policy and its results. The ministry indicated that biomass and wind energy have priority and are considered to give the greatest contributions to the 2020 target. The realization of 6,000 MW installed wind capacity offshore is seen as possible and necessary. Because of this, in October the government issued the final draft of the Spatial Core Decision, which designates an area on the Dutch continental shelf for 6,000 MW of wind capacity. At the same time, the government indicated that the target of 10% probably cannot be reached through domestic production but can be reached through import of renewable electricity form other European Union countries. The new targets are summarized in the following table.

The new targets are given in a percentage of renewable energy or electricity and are indicated in bold. The Netherlands Agency for Energy and the Environment (Novem) estimated the derived energy in petajoules (PJ) and terrawatt hours (TWh) from the targets.

17.2.1 Strategy

The government will create the conditions to reach these targets through various instruments that are facilitating demand for renewables, such as 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.

17.2.2 Progress Towards National Targets

In 2001, approximately 1.3% of national energy consumption was provided by renewable energy. Wind provided approximately 0.9% of this, which amounts to 0.9 TWh of electricity.

Targets	2005		2010				2020			
	%	TWh	%	PJ	TWh	MW	%	PJ	TWh	MW
Energy form RE			**5**	150			**10**	300		
Electricity from RE	6	6.5	**9**	10.6						
Possible from wind				20	3.5	1500		130	22.4	7500

Table 17.1 New targets for renewable energy

17.3 COMMERCIAL IMPLEMENTATION

17.3.1 Installed Capacity

In 2001, a total of 63 turbines were installed with a capacity of 42.3 MW, and four turbines were removed with a capacity of 0.8 MW. This brings the total installed capacity at the end of 2001 to 483 MW with 1,346 turbines. The final numbers for 2000 show a total increase in operational capacity of 32.8 MW. In a normal wind year, this could generate about 1 TWh, which is 0.91% of national electricity consumption.

Year	Generated electricity	Windex	Primary energy savings
	[GWh]	[%]	[PJ]
1985	6		0.05
1986	7		0.06
1987	14	95	0.12
1988	32	100	0.27
1989	40	83	0.33
1990	56	98	0.46
1991	88	80	0.73
1992	147	93	1.22
1993	174	87	1.44
1994	238	94	1.97
1995	317	88	2.62
1996	437	68	3.62
1997	475	68	3.93
1998	640	93	5.30
1999	645	86	5.34
2000	829	88	6.86
2001	900	90	7.45

* 2001 numbers have been estimated

Table 17.2 Electricity production, avoided fuel, and emissions

17.3.2 Rates and Trends in Deployment

The installation rate has been about 40 MW to 50 MW per year in the last five years. The average installed capacity per turbine has been steadily rising from 150 kW in the mid-1980s to approximately 700 kW in 2000. The average hub-height rose from 28 m to 55 m, and the installed swept area per unit of power form 1.7 m^2/kW to 2.5 m^2/kW.

17.3.3 Contribution to National Energy Demand

Final numbers for 2001 are not available yet, but the electricity generated by wind turbines in 2001 is estimated at 900 GWh. The Windex, which compares the annual wind speed in a certain year with the 30-year average wind speed set at 100%, is estimated at 90%. Total national electricity consumption in 2000 was 96,534 GWh, of which wind provided 0.86%. In 2001, national consumption is expected to be 100,000 GWh, with wind contributing 0.9% of that.

17.4 MARKET DEVELOPMENT AND STIMULATION

17.4.1 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 and 2000. Since July 2001, customers were free to buy green electricity form any company that offers it at the most advantageous price, and switching energy suppliers is possible. This has led to several new trad-

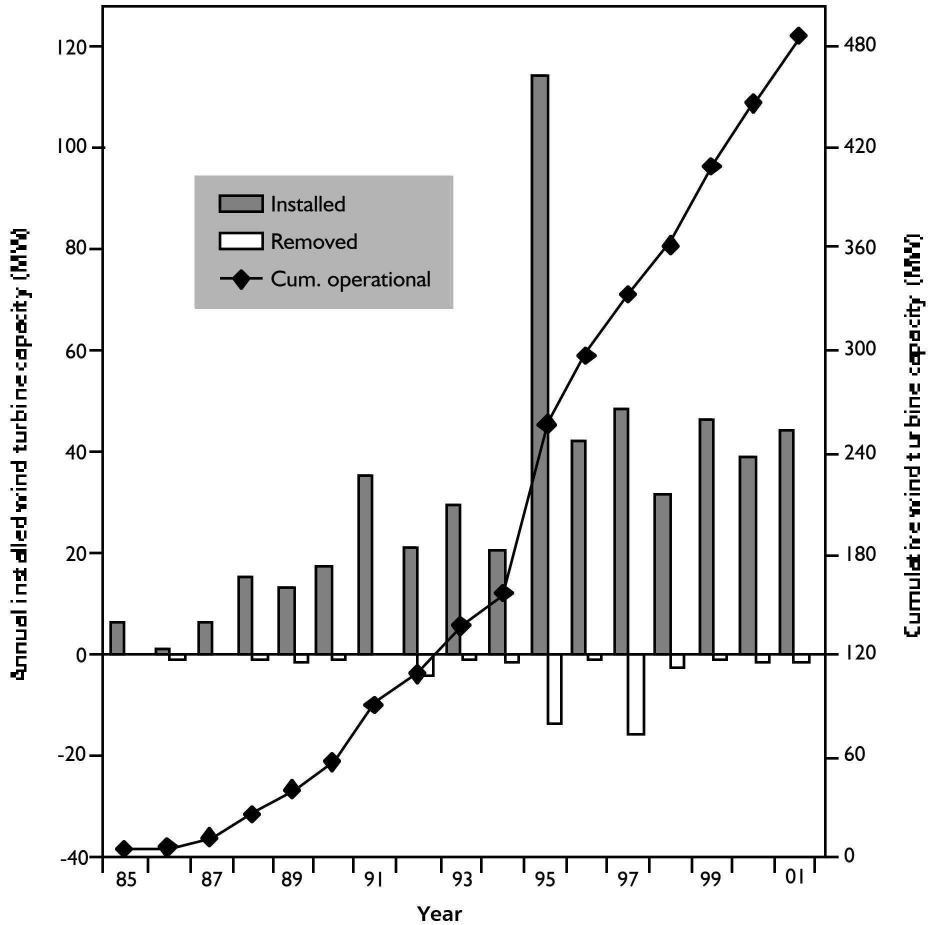

Figure 17.1 Installed, removed, and operational wind capacity

ing companies, like Echte Energie en Energieconcurrent, which is solely devoted to trading in green electricity, in addition to traditional companies such as NUON, Essent, and Eneco. Information about the competitiveness of prices can be found on the Internet at www.greenprices.com. At the end of 2001, there were about 800,000 households in the Netherlands that bought green electricity.

On October 24, the Alteration of the Statutory Regulations of the Green Certificates Electricity Law 1998 was published on behalf of the Ministry of Economic affairs. This law enables imports of green electricity from outside the Netherlands. Electricity has to be physically imported, and in order to be eligible for green certificates, no production support may have been given in the country of production. Green certificates entitle countries with exemption of Regulatory Energy Tax (eco tax) and production support Feedback Eco tax. Issuing bodies in the RECS scheme can provide measuring data about production to the Dutch issuer of green certificates (TenneT). Details can be found on the web site of Groencertificatenbeheer, www.groencertificatenbeheer.nl/UK/fsne

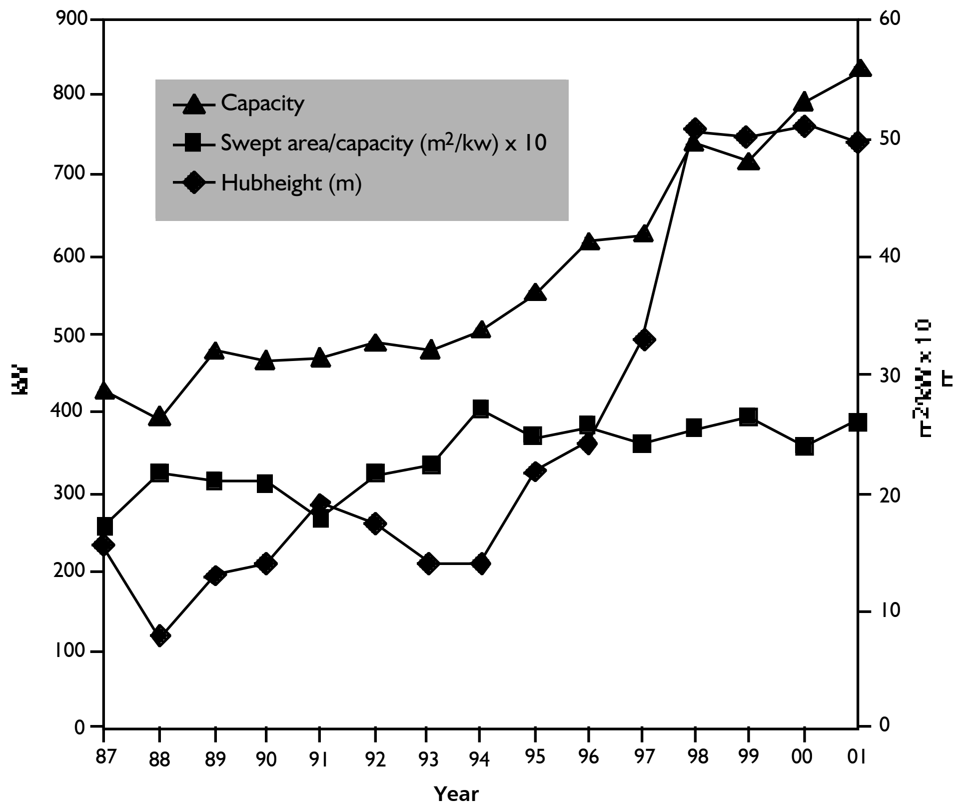

Figure 17.2 Average characteristics of installed turbines

wsUK.html. The eco tax in 2002 is the same as in 2001.

17.4.2 Unit Cost

Like the year 2000, there are no reliable statistical data for 2001. Indications can be maintained for 10-MW to 20-MW projects with 1.5-MW turbines at 1,900.00 NLG/kW for turbines, 200.00 NLG/kW for electrical infrastructure, and 200.00 NLG/kW for project development. Average estimations for large and small projects are 2,100.00 NLG/kW installed and 1,800.00 NLG/kW for turbines.

17.5 DEPLOYMENT AND CHALLENGES

17.5.1 Wind Turbines Deployed

Of the installed wind turbines in 2000, 49% are from Vestas, followed by 39% from NEG-Micon. One new turbine type was the Nordex N43/600.

In 2001, one 9.2-MW wind farm was installed consisting of 14 Vestas wind turbines of 660 kW in the western harbor area of Amsterdam (of which ten wind turbines were mistakenly reported to be installed in 2000). Another farm consists of nine NEG-Micon, 750-kW turbines. The remainder consists of various groups of two to four turbines and solitary turbines (see Table 17.5).

Year	Eco tax [NLG/kWh]			Feed back Eco tax [NLG/kWh]
Range	0-10000 kWh	10000-50000 kWh	50000 and more kWh	
1998	0.0295	0.0295	0.0000	0.0295
1999	0.0495	0.0323	0.0022	0.0323
2000	0.0820	0.0354	0.0048	0.0354
2001	0.1285	0.0427	0.0131	0.0427
2002	0.1324	0.0441	0.0134	0.0441

Table 17.3 Eco tax (Regulerende Energiebelasting)

17.5.2 Operational Experience

There were no major incidents or accidents in 2000.

17.5.3 Main Challenges in Market Development

The main challenge is still securing enough locations to put up wind turbines. The disappointing growth in installed capacity is the subject of political and public debate. To resolve the issue of spatial planning, the government has considered directives to appoint locations for wind farms. Following intense discussions, the parliament announced actions in this direction in 2000. After consultation between the government and the provinces, it was agreed not to follow this course but to conclude to a new agreement as a follow up of the agreement between the government and the

Manufacturer	Turbines [-]	Installed [MW]	Installed [%]	Rotor area [m²]
NEG-Micon	27	20.7	49%	52.233
Vestas	25	16.5	39%	44.184
Nordex	4	2.4	6%	5.809
Bonus	5	1.8	4%	5.156
Enercon	1	0.6	1%	1.521
Lagerwey	1	0.3	1%	707
Total	63	42.3	100%	109.609

Table 17.4 Distribution of new wind turbines by manufacturer

Wind farm	Manufacturer	Turbines	Height	Diameter	Capacity	Swept area
		[-]	[m]	[m]	[MW]	[m²]
Amsterdam, Havens West	Vestas	V47-660/200	65	47	9.2	24,289
Biddinghuizen, Alikruikweg	NEG-Micon	NM 48/750	70	48	6.8	16,422
Lelystad, Knarweg	NEG-Micon	NM 900/52	55	52	3.6	8,495
Workum	NEG-Micon	NM 48/600	40	48	2.4	7,238
Meedhuizen	Nordex	N 43/600	40	43	2.4	5,809
Borssele	Vestas	V47-660/200	65	47	2.0	5,205
Zeewolde	NEG-Micon	NM 900/52	55	52	2.7	6,420
Amsterdam, Havens West	Vestas	V47-660/200	65	47	2.0	5,205
Westernieland	Vestas	V47-660/200	40	47	1.3	3,470
Spijk	Vestas	V47-660/200	40	52	1.3	4,280
Ferwerd	Bonus	B 33/300	30	33	0.6	1,711
Various solitary turbines	Danish/Dutch/ German	-	-	-	8.0	21,065
Total					42.3	109,609

Table 17.5 Size of wind plants installed in 2000

provinces. In 2002, the Administrative Agreement National Development Wind Energy was signed by the ministers of Housing, Spatial Planning, and the Environment; the ministry of Economic Affairs; the sub secretary of state of Agriculture, Nature Management, and Fishing; and the sub secretary of state of Traffic and Waterstate. Co-signing were the provinces and the Association of Dutch Communities. The agreement is directed to the task of 1,500 MW of wind capacity on land in 2010.

17.6 ECONOMICS

17.6.1 Trends in Investment

Although trends in investment for 2001 are not entirely clear, based on an average price of 2,100.00 NLG/kW, the investment in wind turbines totaled 89 million NLG in 2001.

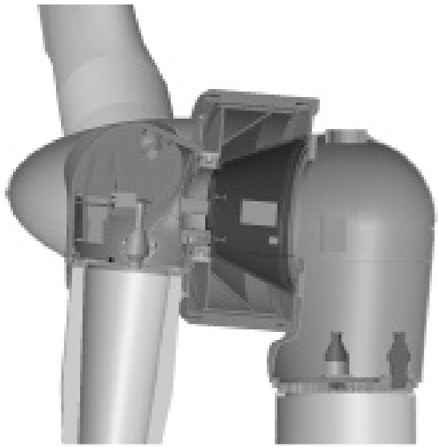

Figure 17.3 Lagerwey 1.5–2 MW turbine, nacelle, and hub

17.6.2 Trends in Cost of Energy and Buy-Back Prices

The total pay-back rate offered by energy companies for five-to-ten-year contracts in 2000 was between 0.15 NLG/kWh and 0.175 NLG/kWh (0.068 Euros/kWh to 0.080 Euros/kWh). Due to the intense marketing campaigns for green electricity of the energy companies this year and the free market for green energy, the demand for green electricity grew approximately 40%. At the end of 2001 there were about 800,000 households that bought green electricity.

17.7 INDUSTRY

17.7.1 Manufacturing

In January, blade manufacturer Aerpac went bankrupt. The factory in Almelo and some assets were sold to Enron wind of Germany. In September, LM Glasfiber Holland announced that it would close their blade production facility in Heerhugowaard in December 2001. The large blades for the Northern European market could not be produced in Heerhugowaard. LM Glasfiber Holland will stay in existence with departments of engineering, service, and maintenance.

Lagerwey has finished the design and component tests of its 1.5-MW to 2-MW Zephyros turbine with advanced direct drive technology. The machine features a 3-kV, permanent magnet direct-drive generator, developed in close cooperation with ABB Finland. Additional features include a 70-m diameter, a rotor speed of 18 rpm to 24 rpm, individually pitched blades, and full ac/dc/ac conversion based on IGCT technology from ABB. The first prototype will be erected mid March 2002 on the Maasvlakte facing the North Sea.

17.7.2 Industry Development and Structure

Former management and employees of Aerpac started three new companies: CTC Technology, which is active in the sale of blade manufacturing technology, and NGUP, which is active in sales of production technology, maintenance of blades, and optimization of output of wind turbines through various blade control. Some other employees started the production of molds in a company that is owned by Suzlon of India.

In 2001, several consortia were founded that will apply for the building permit of the 100-MW demonstration NSW. One is Noordzeewind, which consists of Shell Renewables and the energy company NUON. Another is North Sea Wind Power, consisting of Siemens Renewables; the offshore company Van Oort ACZ; the building company Heijmans; and energy companies ENECO, Essent, and RABO Bank. The final three companies applying for the permit are E.ON Benelux, Electrabel Nederland, and E-Connection, each of which announced that they will apply with various partners.

17.8 GOVERNMENT-SPONSORED R,D&D

Novem's wind program ended in the year 2000. In 2001, Novem began carrying out the Renewable Energy program in which all renewable options compete for subsidy in a tender process. From the 20 million NLG subsidy available for renewable energy, about 3 million NLG was allocated to wind energy projects.

17.8.1 Priorities

The Netherlands' R&D-strategy Wind Energy 1999-2003 (NRW) is still the background for the research programs of the Netherlands Energy Research Foundation (ECN) and Delft University of Technology (DUT) in 2001. The priority subjects are as follows.

- 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

17.8.2 New R,D&D Developments

In a feasibility study, P&R Systems of IJmuiden has researched the possibilities of an Offshore Access System. The technical principle is based on the installation of a stable but flexible gangway from a service vessel to the wind turbine without the transfer of uncontrolled loads.

The Offshore Access System uses a dynamic positioned vessel, which keeps the vessel in a fixed position, although it swings and rolls on the waves. On the vessel is a pedestal with boom suspen-

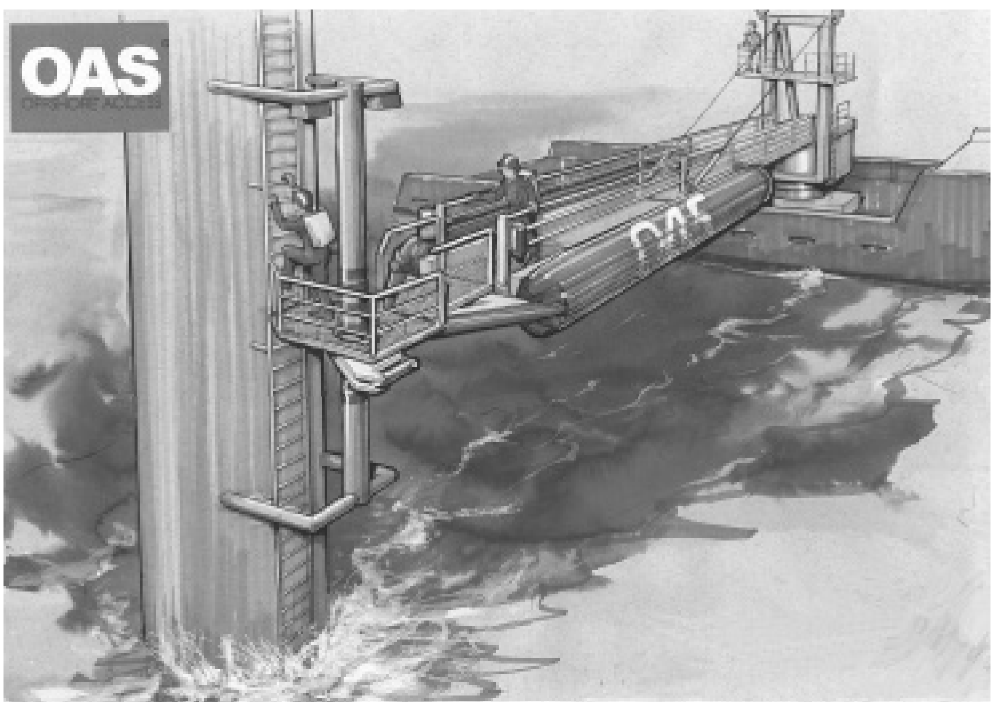

Figure 17.5 Artists impression of the Offshore Access System

sion, a telescopic boom arrangement with cushion arrangement at the outside boom-tip with a hydraulic clamp. On the turbine foundation is a vertical interface bar, a vertical ladder mounted on the rear side of the interface bar. The end of the gangway moves towards the turbine tower. With the help hydraulic drive units and a sensor that fixes on the contact point of the tower, the motion of the end of the gangway resulting form the movements of the vessel are compensated such that it can fix on the vertical interface bar on the tower. The pressure of the hydraulic drive units is then switched to zero to prevent the introduction of load transmission between elements of the system. The system is designed for use with wave heights up to 3 m, compared to more traditional ship-based systems of 1 m to 1.5 m. This increases the accessibility of an offshore wind farm – like the one 15 km off the shore of Egmond aan Zee – from 150 days to 350 days per year. This in turn can increase the availability of the entire wind farm, which leads to a higher yearly output. A prototype of the system is expected in 2002.

17.8.3 Offshore Siting

In October, the government issued the final draft of the Spatial Core Decision (Vijfde Nota Ruimtelijke Ordening), which designates an area on the Dutch continental shelf for 6,000 MW of wind capacity. It announced that before the end of 2003, a concession regime should be in place to allocate areas where wind developers can build offshore wind farms.

Also in October, the government published the selection rules for the 100-MW demonstration NSW to be build offshore near Egmond aan Zee. Conrsortia were invited to submit their plans before 11 January 2002. The winning consortium will be entitled to apply for the building permit. The permit criteria are the strength of consortium; the quality of the project plan; the quality of the financial plan; the quality of the measuring and evaluation program; and the amount of subsidy requested, with a maximum of 60 million NLG. The Measuring and Evaluation Programme (MEP) describes the required and recommended measurements to be carried out in the area of technology and economy and the area of nature, environment, and other use functions.

The main features of the NSW are laid down in the Spatial Planning Procedure (SPP). The second and first houses of parliament approved the final version in December 2001. Among other things, these features arise from the gaps in knowledge established in the Environmental Impact Statement. Novem elaborated the learning objectives in this NSW-MEP. It made an inventory of the learning objectives of all directly involved parties – government, lobbyists, and commercial companies – in order to gain a full impression of the desired content of the NSW-MEP. 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 of the Ministry of Economic Affairs at www.nearshorewindpark.ez.nl.

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CHAPTER 18

18.1 INTRODUCTION

The following information is a summary of activities since the 1998 IEA Wind Energy annual report.

New Zealand has a wealth of renewable energy resources. The availability of hydro, geothermal, wind, bio-energy, and solar resources is sufficient to supply New Zealand's four million residents with an entirely renewable energy supply. Renewables provide 29% of total consumer energy and approximately 70% of the electricity supply.

New Zealand's position in the "roaring forties" latitudes provides the country with an exceptional wind energy resource. A number of sites in the lower North Island offer annual mean wind speeds of 9 m/s to 10 m/s, several even higher. Technical availability of wind energy is estimated at 100 TWh per year, almost three times the present electricity demand. Commercial availability, considering sites that could deliver wind power for less than 0.10 New Zealand Dollars (NZD)/kWh, is estimated at 8 TWh per year, requiring approximately 2500 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 – they comprise the 3.5-MW Hau Nui wind farm near Martinborough and the 32-MW Tararua wind farm near Palmerston North.

The New Zealand electricity industry has undergone major structural reform in the past three 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. This reform was considered by many as detrimental to the commercialization of wind power, in part due to restrictions imposed on ownership of generation assets by the network companies. However, in 2001 this rule was relaxed 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.

Between February 2000 and June 2000, the government carried out a ministerial inquiry into the electricity industry. The inquiry's recommendations covered a wide range of wholesale market, transmission, distribution, and retail issues. Many of these findings were adopted by the government in its Power Package of October 2000, including the formation of an Electricity Governance Board as a primary governing body of the industry. The package also included an Energy Policy Framework statement that noted one of the objectives was "environmental sustainability, including . . . a progressive transition to renewable sources of energy."

These reforms have 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. The Act 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).

Electricity prices are particularly sensitive to variations in catchment lake levels, given the high proportion of hydro-electric generation. Shortages due to low lake levels in mid-2001 were averted by a nationwide, ten-week power saving campaign led by the Minister of Energy and the EECA. Meanwhile, high rainfalls in the latter months of 2001 have restored these lake levels.

18.2 NATIONAL POLICY

18.2.1 Strategy

The core government policy for energy is to ensure its delivery in an efficient, fair, reliable, and environmentally sustainable manner to all consumers. However, direct government funding is not available for the development or assistance of renewable energy. Meanwhile, EECA is funded by the government for the purpose of promoting 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 NEECS was released by the Minister of Energy on 27 September 2001. It sets two specific targets, listed below.

- A 20% improvement in energy efficiency by 2012
- Increasing the supply of renewable energy by an additional 19% to 42% (over "business as usual") by 2012, which equates to a growth in renewable energy supply of between 25 and 55 PJ of consumer 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 in meeting its international climate change commitments.

While the renewable energy target is a welcome move, targets that can be quantified have not yet been set for the electricity sector (as a subset of consumer energy supply). The full strategy is available from the EECA website www.eeca.govt.nz.

18.2.2 Progress Towards National Targets

Specific renewables targets and associated mechanisms will be set after further analysis and consultation over NEECS. It is unlikely that a specific target for wind power will be made.

18.3 COMMERCIAL IMPLEMENTATION

18.3.1 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, which are detailed below.

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.

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.

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 approximately 130 GWh annually, making this wind EDfarm the largest in the southern hemisphere.

18.3.2 Rates and Trends in Deployment

Pre-feasibility studies and site monitoring for a number of further projects have taken place over the last decade. However, no new projects are actively underway. A second stage of the Tararua wind farm, involving an additional 36 MW of wind plant, is ready to proceed subject to the following two items.

- Improvement in the foreign exchange rate for the imported wind turbines
- Improvement and certainty in long-term electricity prices, which depends on how many of the recent gas-fired CCGT generation project proposals go ahead, and on the impacts of New Zealand's climate change commitments

18.3.3 Contribution to National Energy Demand

Wind-generated electricity contributes approximately 145 GWh annually to New Zealand's grid. This represents 0.38% of the total annual generation of approximately 38 TWh each year.

Windfarm	Location	No.	Type	Capacity MW	Commis-sioned	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 18.1 Summary of utility-scale New Zealand wind plant installations as of 31 December 2001

18.4 MARKET DEVELOPMENT AND STIMULATION

18.4.1 Support Initiatives and Market Stimulation Incentives

It is likely that specific initiatives will be needed to achieve the NEECS renewable energy targets. This is the subject of a work program being carried out by EECA and the Ministry for the Environment. Meanwhile, no market support or stimulation incentives are currently in place.

18.4.2 Unit Cost

The unit cost of wind energy at the most cost-effective sites in New Zealand lies between 0.05NZD/kWh and 0.08NZD/kWh, representing some of the cheapest unsubsidized wind power in the world. However, a low exchange rate at the present time 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 construct a demonstration turbine in 2002.

18.5 DEPLOYMENT AND CONSTRAINTS

18.5.1 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 which is provided in Section 18.3.1).

18.5.2 Operational Experience

A total of 160 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.

18.5.3 Main Constraints on Market Development

As listed below, there are a number of 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
- 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)
- Attention 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
- Four new CCGT plants have been proposed, with the potential to defer the need for other new generation, including renewables
- Higher funding within EECA for energy efficiency programs over new renewables
- Significant anti-renewables bias, evident in the IEA report, Energy Policies of IEA Countries – New Zealand 2001 (production of this document involved some government officials)
- Growing opposition from business and farming lobbies to New Zealand's ratification of Kyoto Protocol
- Lack of any market support incentives and 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 have yet to be implemented

18.6 ECONOMICS

18.6.1 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.

18.6.2 Trends in Cost of Energy and Buy-Back Prices

Table 18.2 outlines the selling prices for electricity for the year to March 2000.

M-Co provides a website at www.nzelectricity.co.nz with the spot, daily, weekly, and monthly prices for the New Zealand electricity sector. Significant variation is seen according to seasonal parameters such as lake level inflows. In recent years, the cost of generation has averaged 0.045NZD/kWh for electricity.

18.7 INDUSTRY

18.7.1 Manufacturing

New Zealand has a good manufacturing infrastructure to support any wind turbine assembly needs. Towers for the early 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 manufacturing.

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.

18.7.2 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.

Vortec Energy Ltd. formed in the mid-1990s in an attempt to commercialize a diffuser augmented wind turbine design. Despite high-profile efforts to develop this design from its Grumman Aerospace beginnings, and prove the worth of the technology, the company ceased trading

Residential Incl. 12.5% tax	Residential Excl. 12.5% tax	Commercial Excl. 12.5% tax	Industrial Excl. 12.5% tax	National Average
		NZ cents per kWh		
13.31	11.83	9.49	6.64	9.52

Table 18.2 Electricity consumer prices (source: New Zealand Ministry of Economic Development, Energy Data File, July 2001)

in June 2001. Some disappointment is felt that one promising application, for sub-sea generation, was not fully explored.

Meanwhile, Windflow Technology Ltd. has 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, late in 2002. Local content is being maximized, including rotor blade manufacturing in Auckland.

18.8 GOVERNMENT-SPONSORED R,D&D

18.8.1 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. While the energy portfolio is geared to support renewable energy technologies, it is notable that wind power has received only a small percentage of this funding in recent years. For example, some 4% of recent New and Emerging Energy Technology (NEET) funding has gone to wind power projects. A recent NEET funding round was five times over-subscribed, with the New Zealand Wind Energy Association-backed proposal being declined.

18.8.2 New R,D&D Developments

Windflow Technology Ltd. is developing a wind turbine design as described in the previous section.

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.

Several New Zealand organizations are actively engaged in wind energy research, through programs with the Australian Cooperative Research Centre for Renewable Energy (ACRE).

18.8.3 Offshore Siting

Potential offshore wind farm sites are available around the New Zealand coastline, however these are not being pursued at the present time.

References:

Windflow Technology Limited http://www.windflow.co.nz

Energy Efficiency and Conservation Authority, www.eeca.govt.nz

Ministry of Economic Development, www.med.govt.nz

Foundation for Research, Science, and Technology, www.frst.govt.nz

The MarketPlace Company, www.m-co.co.nz

Windfarm Developer, www.windfarmdevelopments.co.nz

Author: Trevor Nash, Prowind Energy Limited, New Zealand.

CHAPTER 19

19.1 INTRODUCTION

In 2001, one wind farm of 4 MW was erected. Three other wind farms, totaling 83 MW, were granted building permission and public financial support, and these farms will be built during 2002. The planning and construction work to establish a test station for wind turbines has also started, and it will include both large and small installations. In addition, several other commercial projects were notified during 2001. The interest for wind power as a commercial source of electricity is still high. However, financing and public acceptance remain substantial hurdles.

19.2 NATIONAL POLICY

19.2.1 Strategy

Most of the electricity production in Norway is based on hydro-power. The remaining new hydro-power projects are limited both in size and quantity B thus, 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 per year by 2010. This represents approximately 1,000 MW to 1,100 MW of installed capacity, at average availability at the most favorable sites.

With the current market situation, these wind farms might require financial support of up to 2 billion NOK. In 2001, energy production based on wind energy was approximately 30 GWh, with an estimated full-year production of 37 GWh.

19.2.2 Progress Towards National Targets

One wind farm of 4 MW was built during 2001. Two major wind farms, each at 40 MW, have received both permission and financial support and will most likely be erected during 2002. A prototype, 3-MW, Scanwind-type turbine will also be completed during 2002. In addition, several projects have received building permission during 2001. Further development depends on annual grants in coming years.

19.3 COMMERCIAL IMPLEMENTATION

19.3.1 Installed Capacity

One wind power project was commissioned during November 2001, which increased the total national installed capacity from 13 MW to 17 MW. The wind farm consists of five turbines, each rated 800 kW, and it is located on the western coast of Norway, near the town of Måløy. Estimated production is 16.8 GWh per year.

An overview of Norwegian wind turbines and energy production in 2001 and accumulated is shown in Table 19.1. The production is slightly less than estimated, mainly due to wind conditions and some cases of mechanical and technical problems.

19.3.2 Rates and Trends in Deployment

As shown in Table 19.1, the deployment trend is rather slow. However, the two wind farms now under construction, rated 40 MW per year and 120 GWh per year, will represent a first major leap towards reaching the national target of 3 TWh per year by 2010.

19.3.3 Contribution to National Energy Demand

The total Norwegian electricity generating capacity is approximately 28 GW, of which 98.9% is hydro-power. The mean

Wind Turbine Projects	Year	No. Units	Total Power KW	Production 2001 GWh	Accum. Production GWh
Frøya	1986	1	55	0	1.949
Frøya	1989	1	400	0.574	9.273
Vallersund	1987	1	75	0.150	2.591
Kleppe	1988	1	55	0.037	0.591
Smøla	1989	1	300	0.511	7.589
Andøya	1991	1	400	0.876	9.874
Vesterålen	1991	1	400	0.810	10.848
Vikna I & II	91/93	5	2200	5.695	60.557
Hundhammarfjellet	1998	1	1650	3.248	12.544
Lindesnes	1998	5	3750	7.863	32.394
Sandøy	1999	5	3750	8.596	18.580
Kvalheim	2001	5	4000	2.181	2.181
TOTAL		28	17035	30.54	168.971

Table 19.1 Norwegian wind turbine projects and energy production

energy production from hydro-power is 118 TWh per year. Thus, the contribution from wind power is merely 0.03% of the total production capacity.

19.4 MARKET DEVELOPMENT AND STIMULATION

19.4.1 Support Initiatives and Market Stimulation Incentives

In order to enhance the introduction of wind energy in Norway, several measures were introduced in early 1999. One is the exemption for wind turbines and related equipment from the 7% investment tax. Another measure is an energy production support, equaling half of the general electricity levy (0.0565 NOK/kWh in 2001). There is still a need for additional financial support, which has been given to projects based on a cost-benefit comparison between projects. One common criteria related to these measures is that each unit should be at least 500 kW, and the total project installation should be at least 1.5 MW.

19.5 DEPLOYMENT AND CONSTRAINTS

19.5.1 Wind Turbines Deployed

See Section 19.3.1 and Table 19.1.

19.5.2 Operational Experience

No serious incidents have occurred, although some cases of fatigue in the gearboxes have been reported.

19.5.3 Main Constraints on Market Development

In recent years, interest in wind energy has increased, and several projects are being considered. However, the main constraint has been the low energy price, both long term and short term. Visual and environmental concerns are also major factors, which limits the possible deployment of wind energy in Norway. Many of the possible wind farm sites along the coast also play an important role as recreational areas to both tourists and the local population. The coastal areas are quite densely populated, by Norwegian standards, which makes it harder to find favorable sites that do not interfere with already-existing buildings or the landscape. However, choosing areas farther away from the population reduces the number of locations with sufficient grid capacity and other infrastructure (e.g., roads).

19.6 ECONOMICS

19.6.1 Trends in Investment

The unit cost of the Norwegian wind turbines erected in 2001 is approximately 9,200.00 NOK/kW, including infrastructure and grid connection.

19.6.2 Trends in Cost of Energy and Buy-Back Prices

The Norwegian spot market price of electricity at the main grid level is shown in Figure 19.1. The average price on a yearly basis did steadily decrease during 1997 through 2000, from 135.00 NOK/MWh in 1997 to 103.00 NOK/MWh in 2000. However, in 2001, the average price was up to 187.00 NOK/MWh. This price has represented the typical buy-back price for wind-generated electricity, delivered into the grid transmission system.

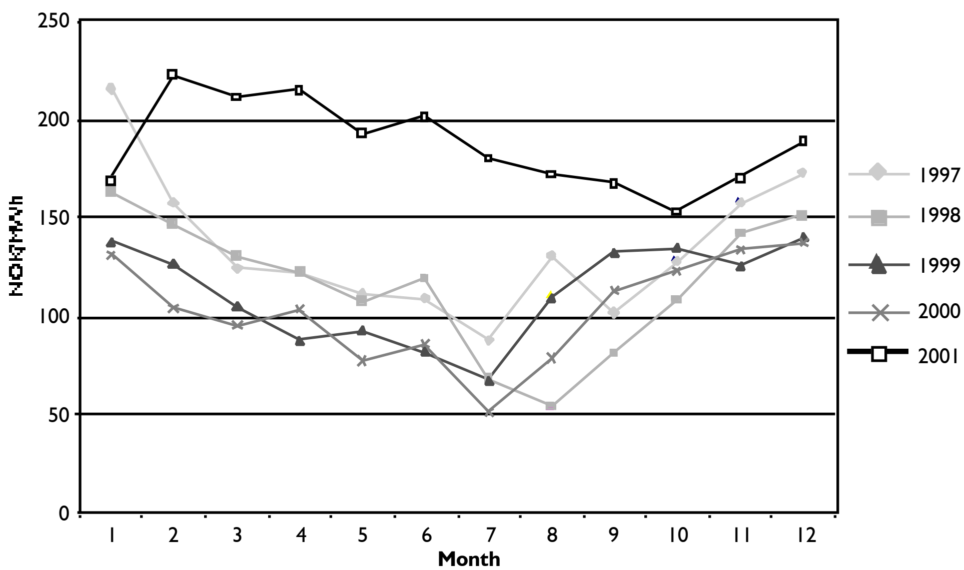

Figure 19.1 Spot market price of electricity 1997-2001

However, interesting commercial agreements were made during 2001, 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 increase in the years to come.

Apart from the consideration of the spot market price the customer must include, costs cover transmission and taxes to estimate the resulting wind energy 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 with the shown spot market electricity price, wind energy cannot yet compete on commercial terms. However, compared with the price of new hydro-power projects, some wind energy projects are almost competitive.

19.7 INDUSTRY

19.7.1 Manufacturing

There are at present no manufacturers of complete wind turbines in Norway, due mainly to the fact that the market for wind turbines has been too small. However, the Norwegian/Swedish company Scanwind AS is developing 3-MW wind turbines. The first prototype installations are expected to be ready during 2002.

The Umoe-group B a Norwegian-based investment company in maritime industry, shipping, and oil-service B recently decided to establish production of large blades to wind turbines. The production is located in Mandal, Norway, at the naval shipyard Umoe Mandal, a leading builder of advanced, naval, high-speed craft in composites. The company 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.

19.8 GOVERNMENT-SPONSORED R,D&D

19.8.1 Priorities

Norwegian Water Resources and Energy Directorate co-ordinate public support for projects in close collaboration with the Norwegian Research Council. The current priorities include projects quite close to market introduction, and researchers should have an industrial partner in the project, where appropriate.

19.8.2 New R,D&D Developments

The following wind energy related projects during 2001 were partly financed by the Norwegian Research Council and/or by the Norwegian Water Resources and Energy Directorate (NVE).

1. Test station for wind turbines

In order to assist the development of wind energy in Norway, SINTEF Energy Research, Institute for Energy Technology (IFE), and the University in Trondheim (NTNU) have taken a joint imitative to develop a test station for wind turbines. Both permission and funding was granted by NVE during 2001, and installation work will take place in 2002. The test station will be located on the west coast of Mid-Norway, which has an annual average wind speed of approximately 8.4 m/s at 50 m above ground level and excellent conditions for testing large wind turbines. The development is considered an important step in building know-how and as a support to the wind energy industry, intending to cater the emerging Norwegian market.

2. Forecasting

A project with the Norwegian Meteorological Institute, IFE, and Kjeller

Vindteknikk AS started in the beginning of the year 2001. The aim of the project is to develop and test techniques for short-term forecasting of wind energy production. One of the main focuses of the project is to investigate the benefit of introducing one or two additional steps of physical modeling between the Numerical Weather Prediction Model (HIRLAM) and local winds in this context. The meso-scale model MM5 has been tested for several cases and compared with observations.

The research project, Development of Norwegian Wind Energy Technology Project participants are SINTEF (coordinator), IFE, NTNU, and industrial partners. Together these groups have formulated a joint R&D project to further enhance the building of know-how required for rational development of wind energy in Norway. The project was started mid 2001 with public funding and Norwegian industry funding, and it will continue for a five-year period. Part of the project includes tasks related to forecasting and aerodynamic and structural design of wind turbines. The first project is mainly a PhD-work, focused on turbulence modeling of wind fields in complex terrain. The second task includes wind turbine rotor design. The code XFOIL was used for the investigation of different 2-D-rotorblade sections. Results were used in a Blade-Element-Model program (BLADES) in some initial rotor designs for a pitch-regulated, 30-kW windmill.

3. The Strategic Institute Program (SIP) at the Institute for Energy Technology (IFE)

Activities are focused on the further development of the micro-scale flow solver 3DWind (i.e., improvement of pre/post processing and solver algorithms). The numerical model was further ported and tested on Windows and Linux/Unix operating systems.

Author: Harald Birkeland, Norwegian Water Resources and Energy Directorate, Norway.

CHAPTER 20

20.1 INTRODUCTION

Wind energy in Spain continues the growth started several years ago and is taking a leading position in the world together with Germany and the United States. At the end of the year 2001, the total power in operation in Spain was 3,200 MW. The electricity generation by wind energy represents more than 3% of the total electricity, and plans for the future show the possibility of reaching 9,000 MW grid connected at the end of the year 2010.

One of the reasons to explain this growth is the existence of a stable legal framework for electricity producers using renewable energy sources. The regulations contained in the Special Regime of the Electrical Sector Act imply that electricity producers using wind have guaranteed access to the grid. The price per kilowatt-hour generated has a bonus over the sale price of electricity.

Energy balance in the Electricity System	2000	2001	Incr. 2001/2000
Source	GWh	GWh	(%)
Hydro	27,842	39,538	42.0
Nuclear	62.206	63,718	2.4
Coal	76,374	68,029	-10.9
Oil	5,869	6,418	9.4
Gas	4,380	5,240	19.6
Special Regime (including renewables	26,613	30,411	14.3
Electricity Demand	194,992	205,414	5.4

Table 20.1 Energy balance in 2000 and 2001(source: Red Eléctrica de España)

New manufacturers, investors, producers, and researchers have been incorporated to the wind energy business in the last year.

20.2 NATIONAL POLICY

Spain is a country with a strong dependency on external energy sources because there are no oil fields or gas fields within Spanish territory. A few coal mines exist, but they unfortunately have low-quality coal. The following table shows the energy balance in the mainland electricity system during the years 2000 and 2001. During the year 2001, the electricity demand was 5.4% higher than the previous year, with an amount of 205.414 GWh.

During 2001, the electricity produced by hydro represented 19.2% of the demand, nuclear represented 31%, coal represented 33.1%, and the electricity produced inside the Special Regime (which includes co-generation, small hydro, and renewable energy) represented 14.8%. During December 2001, a peak value in the demand took place, and a regulation of the system was necessary in order to maintain stability.

The wind energy target for the year 2010 is to reach 8,974 MW installed, with an average production of 21.5 TWh per year.

20.2.1 Strategy

The strategy of the Spanish government is summarized in the new Program for Promotion of Renewable Energies (PPRE), approved by the parliament. It maintains the situation of the Royal Law 2818/1998-23 December 1998 about the Electrical Special Regime for Renewable Energy Plants connected to the grid. That law

Figure 20.1 The 1-MW class wind turbine, ECOTECNIA

fixed the price and the bonus of electricity produced by renewable energy plants – a price that will be updated every year by the Spanish Ministry of Energy and Industry according to market price annual variation.

This program 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 defines the target of achieving at least a 12% contribution to electricity demand in Spain from renewable energies by the year 2010. The work was, at the same time, the Spanish incorporation of the European recommendations made in the White Paper on Renewable Energies.

The target of the PPER from 1999 to 2010 is to install 5,540 MW in the seven-year period from 1999 to 2006, and another 2,600 MW between 2007 and 2010 (650 MW per year). In total, 8,140 MW must be added to the existing 834 MW by 31 December 1999 in order to reach 8,974 MW for the year 2010. Table 20.2 shows the share by autonomous communities.

Other actions included in the PPRE are as follows.

- New R,D&D national program for large and small wind turbines
- Financing improvement for evacuation grids
- Regulation of the administrative procedures for renewable energy power plants

AUTONOMOUS COMMUNITY	P.P.R.E. TARGET FOR 2000 (MW)
ANDALUCIA	1,100
ARAGÓN	1,000
ASTURIAS	300
ISLAS BALEARES	49
ISLAS CANARIAS	250
CANTABRIA	300
CASTILLA Y LEÓN	850
CASTILLA-LA MANCHA	400
CATALUÑA	425
EXTREMADURA	225
GALICIA	2,500
MADRID	50
MURCIA	300
NAVARRA	635
LA RIOJA	100
COMUNIDAD VALENCIANA	290
PAÍS VASCO	200
TOTAL	8,974

Table 20.2 Power target by autonomous communities

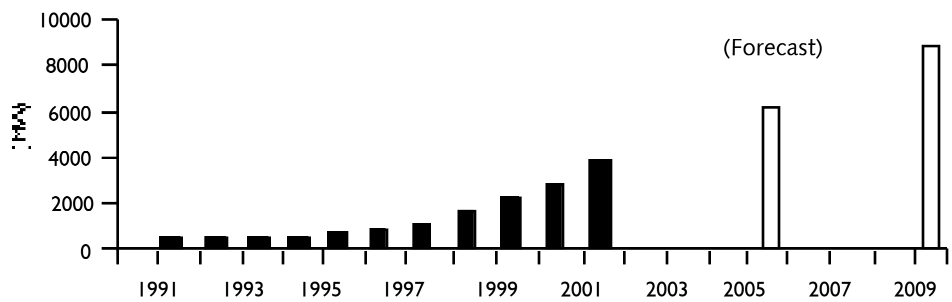

Figure 20.2 Wind installations in Spain: PPRE targets

- Support to the Spanish participation on the working groups for standards elaboration
- Information programs
- Educational programs

The PPRE is complemented with the new National Plan for Scientific Research, Development, and Technological Innovation (2000 to 2003).

20.2.2 Progress Towards National Targets

For the time being, 795 MW were installed in 2000, and another 8 MW in 2001. For the year 2002, there are more than 900 MW under construction. The target looks to be realistic, and in accordance with present data targets, it will be reached before planned. However, the majority of the autonomies have regional wind energy programs that have a total of more than 10,000 MW to be installed in the next decade (exceeding the PPRE target).

YEAR	POWER INSTALLED (MW)	ACCUMULATED POWER (MW)
1995	46	119
1996	95	214
1997	213	427
1998	407	834
1999	705	1,539
2000	795	2,334
2001	861	3,195

Table 20.3 Accumulated wind power

20.3 COMMERCIAL IMPLEMENTATION

20.3.1 Installed Capacity

In 2001, an additional 861 MW was installed, and the total power at the end of December 2001 was 3,195 MW.

20.3.2 Rates and Trends in Deployment

Annual power installed continues to grow. Figure 20.3 shows the annual power installed in Spain in the last years.

For 2002, annual power installed is estimated at more than 900 MW. The new wind farms are large and medium in size and are located in the mainland. They are primarily owned by consortiums formed by utilities, regional institutions implied in local development, private investors (national and foreign), and in some cases, manufacturers. Private individuals are not taking an important role in the development of wind energy in Spain.

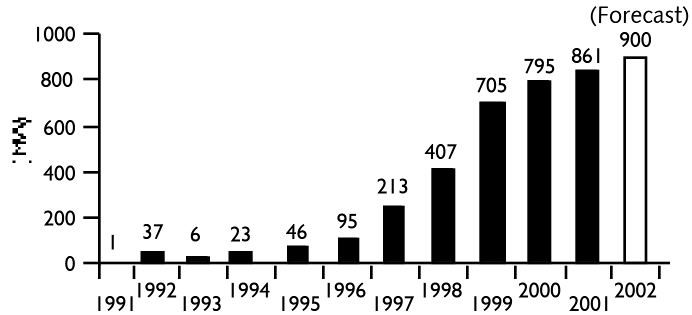

Figure 20.3 Annual power installed

Galicia, Castilla-La Mancha, Castilla Leon, and Navarra are the autonomous communities with more activity during 2001. It is important to point out that during the year 2001, another strategic wind energy plan was approved in Comunidad Valenciana in the east of the country that implies more than 2,000 MW of new wind farms under development by several promotors who have started activity in the region.

At the present time, almost all Spanish autonomies are involved in the incorporation of wind energy in their energetic structure.

Autonomous Communities	Total Power 31/12/2000 (MW)	Power total	Total Power 31/12/2001 (MW)
Andalucía	148	28	176
Aragón	234	108	342
Canarias	109	8	117
Castilla y León	215	196	411
Castilla La Mancha	323	98	421
Cataluña	71	0	71
Galicia	683	135	818
Murcia	11	0	11
Navarra	486	133	639
C. Valenciana	3	0	3
País Vasco	26	3	29
Principado de Asturias	0	83	83
La Rioja	24	50	74
Total	2,334	801	3,195

Table 20.4 Wind power installed distributed by autonomies

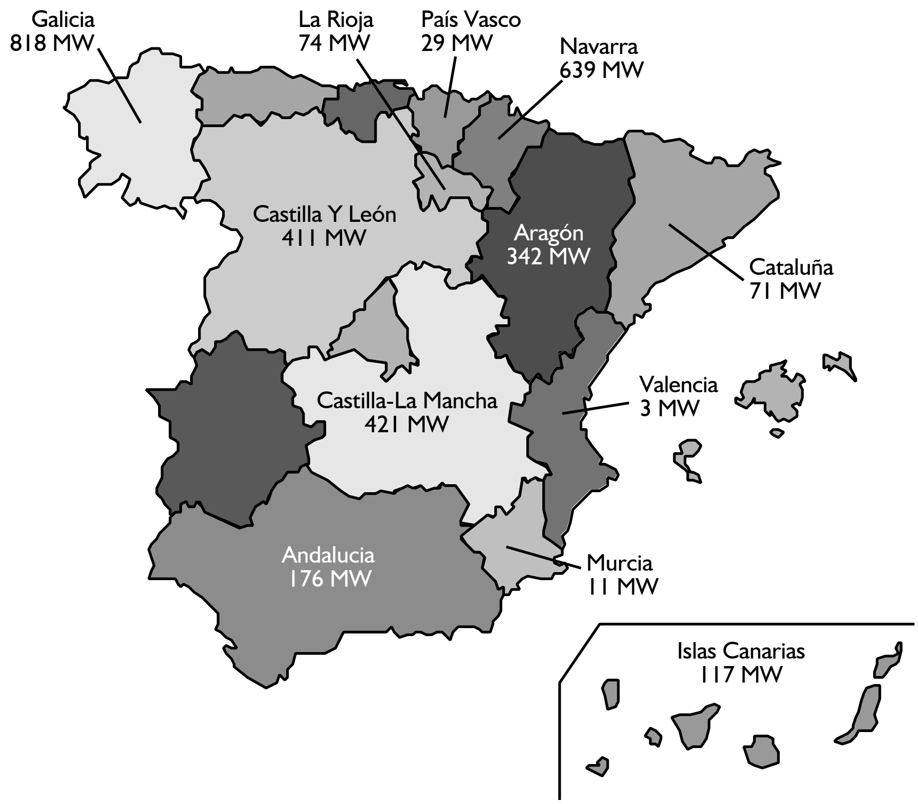

Figure 20.4 Regional distribution of wind installations (year-end 2001)

20.3.3 Contribution to National Energy Demand

The production data of wind power plants for 2001 was 6.692 GWh. (Reference: National Energy Commission, more than 2.880 MW of wind power considered). The total electricity demand in Spain in 2001 was 205.414 GWh (5.4% higher than in 2000).

The evolution of wind energy production was 2.696 GWh in 1999, 4.609 GWh in 2000, and 6.692 GWh in 2001. Wind electricity reached 3.26% of total electricity demand in the country.

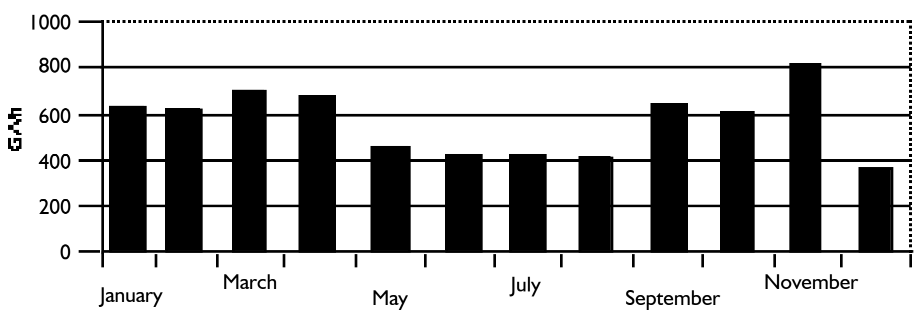

Figure 20.5 Monthly distribution of electricity produced by wind farms in 2001

Figure 20.6 Mtorres's 1.5-MW wind turbine

20.4 MARKET DEVELOPMENT AND STIMULATION

20.4.1 Support Initiatives and Market Stimulation Incentives

The main action for market stimulation is the price paid for the electricity generated by renewable energy sources, and it is regulated through two Royal Decrees (the latest approved in December 1998) that obligate utilities to pay a guaranteed price to renewable energy source generators for a five-year period. This price and the related bonus are revised and fixed every year according to the variation of the electricity market price.

20.5 DEPLOYMENT AND CONSTRAINTS

The strong growth of installed power is welcomed by society, which appreciates not only the contribution to environmental conservation but also the industrial development and associated job creation. Job creation is the most important item of wind energy for the Spanish population. Also, the benefits obtained at the local level (landowners and municipalities) favor the development of new installations.

The 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 have the obligation to allow the connection of wind turbines to the grid. Developers have to fulfil the technical requirements defined in the electrical law. The cost associated to the connection is the responsibility of the plant developer. There are not wide-spread complaints about the process to obtain permission for connection to the grid.

20.5.1 Wind Turbines Deployed

The wind turbines installed in 2001 in Spanish wind farms were between 850 kW and 1,750 kW. The largest wind turbine is the 1,750-kW Gamesa-Vestas. Only one wind farm is currently operational in Spain, with wind turbines of more than 1-MW capacity. At the El Aguila wind farm, 15 Nordex model N62, 1.3-MW wind turbines were put in operation during 2001. Construction of an additional wind farm using megawatt-class wind machines is also underway. A wind farm in Castilla Leon that will have 14 Made model AE61, 1.3-MW power has also been announced. Production of the new model of 2-MW (AE-80 model) turbines will begin during 2002. Table 20.5 shows the megawatt-class wind turbines under development in Spain.

20.5.2 Main Constraints on Market Development

In the last period, some opposition emerged against the installation of new

RENEWABLE SOURCE	BONUS ADDED TO THE BASE PRICE (Euro/kWh)	FIXED PRICE (Euro/kWh)
Small Hydro	0.030051	0.063827
Wind Plants	0.028969	0.062806
Primary Biomass *	0.027887	0.061724
Secondary Biomass *:	0.025781	0.059620

1 EURO= 166.4 Pts
(*)Primary Biomass: Agricultural crops
Secondary Biomass: Agricultural and Forest residues

Table 20.6 Buy-back electricity prices for renewable energy sources in 2002

wind farms in areas with strong development. Local ecologist groups complain about the landscape impact and the possible impact on bird life. This opposition causes delays in the permission of wind farms.

The main constraint on market development is the existing limitation on the capacity of the grid for energy evacuation. Generally, wind farms are located in areas with low-density population, and the grids are weak grids that require reinforcement and improvement. Concerted actions between utilities and developers are going on to solve the problem.

20.6 ECONOMICS

20.6.1 Trends in Cost of Energy and Buy-Back Prices

The Royal Law 2818/1998-23 December 1998, about the Electrical Special Regime for renewable energy plants connected to the grid, fixed the conditions of the plants to be included in this special regime. This law was a new step in the strategy for promoting the use of renewable energies, with the specific target that "the contribution of the renewable energies to the Spanish energetic demand will be at least 12% for the year 2010." All the installations using renewable energies as their primary source, with an 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 kilowatt-hours generated; and a second option is a variable price calculated from the average price of the market-pool, plus a bonus per kilowatt-hour produced. The fixed price and the bonus will be updated every year by the Spanish Ministry of Energy and Industry in accordance with the annual variation of the market price. The updated values for the year 2000 are presented in Table 20.6.

Prices will be maintained for the year 2001, even taking into account that the average electricity price in 2000 decreased nearly 2%.

20.7 INDUSTRY

Important activities in the wind energy field have activated the development of the Spanish wind industry, covering not only the manufacture of complete wind turbines but also the manufacture of components for the wind industry (such as blades, generators, gear boxes, towers, and wind sensors). The service sector (installation, maintenance, and engineering) has also grown in the last year.

20.7.1 Manufacturing

The companies that are leading the national Spanish industry are Gamesa Eólica, Ecotecnia, Made, Izar-Bonus, and Neg Micon. Additional manufacturers currently initiating activities in Spain are DeWind, Enron, and Nordex.

Gamesa Eólica is manufacturing wind turbines using Vestas technology. The majority of the components are manufactured in Spain (including blades). During the year 2001, Vestas sold its 40% share in Gamesa Eólica to the parent company. Gamesa Eólica will be free to use its technology in all world markets without restrictions. The new developments included wind turbines of 1,750-kW rated power and projects of G-80 of 2 MW. There are ten Gamesa Eólica factories working in the country.

Ecotecnia started wind technology development activities in 1981, having more than 19 years of experience in the field. The company has a technical staff of 60 persons, and two factories, one located in Somozas (La Coruña) and the other in Buñuel (Navarra), with a total of 120 workers. During 1999, Ecotecnia was incorporated to the MCC group, one of the world's largest co-operatives, with activities in the industrial, distribution, and financial sectors. The models on production, the ECO/640 kW and ECO/750 kW, are three blades stall control wind turbines, incorporating a very advanced design in the drive train. The company has in operation a new model of 1.3 MW and 60 m in diameter.

Made is another of the pioneer companies in Spain that has developed ten different models of wind turbines since 1982. The models range from the first design of a 24-kW turbine to the last, a AE-61, 1,320 kW machine. New designs – the Made AE/52 (800 kW) and Made AE/61 (1,320 kW) – started operation in November at the Monteahumada (Andalucia) and the Somoza (Galicia) wind farms. The Made AE/52 is a pitch-controlled wind turbine with a synchronous generator and variable-speed design. The AE/61 is a stall-controlled wind turbine with an asynchronous generator (four and six poles). A new, 2-MW model is planned.

New manufacturers are also emerging, such as Mtorres and EHN. Mtorres is a company with activity in the aeronautical field with a new model of 1.5-MW wind turbines, which is a direct drive multi pole model with permanent magnet. EHN is a big wind promoter that has designed and put into operation its own model of megawatt-class wind machines – a pitch-control, variable rpm turbine.

In the sector of small wind turbines, Bornay is the company leader, with more than 170 units installed during 2000 in Spanish territory and other countries (such as Germany, Portugal, Japan, and Tanzania). Bornay is manufacturing eight models from 60 W to 12 kW. The company has signed a contract with Atlantic Orient Corporation (AOC), of the United States, to distribute the 50-kW AOC wind turbine in Spain. Solener is another company manufacturing small wind turbines from 300 W to 15 kW.

20.7.2 Industry Development and Structure

New Spanish manufacturers are active in the wind energy industry, using foreign technology from Enron Wind Iberica, Nordex, or DeWind or developing their own technology like Mtorres company, that will increase the capacity of the Spanish industry to fulfil not only the internal market but also other markets.

Spanish manufacturers are participating at the present time in future projects in North Africa (areas such as Tunisia, Morocco, and Egypt) and also increasing marketing activities in other countries (India, China, and South-America). The wind industries are spread in the Spanish territory – almost all the autonomous communities are involved in the development of wind energy industry. New factories of components for the industry have been inaugurated during 2000.

20.8 GOVERNMENT-SPONSORED R,D&D

20.8.1 Priorities

A new National Plan for Scientific Research, Development and Technological Innovation (2000-2003) has been launched. The target areas defined in the plan 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

20.8.2 New R,D&D Developments

The centers and universities involved in R&D projects have continued and increased their activities during the year 2000 (see the list included in the 1999 Annual Report). The most important item during the year was the creation of a new, national center for the development of renewable energies that will be located in Pamplona (Navarra). The new center, Centro Nacional de Energias Renovables (CENER), has participation from the national center CIEMAT and will cover new activities in the field of renewable energy. The activities in wind energy will be focused on large wind turbine testing, blade developments, and control systems. The new center began activities during 2001.

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CHAPTER 21

21.1 INTRODUCTION

Sweden has a good wind energy resource, but deployment has been slow so far. In the last couple of years, however, deployment and development of wind power technology have sped up. One of the most important factors for wind energy deployment is the economic terms for renewables on the deregulated market, which are now being revised.

21.2 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 effect on health, the environment, and climate – while at the same time assisting the move toward 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 make the development and market introduction of alternative energy sources – as well as successful energy efficiency measures – of crucial importance.

Wind energy is one of the key elements in the transformation of Sweden's power system.

In May 2001, the Swedish National Energy Administration (SNEA) reported to the government an appointment to suggest a planning target for the implementation of wind power in Sweden. Furthermore, the administration was appointed to identify localizations especially suited for wind power. In the report, SNEA suggests a planning target of 10 TWh within ten to 15 years. A planning target had not yet been established as of the end of 2001.

The government is considering a system of green certificates to improve the conditions for electricity from renewable energy on the liberalized electricity market. At the end of 2001, an investigator reported the final proposal on the system to the government. The proposal includes specific support for existing wind turbines during a transitional period. This system is planned to be in place by 2003.

21.2.1 Strategy

An extensive energy policy program has been started in order 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.

More than one billion Euros have been allocated to the program, which consists of two parts. The first part is a seven-year research, development, and demonstration initiative aimed at promoting renewable energy sources, new conversion, and 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 ethanol from forestry raw materials; alternative motor fuels; wind power; and solar and energy efficiency in building, industry, and transport sectors.

The second part of the energy program is to replace the electricity production loss of about 4 TWh from Barseback nuclear power plant. This five-year, short-term subsidiary program is in progress to promote energy efficiency as well as electricity production from renewable energy sources such as bio-fuels, wind, and small hydro-power plants. Conversion of electrical heating to district heating is also promoted.

The total cost of the program 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 SNEA, which was formed on 1 January 1998.

As for wind energy, the government is supporting the development and installation of wind turbines in the following three programs, managed by SNEA.

- A fully financed research program with a three-year budget of 46.80 MSEK for 1998 to 2001. This program is presented in section 21.8.
- A development and demonstration program for wind systems, with a maximum of 50% support.
- An investment subsidy program that has been running since 1997 that has the possibility to receive 15% of the total investment cost. This program for 2001 and 2002 is now expanded and limited to 100.00 SEK for the year 2001 and to 100.00 MSEK for 2002.

The utilities are engaged in studies, demonstration, and evaluation projects. Since 1994, the research and development activities of utilities have been co-ordinated 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.

21.2.2 Progress Towards National Targets

The target of the five-year investment subsidy program (July 1997 to June 2002) is 0.5 TWh wind electricity production. The 2001 program was extended to the end of 2002 with an increased budget. When less than half of the program remains, the prognosis is that a total of 0.85 TWh will be reached when the program ends. The government has stated that a new national deployment target will be determined shortly.

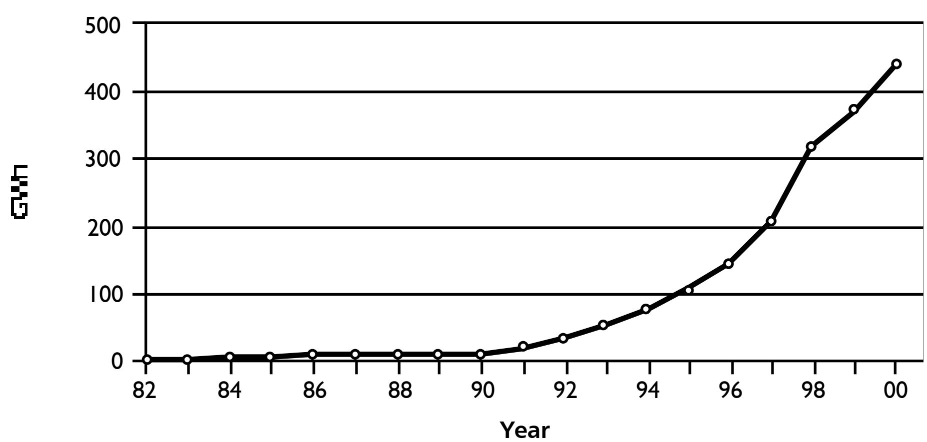

Figure 21.1 Wind power generation (GWh)

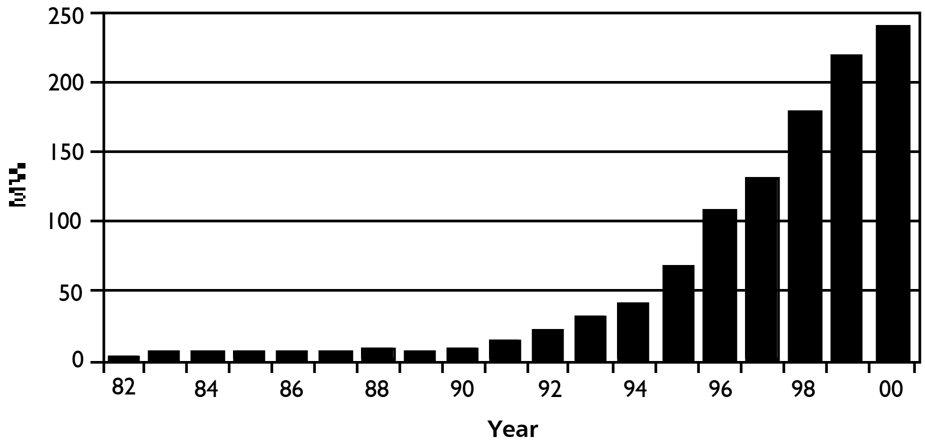

Figure 21.2 Wind power capacity (MW)

21.3 COMMERCIAL IMPLEMENTATION

21.3.1 Installed Capacity

Sweden's expansion of the annual power generation from wind turbines (in GWh) and the installed capacity (in MW) at 31 December of each year is shown in Figures 21.1 and 21.2.

The total installed wind power capacity in Sweden is 290 MW (as of 31 December 2001), an increase of 49 MW, or 20%, since 31 December 2000. The number of wind turbines increased during 2001 by 48 to 565 turbines, or 9%. Wind power generation during 2001 was 466 GWh, an increase of 448 GWh, or 4%, since 2000. The year 2001 was a low-wind year in Sweden – 88% of a normal wind year. The generation recalculated to a normal year is 530 GWh.

21.3.2 Rates and Trends in Deployment

No wind turbines in Sweden are erected today without the investment subsidy. Deployment has been generally evenly distributed over the years, since the investment subsidy budget is evenly dis-

	2001 MW	2001 TWh
Hydropower	16 229	77.9
Nuclear power	9 439	69.0
Thermal power production (CHP, cold condensing)	4 869	8.9
Wind power	241	0.47
Net import		-7.1
	30 778 MW	149.3 TWh

Table 21.1 Total installed electricity capacity and generation in Sweden for 2001

tributed. During 2001 the budget was 100.00 MSEK.

21.3.3 Contribution to National Energy Demand

Wind power contributes to the national energy demand with 0.3% of the total electricity consumption. The total installed electricity capacity and generation in Sweden is shown in Table 21.1.

21.4 MARKET DEVELOPMENT AND STIMULATION

21.4.1 Support Initiatives and Market Stimulation Incentives

During the 1990s, the Swedish electricity market was reformed in several ways. Since 1 January 1996, Sweden has had a liberalized electricity market, and all consumers are free to choose their electricity supplier. The objectives of the reform were to increase freedom of choice for electricity consumers and to create conditions for greater pressure on prices and costs in the electricity supply.

The successful deregulation of the Swedish and Nordic electricity markets has led to low electricity prices, and there is an obvious risk that renewables might lose market shares due to the low electricity prices. In 2001, however, prices were higher due to less rain and lower hydropower generation. The liberalization of the electricity and gas markets forces the industry to constantly strive for improving their efficiency and competitiveness.

Since 1 November 1999, wind energy producers have been competing on the same market as conventional electricity producers. The average North Pool price in Sweden during 2001 was 0.21 SEK/kWh. (See North Pool's homepage at www.nordpool.no under Elspot and then Monthly Prices.)

On top of that market price, the wind turbine owner receives by law an "environmental bonus," which was 0.181 SEK/kWh during 2001 (corresponding to the electricity tax for households). Additionally, a temporary support of 0.090 SEK/kWh will secure the economy of the "small-scale" electricity producers (with a maximum generator size of 1,500 kW). The wind turbine owner also gets an income from the net owner, related to the value of the decreased electricity net losses, which on average results in about 0.010 SEK/kWh to 0.015 SEK/kWh. The deregulated market also gives the possibility to the turbine owner to sell his electricity to any customer. This gives opportunity for a "wind electricity market."

A second market stimulation program, which amounts to 15% of the investment subsidy, began 1 July 1997. The investment subsidy has a budget of five and a half years, totaling 450.00 MSEK. By the end of 2001, SNEA had received applications for investment subsidies for projects with a total investment value of 4,476.00 MSEK, and the total granted subsidies amounted to 330.00 MSEK. The total subsidies granted for 2001 totaled 84.90 MSEK. These projects had a total capacity of 55 MW.

21.4.2 Unit Cost

The mean cost for 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; does not include 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.

21.5 DEPLOYMENT AND CONSTRAINTS

21.5.1 Wind Turbines Deployed

The wind turbines erected in Sweden from 1997 to 2001 have a capacity between 225 kW and 1,750 kW, with the majority of turbines operating at 600 kW (see Figure 21.3). They are mainly manufactured in Denmark or in Germany.

21.5.2 Operational Experience

According to Swedish wind turbine monthly and annual statistics, the average availability during 2000 was 98.8%. For each year from 1996 to 1999, availability was 97.8%, 98.4 %, 98.5%, and 98.3%, respectively.

21.5.3 Main Constraints on Market Development

Public attitudes toward wind power, especially its impact on the landscape, is an important factor that influences practically every wind project. Noise emission is also important but is considered more of a "technical" problem. So far, the impact on bird life has been minimal, but the question of migrating birds is being raised, as more offshore wind power plants are being planned. The issue of marine life in connection with offshore wind power has also been 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 flying at low altitudes.

1. Public attitudes

A row of investigations on the public attitude toward wind power plants has been carried out. The investigations have included both inhabitants and summer residents around the plants as well as politicians and civil servants from the municipalities. The majority of individuals interviewed showed a positive attitude toward wind power, but there were more doubts about wind power plants among residents in the summer house areas.

Public attitudes are also being investigated in a research project examining how attitudes can be improved – by public consultation in the permission process for wind power, for example.

2. Noise

Noise is a subject frequently discussed in wind turbine projects. The studies on assessment of wind turbine noise have shown that several factors are important

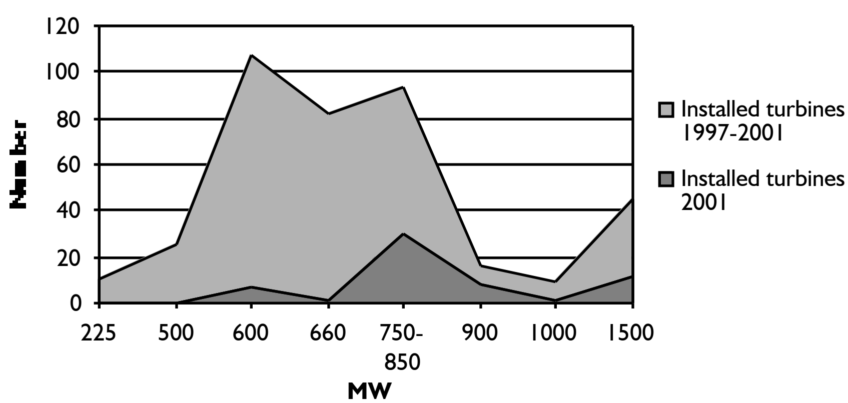

Figure 21.3 Size of installed wind turbines in the investment subsidy program (1997 to 2001)

for subjective responses, not just sound level and its temporal pattern. Work is continuing on how to describe the noise disturbances in physical terms.

3. Disturbances on military structures

One research project is aiming to create a reliable model of the disturbance wind turbines cause on military microwave links, radar, and intelligence activities. This far, the results show that the disturbance due to wind turbines on radar has been quite overestimated until now.

21.6 ECONOMICS

21.6.1 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 in 2001 increased the investments for that year to 660.00 MSEK.

21.6.2 Trends in Cost of Energy and Buy-Back Prices

The prices on the market 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, the 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 and payable by a household without electric heating (see Table 21.2). 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 2001, wind turbine owners received a market tender price and other support as follows.

- A market tender price of approximately 0.20 SEK/kWh, a bit below average Nordpool spot
- An environmental bonus of 0.81 SEK/kWh
- A temporary subsidy of 0.09 SEK/kWh for small generators (1,500 kW maximum)
- A "local grid value" averaging 0.01 SEK/kWh, which gives a total of 0.481 SEK/kWh

This price model will be in force until the end of 2002. Thereafter, a new system with Green Certificates will probably be implemented.

21.7 INDUSTRY

21.7.1 Industry Development and Manufacturing of MW-Rated Turbines

Two manufacturers have developed large-wind turbines in Sweden: Kvaerner Turbin AB and Nordic Windpower AB. Kvaerner Turbin AB developed and sold Näsudden I (2,000 kW) and Näsudden II (3,000 kW). Vattenfall AB is the purchaser of both turbines. Kvaerner has also been a part in the OPTI OWEC project for off-shore wind turbines in Europe within the THERMIE program. During 1999, the company name for these wind power activities changed to SW Vindkraft AB. During 2001, Nordic Windpower AB manufactured and erected a new, two-bladed, light-weight Nordic 1,000-kW wind turbine at Näsudden on Gotland.

21.8 GOVERNMENT-SPONSORED R,D&D

The overall goal for the Swedish wind energy research program is to develop enough knowledge within the wind energy area in order to manufacture and develop wind turbines and use wind

Typical customer	Network services öre /kWh			Electrical energy, öre/kWh		
	2000	2001	Change %	2000	2001	Change %
Apartment	42.3	42.9	1.42	26.0	29.5	13.5
Single-family house without electric heating	37.2	37.5	0.81	23.9	26.0	8.8
Single-family house with electric heating	20.8	20.8	0.00	22.5	24.2	7.6
Agriculture or forestry	21.9	22.2	1.37	22.0	24.0	9.1
Small industrial plant	15.2	15.0	-1.32	21.0	24.0	14.3
Medium-sized industrial plant				20.0	24.0	20.0
Electric-intensive industrial plant				20.0	24.0	20.0

Table 21.2 Price of network service and electricity, excluding taxes, on 1 January 2001 in sales of electricity to various typical customers (100 öre = 1 SEK)

energy efficiently in the Swedish energy system.

On 1 July 1998, a fully financed research program started with a three-year budget of 46.80 MSEK for 1998 to 2001. The subject areas of this research are listed below.

- Meteorological data and power performance
- Aerodynamics and structural mechanics
- Loads and design
- Electric system and control technology
- Acoustics
- Socio-technological aspects

The work has mainly been carried out and administrated in the Wind energy Program, VKK (in Swedish, VKK stands for wind energy, knowledge, competence). VKK was formed in 1994, and is lead by the Swedish Defense Research Agency (FOI). More information can be found on the Internet at www.vindenergi.foi.se.

During 2001, this program was evaluated with a good result, and planning began for a new wind research program, which will contain basic and applied research as well as development projects.

21.8.1 Priorities

So far, research has been primarily technology oriented, but in a stage when more wind turbines are fiting into the landscape, "softer" issues – such as planning, environmental impacts, and acceptance) – have to be given a higher priority. At the same time, it is important to continue research in the conventional technology areas in order to increase availability and reduce costs.

21.8.2 New R,D&D Developments

The following sections outline some of the current research and demonstration projects.

1. Complex terrain and cold-climate siting

Rodovålen in Härjedalen: The company Agrivind has erected three wind turbines on a mountain top in Härjedalen in the middle of Sweden. One turbine has a capacity of 750 kW and two have a capacity of 600 kW. The objective of the project is to contribute to the development of wind power technology in cold climates. The project is sponsored by SNEA. In connection to this project, a study of environmental effects on reindeers has been initiated.

Suorva in Lapland: In October 1998, the utility Vattenfall erected a 600-kW wind turbine with a Finnish-Danish, non-icing system in the blades at one of its large hydro-power dams in the Lule River valley. Suorva is situated 100 km north of the Arctic Circle. Since 1995, a 35-m mast with four anemometers has shown a good local wind resource equivalent with the island of Gotland. An evaluation program has been in operation for three years. This project is sponsored by SNEA.

2. Bockstigen offshore wind farm – medium-term elevation of meteorological conditions, power performance, and loads

The first offshore wind arm in Sweden, Bockstigen, consists of five, 500-kW, stall-controlled, wind turbines on monopile foundations. The main objectives of the technical evaluation are as follows.

- Verify the original design assumptions made for a load-carrying monopile and bedrock
- Investigate offshore power production versus onshore power production and determine park effects
- Analyze meteorological, multi-mast statistics that serve as reference data to a newly developed computer code for offshore wind energy potential mapping

The main measurement system has continuously been acquiring data at 1 Hz/channel and 20 Hz/channel since the summer of 1998. A 40-m meteorological mast was built within the wind farm in the summer of 1999 in order to acquire relatively undisturbed wind speed data from free sectors as well as to enable wake measurements.

21.8.3 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 demo-plant (five 200-kW turbines) was erected in early 1998 4 km south of Näsudden on Gotland. The Swedish wind farm developer Vindkompaniet AB performed the project. The Bockstigen Valar project is sponsored by EU (THERMIE) and SNEA.

3. Utgrunden

In autumn of 2000, the company Enron/Tacke erected and commissioned a 10-MW wind farm (seven 1.425-MW turbines) south of the Utgrunden lighthouse in the sound, Kalmarsund, between the mainland and the island Öland. The plant is built 12 km offshore from Bergkvara at the Swedish southeast coast and 9 km from Öland. The Utgrunden project is sponsored by SNEA and now includes a scientific evaluation program with focus on migrating bird studies.

4. Yttre Stengrund

In spring 2001, the company Vindkompaniet erected and commissioned another 10-MW wind farm (5 x

2000 kW, NEG Micon) in the sound, Kalmarsund, about 4 km offshore from the mainland.

5. Other plans for wind power offshore

The company Eurowind has received governmental permission for an offshore project with 48 1.5-MW wind turbines in the sound, Öresund, between Sweden and Denmark. West of the city Karlskrona, in southeast Sweden, the utility Vattenfall has made a feasibility study for an offshore project with large 3-MW to 4-MW wind turbines. In the city's preliminary oversight planning, the offshore site is planned for about 100 large megawatt wind turbines.

Sweden has many large offshore wind farm projects in different planning and study phases. 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 be highly dependant on the results of four 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 SNEA
- The government determining a long-term, national deployment target for wind power

(All of the above initiatives are mentioned in the first sections of this chapter.)

Additional input on Section 21.8.2: Ola Carlsson, Chalmers University of Technology; Hans Ganander and S. Dahlman, Teknikgruppen; Göran Ronsten and Sven-Erik Thor, FOI; and Hans Bergström, Uppsala University, Sweden.

Authors: Susann Persson, the Swedish National Energy Administration, Sweden; and Kenneth Averstad, Vattenfall AB, Sweden.

CHAPTER 22

22.1 INTRODUCTION

The year 2001 showed continued solid growth in the United Kingdom, providing 59 MW of new capacity with high expectations for next year. Although promising, accelerated deployment of wind is needed in order for the country's target to be reached, which is 10% of electricity generated from renewables by 2010.

Against this background of increased political willingness and awareness, there has been an increasing drive toward larger wind farms. Permission to build one wind farm of over 50 MW was granted, with developers looking ahead to wind farms of up to 1,000 MW in Scotland, as well as hoping for large-scale opportunities offshore in the future.

Obtaining planning consent remains the greatest obstacle to increased wind deployment, and future capacity will also be limited by electricity network constraints unless there is major reinforcement. There were positive moves toward addressing these deployment issues in 2001. Non Fossil Fuel Obligation (NFFO) contract location flexibility was introduced, which could result in approximately 350 MW of additional wind power projects being built. In recognition of the need for grid reinforcement, an initial investigation was launched into the feasibility of an undersea transmission cable to enable large-scale renewables development in Scotland and the North.

Clarity was also brought to offshore planning when the Crown Estates announced a first round of offshore sites with the potential for well over 1,000 MW of new capacity.

22.2 NATIONAL POLICY

In February 2000, the government published its new policy on renewable energy. This has five key aims, which are listed below.

- Assist the United Kingdom in meeting national and international targets for the reduction of emissions, including greenhouse gases
- Help provide secure, diverse, sustainable, and competitive energy supplies
- Stimulate the development of new technologies necessary to provide the basis for continuing growth of the contribution from renewables in the long term
- Assist the U.K. renewables industry in becoming competitive at home and export markets and, in doing so, provide employment
- Make a contribution to rural development

The main objective is to increase the contribution of electricity supplied from renewables to 5% by the end of 2003, rising to 10% by 2010, subject to the acceptable cost to the consumer.

22.2.1 Strategy

The government's new strategy has a number of key policy themes, including the new Renewables Obligation for England and Wales (and the analogous Scottish Renewables 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 United Kingdom's electricity from renewable sources by 2010 (see Section 22.4.1 for more details). Other policy strands include the following.

- Exemption of electricity generated from renewables from the Climate Change Levy (a tax on business use of energy)

- A supporting program of research and development and technology transfer to provide a technology push and assistance in addressing other deployment issues
- Development of a proactive strategic approach to planning in the regions and the introduction of regional targets for renewables based on renewable energy resource assessments
- Capital grants for early offshore wind and energy crops projects.

22.2.2 Government-Sponsored R,D&D

The U.K. government, through its Department of Trade and Industry (DTI), aims to remove barriers to the uptake of renewables by stimulating research and development, fostering innovation, promoting technology transfer, facilitating industrial development, and encouraging exports. The Sustainable Energy Programme supports the following items.

- Resource, technology, and environmental assessment
- Research, development, and innovation in industry
- Work to address deployment issues
- Technology transfer, information dissemination, and public awareness

The wind program area seeks to improve market share, reduce the cost of wind energy, and improve competitiveness as well as evaluate and address concerns over public acceptability, electrical integration, and environmental impact. The program has increasingly encompassed the offshore sector.

The principle mechanism for supporting R&D in the wind sector is through a twice yearly open call for proposals. Priority areas this year were offshore foundations and installation. Proposals were also invited that developed offshore components and enabled improved access to offshore turbines. Onshore wind was not a priority area.

22.2.2 Progress Towards National Targets

The government is committed to a new and strong drive to develop renewable sources of energy. Since coming to power, the government has issued a series of consultation papers relating to sustainable energy and climate change. In addition to the commitment to Kyoto, the government has set its own domestic target of achieving a 20% reduction in carbon dioxide emissions by the year 2010.

The government has expressed its intention of working towards the aim of achieving 10% of the total electrical energy consumption from renewable sources by the year 2010. It is anticipated that this will be met from a combination of sources, including both onshore and offshore wind, land-fill gas, energy from waste, and energy crops. Estimations suggest that onshore wind may contribute between 13% and 26%, and offshore wind may contribute 8% to 18% of the renewable target.

One strand of the Climate Change policy is the Climate Change Levy, which came into effect in April 2001. This is a levy on energy use by businesses to encourage low energy use, energy efficiency, and the use of low emissions energy sources. The Levy on electricity sales is 0.43 p/kWh. Qualifying electricity from renewable sources will be exempt from the levy.

22.3 COMMERCIAL IMPLEMENTATION

22.3.1 Installed Capacity

At the end of December 2001, the United Kingdom had 924 wind turbines, which comprise 468 MW of installed capacity.

This is much less than the 2,675.8 MW of wind capacity with power purchase contracts under NFFO.

22.3.2 Rates and Trends in Deployment

The improvement in the rate of deployment in 2000 continued into 2001. In addition to installing an additional 59 MW of capacity, expectations for next year are even higher. The British Wind Energy Association (BWEA) anticipates that slightly less than 200 MW will be constructed in 2002. The greatest deployment to date was reached in 1997 when 84.5 MW were installed. Obtaining planning consent remains the biggest impediment to deployment and is discussed further in Section 22.5.2. The graph below shows trends in planning success for NFFO, NI-NFFO, and the SRO.

22.3.3 Contribution to National Energy Demand

With a total electricity demand of approximately 395 TWh per year in 2001, 955 GWh was supplied by wind energy, which is 0.24%. Large hydro contributed 0.96%, and the sum of all other renewables contributed approximately 0.48% (excluding waste incineration).

22.4 MARKET DEVELOPMENT AND STIMULATION

22.4.1 Support Initiatives and Market Stimulation Incentives

The incentives are currently in a stage of transition from NFFO to the Renewables Obligation (RO). NFFO (SRO, NI-NFFO) has been the mechanism since its introduction in 1990, with some contracts still available for uptake, but with a diminishing window economically. The RO is the current mechanism coming into force in 2002, with all licensed electricity suppliers obliged to provide 3% of their electricity sales from renewable sources until March 2003, rising to 10.4% of sales for the year ending March 2011. Liberalization of the electricity market and the splitting of the supply and generation businesses is shaping the current incentive mechanisms. A revised market structure for electricity called the New Electricity Trading

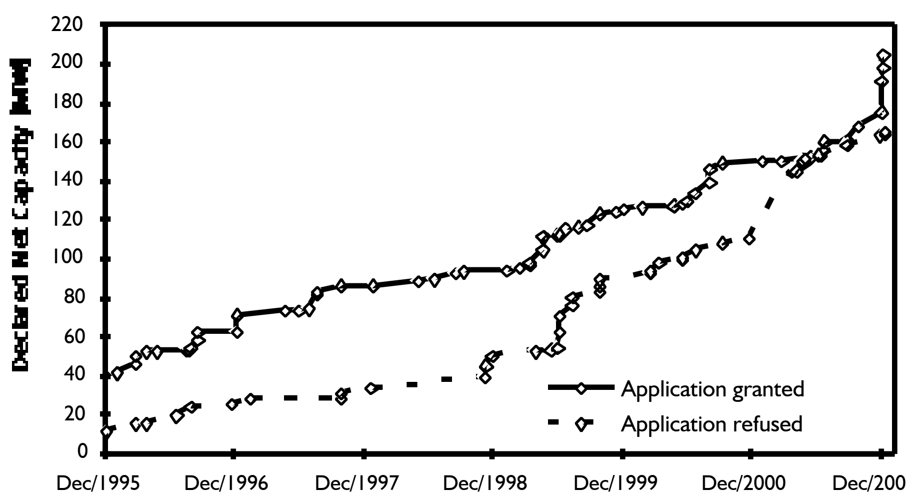

Figure 22.1 Wind farm planning application success and failure rates by declared net capacity

Arrangements (NETA) came into force in March 2001.

Following response to the consultation paper published in 1999, New and Renewable Energy: Prospects for the 21st Century, the government decided on the new support mechanism for renewables, the RO, which formed part of the Utilities Act 2000.

All eligible renewable generators will receive a certificate for each unit of electricity generated, commonly referred to as a Renewables Obligation Certificate (ROC). This can then be sold directly or traded but eventually will be submitted by suppliers against their obligation. An effective cap will be set on the value of the certificates to control the cost of the obligation to the consumer. If suppliers do not have enough certificates to meet their obligation, they can pay a buyout price. The buyout price will be 3 p/kWh. The first period of the obligation is expected to run from April 2002 through March 2003. After this, targets for suppliers will be set yearly. Targets have not yet been set.

22.4.2 Unit Cost

No clear cost reduction has been observed in the last year. In the United Kingdom, a wind farm built today would typically cost approximately 675 GBP/kW installed, including infrastructure. Costs as low as 550 GBP/kW are possible where accessibility is good and grid connection costs are very low. Developers continue to be optimistic that onshore costs will fall further, to as low as 500 GBP/kW for some sites due to larger, more efficient turbines and economies of scale.

Similarly, for offshore, the general opinion is that there is considerable room for cost reduction coming from greater experience, improved installation techniques, larger turbines, and larger schemes. Costs extrapolated from the United Kingdom's only offshore installation at Blyth provide a figure of approximately 853 GBP/kW installed capacity, based on a wind farm of 60 MW. Table 22.1 shows the cost breakdown for Blyth, together with extrapolated costs for a generic, 60-MW wind farm based on the experience of Blyth. The Blyth machines are two Vestas 2-MW turbines, mounted on steel monopiles grouted into drilled rock sockets. The predicted costs are based on the following assumptions.

- 30 wind turbines, 2-MW output capacity installed in one season
- Located in three arrays of ten turbines perpendicular to the shore
- Minimum distance to shore is 5 km
- Sand/clay sea bed (suitable for driven piles)
- Driven pile foundation
- Grid connection on shoreline at 33 kV

22.5 DEPLOYMENT AND CONSTRAINTS

22.5.1 Wind Turbines Deployed

There is an increasing drive toward larger wind farms. Several wind farms of more than 50 MW have applied for building consent in the short term, with developers looking ahead to wind farms of up to 1,000 MW in Scotland and hoping for large-scale opportunities offshore in the future.

In spite of the poor planning success rate for large-wind farms in England and Wales, last year did see a new development with developers applying for wind farms of more than 50 MW of capacity. Perhaps surprisingly, 2001 then saw the first granting of a construction permit through Section 36, a part of the electricity act applied to all generation projects of

Budget Item	Summary	Blyth Cost 1kW Installed	"Generic" wind farm 80 MW	"Generic" Summary	"Generic" wind farm Cost 1kW
PREFORMATION					
Lease (legal fees and stamp duties)			30,000		
Consents (inc EA and fees)			100,000		
Initial foundation design			50,000		
Wave data			20,000		
Site investigation			200,000		
Geotechnical study			50,000		
Grid connection study			30,000		
Foundation & piling design			250,000		
Cable route survey			50,000		
Resource analysis			300,000		
Consortium legal work			100,000		
Project management	342,000	86	500,000	1,680,000	28
MATERIALS & EQUIPMENT					
Turbines, towers etc			24,000,000		
Onshore switch gear			300,000		
Offshore swltchgear (Sentinel, 2 off)			600,000		
HV Cabling (11 kV)			1,700,000		
Telecomms			200,000		
Monopile foundations and platforms			4,500,000		

Table 22.1 Blyth offshore wind farm and implications on cost for generic, larger wind farms

more than 50 MW. Section 36 consent applications are handled by the DTI, rather than the usual planning consent process through local planning authorities. The granting of the first Section 36 approval for a wind farm was for Cefn Croes for 39, 1.5-MW turbines (58.5 MW) and, equally significantly, for a project in Wales. The announcement by Energy Minister Brian Wilson was made at the opening of a new wind farm in Wales, Parc Cynog (3.6 MW), the first to be commissioned in Wales in two years.

AMEC Wind and British Energy Renewables announced what could become the world's largest wind farm. The project is for 300 wind turbines totalling between 600 MW and 1,000 MW on the Isle of Lewis, one of Scotland's Western Isles. The project has been welcomed by both locals and the U.K. government as a big step on the way to meeting targets for renewables, capable of providing slightly less than 0.5% of the United Kingdom's electricity needs. The project is dependent upon the installation of a sub-sea power cable to link to the U.K. mainland.

22.5.2 Main Constraints on Market Development

Obtaining planning consent remains the greatest obstacle to increased wind deployment. Although there have been some promising developments in the last two years, reaching the government's targets requires greatly increased deployment. This can only be achieved through accelerated development both onshore and offshore. Future capacity will also be limited by electricity network constraints unless there is major reinforcement. This is particularly the case for the system in Northern Ireland where the network operator considers that operational constraints make the integration of a significant proportion of power from wind unfeasible at present.

To take forward the objective of getting more local involvement and ownership of environmental policy, the government requested in 1999 that the regions come forward with regional strategies and targets for renewable energy. These were to follow from an examination of the local resources and a full consultation with local groups of what is realistically achievable in the region. The overall aim is that the strategies and targets should feed through into development plans, which are the starting point for planning decisions at a local level. The target was that this process should be complete by the end of 2000.

The majority of the regional renewable energy assessments have now been completed. Although a detailed analysis of the findings has yet to be undertaken, some common themes are beginning to emerge. The concept of regional targets for electricity from renewable energy sources is widely supported by all parties to the renewable energy debate. However, it is more difficult to reach regional consensus on their scale and composition. In some regions, there is no clear consensus about an appropriate scale for the onshore wind target.

There have been a number of positive changes in the last two years that may reduce the constraint on building. They are as follows.

- Positive political pressure in Scotland, with the issue of new planning guidelines in 2000 that will be reviewed again in 2002
- Approval of a Welsh wind farm of more than 50 MW this year (see Section 22.5.1)
- Announcement by the Crown Estates this year of a first round of offshore

sites with the potential for more than 1,000 MW of new capacity (see Section 22.8.3)

- NFFO contract location flexibility was introduced by Energy Minister Brian Wilson at the end of December 2001; this could see the construction of approximately 350 MW of wind power projects that had previously not achieved planning permission
- An initial investigation was launched into the feasibility of an undersea transmission cable to enable large scale renewables development in Scotland and the North
- In December 2001, AMEC Wind announced Europe's largest brown-field wind farm (47.5 MW), on Tees-side; brown-field sites are a new avenue for the industry, utilizing sites that would otherwise remain eyesores.

Following the publication of the new Scottish Planning Guidance for renewables in 2000, the year 2001 saw Powergen Renewables winning planning permission for a 30-MW wind farm in Scotland, An Suidhe, bringing the total to nine new projects with a total of 195 MW approved in 2001.

The premium fixed price NFFO contracts were tied to specific sites, being awarded competitively before any planning applications were made. As a consequence, many of these contracts have not been able to be taken up because of planning difficulties. The ability to exploit them at new sites should change this. They can even be moved offshore, but can not be used in addition to the RO, which instead issues green certificates (ROCs). The BWEA had estimated that 350 MW will be built as a result of the portability of NFFO contracts.

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, and most renewables projects exacerbate this. Although the cost may prove to be prohibitive, a contract has been placed by the government to look into the feasibility of a subsea connector from the western seaboard of Scotland to the North West, Northern Ireland, West Wales, and the South West of England. The cost of such an interconnector is likely to be in excess of 400 million GBP.

In the case of one Scottish wind farm, large savings were made on grid connection by limiting the output of the wind farm for short periods each year. The developer agreed with the utility to restrict output in the event of high summertime winds or under local fault conditions, to prevent power flows from exceeding the firm capacity of the transmission system. This is a model that other developers can follow for generation in weak-grid areas.

In 2001, the developer National Wind Power (NWP) launched a new scheme called WindWorks. This new service provides a one-stop-shop for small wind energy projects typically comprising one, two, or three turbines. The WindWorks package has been developed to provide farmers and landowners with the financial rewards associated with ownership of a wind energy project while avoiding exposure to financial risks by providing the project equity. Using a model that has formed the backbone of historical development in Denmark, it hopes to encourage local interest, which may help planning, though NWP is likely to retain majority ownership.

One constraint not common to the rest of Europe, and of increasing prominence over the year, comes from the effect that wind farms may have on aviation, both in terms of radar systems and low flying. There is a working group on wind farms and their impact on aviation interests, including representatives from defence and civil aviation as well as DTI and U.K. industry. The aim of the working group is to provide information and advice to developers, planners, military, and civil aviation personnel on potential effects. Interim guidelines on the siting and assessment of the effects of wind farms is anticipated in 2002. Technical studies will generate improved guidelines subsequently.

22.6 ECONOMICS

22.6.1 Trends in Investment

1. Type of funding available

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 their exposure to penalty payments. Wind has found particular favor because of its economics, maturity, and ability to deliver relatively quickly.

There has been no direct public funding available for capital investment in wind farms, but this year the government announced grants for the first offshore wind farms. Support of approximately 75 million GBP is considered sufficient for at least 450 MW, to reduce risks and provide industry momentum. The grants will be awarded through a competitive process and will support approaching half the developments that have pre-qualified for licenses with the Crown Estates.

2. Typical financial interest rates

Interest rates asked by banks are typically 1.5% above the London Inter Bank Offered Rate (LIBOR). Equity/debt ratios are typically 25/75, with investors requiring a post tax return on equity of between 15% to 25%. Clearly, these figures can vary considerably from project to project. However, many of the recent developments are financed off the balance sheet of larger companies (mostly utilities). They accept lower real rates of return, between 8% and 12%, depending on the associated risk. This has contributed to the reduction of costs and accounts for the lowest bid prices in recent NFFOs.

22.6.2 Trends in Unit Costs of Generation and Buy-Back Prices

In the existing U.K. market, it is extremely difficult to decipher a typical generation cost from wind. Projects have been developed for less than 3.00 p/kWh under long-term, fixed-price power purchase contracts where wind speeds are high (more than 9.0 m/s at hub height). However, since the cessation of the new NFFO tranches, there is no direct measure of a fixed price that enables wind development. The value of wind energy in the new climate, with electricity traded under NETA and the renewable obligation coming into force soon, can most easily be seen through auctions of the power generated from NFFO contracted wind farms. The last auction was held in August for the electricity generated from 580 MW of renewables plant. Wind sold for 2.84 p/kWh. This was substantially higher than the previous auction price at which it was sold at 1.84 p/kWh. The higher value reflects the expectation that the Renewables Obligation will come into effect during the generation period and that some green certificates (ROCs) will be awarded.

Under the RO, the value of wind-generated electricity is made up of three components.

1. The free market value of the electricity

Within NETA, electricity from wind currently appears to attract a price of approximately 1.5 p/kWh. Wind is disadvantaged because of its unpredictable output.

2. The free market value of ROCs

The value of ROCs will be highly sensitive to an overall under or over supply, against the cap price of 3.00 p/kWh.

3. The fixed value of Climate Change Levy exemption

The levy is charged at 0.43 p/kWh on electricity supplied to non-domestic customers, with perhaps 75%, or approximately 0.32 p/kWh, going to wind generators. Onshore wind may also receive some embedded generation benefits (in which electricity suppliers pay the wind farmers a little extra for supplying electricity near to where it is used).

22.7 INDUSTRY

22.7.1 Manufacturing

The United Kingdom continues to supply a wide range of components to the wind turbine industry, including blades, castings, towers, pitch bearings, and elastomerics. This is despite the continuation of the unfavorable exchange rate and a limited home market. The new support mechanism for renewables in the United Kingdom and the expectation of increasing offshore development offer better prospects at home in the medium term – and some export markets look buoyant.

NEG-Micon rotors continued to grow through its blade-production facility on the Isle of Wight and its hub assembly facility at Thorpe, Surrey. Turn-over in 2001 was approximately 20 million GBP and is expected to increase to approximately 30 million GBP in 2002. In total, 600 blades and 40 hubs were constructed.

Figure 22.2 NEG Micon's Bladerunner, operating out of the Isle of Wight facility

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.

22.7.2 Industry Development and Structure

The year 2001 has seen more utilities spin-off companies. Even the nuclear industry is looking to invest in wind, with British Energy partnering with AMEC Wind.

Co-generation has also been discussed with early plans to combine wind with natural gas offshore and an Anglo-German co-operation looking at combining wind with landfill gas. Both these ideas present a way of overcoming the difficulties of unpredictable supply from wind, which can greatly add to the value of the electricity under NETA.

There are a number of smaller developers, some of whom specialize in niche development such as small wind farms or single wind turbines. The non-utility developers are increasingly looking for development prospects outside the United Kingdom. Activity is particularly high in the Irish Republic, France, and the United States, but there are interest areas as far away as China, Australia, and the Caribbean as well as other European countries.

22.8 GOVERNMENT-SPONSORED R,D&D

In 2001, approximately 1.3 million GBP was spent on the wind program area of the DTI's R&D Programme on Sustainable Energy. The U.K. government intends to increase the budget for R&D support of renewables to 18 million GBP for 2001 and 2002. The proportion of these budgets assigned to wind energy has yet to be decided and will depend partially on the industry's level of activity in the United Kingdom.

22.8.1 Priorities

The government program continues to support a cost-shared program with the industry, but as the technology achieves maturity – and subject to the renewables review currently being undertaken – the trend is toward decreasing contributions from government for onshore technology. Greater attention is now being directed to the development of offshore resources, which include technical innovation to develop foundations and installation technology, offshore components, access to offshore turbines, and monitoring and evaluation of installations.

In 2001, scoping studies on the potential effects of offshore wind farms on birds and on wildlife through sub-sea noise were completed. There has been no follow-up work to date.

22.8.2 New R,D&D Developments

In an effort to develop lighter, stiffer blades for large wind turbines, NEG Micon has produced a 40-m blade made from a composite of wood and carbon fiber. Laboratory tests have been successful, and prototype blades are now installed on a machine in Germany for further testing.

Harland and Wolff Licences completed a feasibility study on new approaches to offshore foundations. They found that a multi-piled steel foundation offered flexibility in ground conditions, while enabling the use of standard piling equipment and exploiting its steel fabrication capability.

A project that started in September will try to quantify the effects wind turbines have on radar systems. The models developed and validated within this work should enable a more accurate assessment to be made of new wind farms proposed near to radars that provide either early warning information or air traffic control. The project is due to be completed in late 2002.

22.8.3 Offshore Siting

In 2001, the Crown Estates, which own the seabed around the United Kingdom to the territorial limit, announced the allocation of the first round of U.K. offshore sites. The Agreement for Lease will give each developer a three-year option on a lease, the lease itself being for 22 years.

A total of 18 projects were allocated at 13 different sites, as shown in Figure 22.3. The sites in this first round will be for a maximum of ten square kilometers and will permit a development of up to 30 turbines on each site, with a minimum output for the site of 20 MW. All Crown

Figure 22.3 U.K. offshore sites

Estate agreements will be subject to the developer obtaining all the necessary consents prior to development. Developers had to first pre-qualify by showing that they had adequate financial resources as well as expertise in offshore project management and wind energy.

It is likely that some announcement on a further round of offshore sites will be made during 2002.

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CHAPTER 23

23.1 INTRODUCTION

The United States has a long history of leading wind technology development and commercial applications. The first large-scale wind power plants were installed in California during the early 1980s. Today, about 20% of worldwide capacity is in the United States. For the past several years, wind energy has been one of the fastest growing new sources of electricity generation in many parts of the country. This report will describe recent market developments in the United States, some of the reasons for that growth, and why it is expected to continue. Emphasis in the report is on the United States Department of Energy (DOE) Wind Energy Program and its role in leading development of new wind energy technology that will be economically competitive with other electricity sources, without the need for subsidies.

23.2 NATIONAL POLICY

23.2.1 Strategy

The United States' strategy has been to encourage the development and deployment of wind energy with a research and technology development program, complemented by a variety of market stimulation activities and financial incentives that encourage commercial project deployment. Over the past 25 years, emphasis has shifted from government-led R&D to cost-shared government/industry partnerships. Financial incentive policy 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 and subsidies for other energy sources are removed.

A new National Energy Policy report was published on 17 May 2001. This document contained recommendations to help diversify the national energy supply; move toward clean, affordable energy sources; and modernize the electricity grid and infrastructure. The policy proposed to expand performance-based research and development focused on next-generation technologies; extend wind-energy production tax credits; and encourage the use of renewable resources on federal land, which includes vast areas with excellent wind resources. The policy specifically acknowledged that wind energy could be significantly expanded by developing next generation technology for sites with lower wind speeds than are economically feasible today. As a result, low wind speed technology is now emphasized in the DOE R&D program.

Broad authority for the current energy programs and policies in the United States stems from the Energy Policy Act of 1992, Public Law 102-486. This legislation – with subsequent amendments, modifications, and extensions – is the primary basis for continuing research and development on wind, incentives for electricity production from renewable energy sources, and other DOE energy programs.

The DOE Wind Energy Program strategy emphasizes research that expands the knowledge base, explores new and innovative systems, and supports the cost-shared development and testing of improved, lower-cost, higher-efficiency turbines in a wide range of sizes for multi-regional applications. The overall goal is to develop wind turbine technology that will reduce life-cycle cost of energy to levels that will allow wind to compete in bulk electric power markets with-

	2002 (Base Year)	2004	2010
High winds speed sites with Wind Power Class 6 (6.4-7.0 m/s)*	4.0	3.0	
Low wind speed sites with Wind Power Class 4 (5.6-6.0 m/s) *	5.5		3.0

* Annual average wind speed measured at the standard 10m height

Table 23.1 Cost of energy goals for the R& D program

out financial subsidies. The cost goals are shown in Table 23.1.

In order for wind energy to be used in many parts of the country, it is necessary to develop turbines that are efficient at low-to-moderate wind speeds. Cost-effective, low-wind-speed turbine technology will expand the economically viable land area for harnessing wind power by a factor of 20 or more. This will also help to relieve power transmission constraints by placing turbines in closer proximity to consumers.

The DOE program also conducts R&D focused on smaller wind-energy systems for serving a broad range of distributed energy needs. Performance improvement targets for these technologies are similar, except they are aimed at applications in more moderate Class 3 wind sites (5.1 m/s to 5.6 m/s at 10-m heights).

Efforts are underway to increase access to federally owned land in order to tap into more renewable energy resources. Following recommendations contained in the Report of the National Energy Policy Development Group, DOE and the Department of Interior are working to identify and eliminate barriers to the use of public land for clean energy development. In a Renewable Energy conference, held in November 2000, government and industry leaders met to discuss these issues. Representatives from the environmental, financial, and energy project development communities participated with state and local officials in developing a series of recommendations that are being considered.

The federal government is working to expand its own use of energy from wind and other renewable energy sources. Federal agencies are required to purchase a portion of their electricity from renewable resources according to Executive Order Number 13123, issued 3 June 1999 by the President, as well as by other policy guidance. While a variety of options exist to purchase this power, new mechanisms, such as renewable energy credits, are being developed. In addition, specific goals and timetables are being considered. Several states have already moved forward to establish and implement programs aimed at increasing renewable energy use.

Environmental policy considerations are also driving wind development. At the national level, the Environmental Protection Agency and state environmental agencies are pursuing enforcement of the Clean Air Act and other laws that restrict sulfur dioxide, nitrogen oxide, and other emissions from many sources, including electric power plants. This is expected to increase demand for wind power and other clean energy technologies.

In addition, 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 at the state level, causing many variations in procedures and pace. This is one reason for regional differences in the adoption of wind. Other regional factors and specific examples will be discussed later in this report.

23.2.2 Progress Towards National Targets

The process of setting national targets for the use of renewable energy is being reevaluated in response to the new National Energy Policy recommendations and recent international events that have a direct bearing on the energy industry. On a national scale, there is increasing interest in expanding the use of domestic energy supplies, such as renewables. The DOE program, working with industry stakeholders, has developed peer-reviewed forecasts for penetration of wind energy technology in the power generation portfolio. Based on independently peer-reviewed national energy modeling projections, achievement of the program's large wind systems cost goals would result in U.S. installed wind energy capacity of 60,000 megawatts by 2020. These projections are revised periodically depending on research program results, funding levels, changing policies on tax and other financial incentives for renewable energy development, cost of fuels for other power-generating options, electric industry deregulation, and many other factors.

23.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

23.3.1 Installed Capacity

Wind power plant installations are expanding rapidly in many parts of the United States. At the end of 2001, installed wind capacity totaled 4,260 MW (See Figure 23.1). New turbines installed during the year totaled 1,694 MW, which is a 66% increase in capacity in only one year. Many additional projects are under development, continuing this dramatic and unprecedented expansion. Twelve states added more than 20 MW, and four states added more than 100 MW of capacity. These states were Kansas with 324 MW, Oregon with 157 MW, Texas with 1,095 MW, and Washington with 178 MW. The state of Texas saw the fastest growth, with capacity increasing by 915 MW, due in large part to the State Renewable Energy Portfolio Standard (See Figure 23.2). Combined state and federal financial or other incentives helped to stimulate the market in each case.

23.3.2 Rates and Trends in Development

The rate of wind energy deployment is continuing to accelerate, and wind plants are being installed in more parts of the country. Declining cost for wind power and increasing demand for clean energy are primary drivers, but the catalysts for this growth are the state and federal policies.

Wind turbines and wind power plants are also growing in size. Several multi-year projects, each with a total capacity in the 250-MW to 300-MW range, are planned in the states of Washington, Oregon, Texas, and Nevada. Many of the larger projects employ turbines rated over 1 MW. Markets for small- and intermediate-sized wind turbines in grid-connected and off-grid applications are also growing rapidly. As accept-

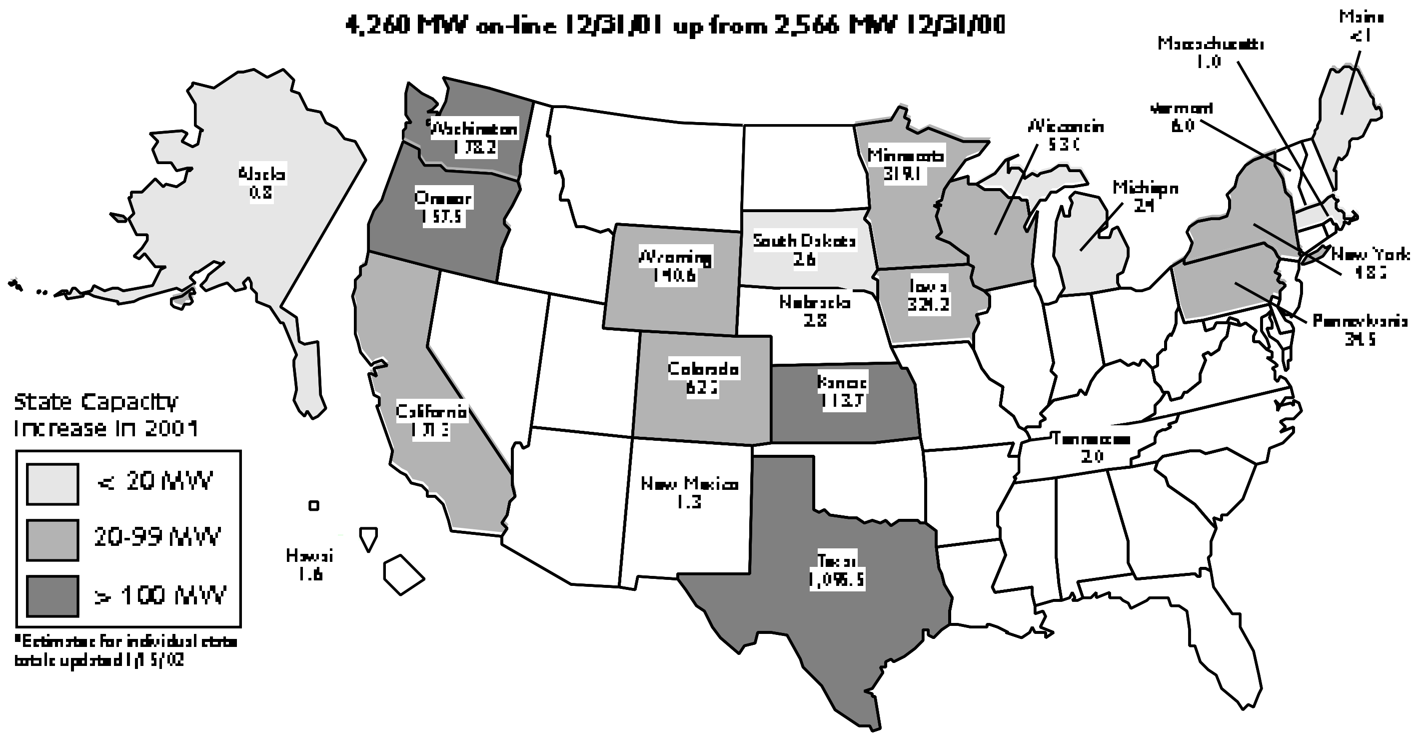

Figure 23.1 Growth and capacity of wind power plant installations in the United States

Figure 23.2 Enron Wind 1.5-MW turbines in 150-MW Trent Mesa wind power plant located near Sweetwater, Texas

ance of wind energy spreads, isolated communities and areas with weak or overloaded distribution and transmission systems are finding wind to be an economically competitive energy source. Sales of machines 10 kW or less are at record levels with an estimated 12,000 turbines sold during 2001 at a value of approximately 10 million USD. Small machines are increasingly attractive power sources because of their reliability, and because their owners gain a level of self-sufficiency and insulation from price volatility by controlling their electricity supply.

23.3.3 Contribution to National Electricity Demand

Energy production from all the wind systems in the United States during 2001 is estimated to have been 10.8 TWh, assuming an average capacity factor of 29%. Currently, wind energy is only 0.3% of the national electricity supply, but its importance is growing, especially in areas with good wind resources and incentives for development.

23.4 MARKET DEVELOPMENT AND STIMULATION

23.4.1 Support Initiatives and Market Stimulation Incentives

State policies and incentives are having an increasing influence on regional development of wind power, especially in combination with federal tax incentives. A variety of approaches are being developed at both state and federal levels. Many of these innovative programs are working, but the most effective are those that feature clearly defined goals, long-term (typically ten years) benefits and/or penalties, and flexibility in allowing suppliers and consumers to choose among various renewable energy technologies.

The following are examples of mechanisms that have helped to expand wind energy use. The incentives described below often work together.

1. Wind energy production tax credit

A tax credit from 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 0.017 USD for every kilowatt-hour produced. This tax credit can be claimed for the project's first ten years, and the value of the credit is indexed to inflation. These plants had to be brought on line prior to 31 December 2001. Subsequently, the tax credit was retroactively extended for two years through 31 December 2003. This incentive is one of the key drivers for the surge in wind plant development over the past year.

2. Renewable energy production incentive

The renewable energy production incentive is an incentive payment available from DOE for municipal utilities that do not pay taxes to the federal government. As with the tax credit described above, applicants can receive a payment of 0.017

USD/kWh (indexed to inflation) for energy produced over a ten-year period, for plants brought online prior to 31 December 2001. This payment is subject to available funding.

3. Green power purchasing choices

In an increasing number of states, residential and commercial customers can choose to purchase electricity from environmentally benign or green sources. Typically, a premium is paid by the green power purchaser. The size of the premium depends on the renewable resource and the supplier. For wind power, the premium is sometimes as low as 0.01 USD/kWh, with an average of approximately 0.025 USD/kWh for all renewable technologies. More information is available on the Internet from the Green Power Network at www.eren.doe.gov/greenpower. Green electricity rates and products are described and evaluated at www.powerscorecard.org.

4. Green tags

The use of renewable energy credits, or green tags, is being explored in several states and at the federal level. Under this concept, the customer purchases the environmental attributes of renewable energy generation (e.g., wind energy). Tag purchasers may be power consumers or others interested in the future value of the green tags. The supplier of the green tag receives the premium payment once the renewable energy is sold to the local power pool at market price. As a result, green power is purchased and fed into the pool, thus avoiding an equivalent amount of fossil-fueled generation. In some cases, disbursed generation resulting from the use of tags may also help to alleviate transmission constraints.

5. Renewable energy portfolio standards

Some states are implementing requirements that a portion of the energy sold by utilities come from renewables. In Texas, a renewable energy portfolio standard requires that 2,000 MW of new renewable energy systems be installed by 2009. Electric power producers in the state are required to include renewable energy sources in their generation mix. Suppliers not meeting these standards are required to pay penalties, and suppliers with excess renewable energy can trade credits with others that need them. This Renewable Credit Trading Program started in January 2002 and will continue through 2019. Energy suppliers not meeting their portfolio standard, with either renewable energy or credits, are subject to a penalty of 0.05 USD/kWh on the shortage, or 200% of the average cost of credits traded during the year.

6. Compatible land use and tax benefits

Farmers and ranch owners in the United States are finding it attractive to harvest wind along with crops. Typically, a Midwest farmer leases land to a developer under a long-term contract. The developer installs the turbines, each occupying about 0.25 acre. In return, the farmer normally receives an annual cash payment plus a portion of the energy sales, typically 2%, amounting to an annual revenue of 2,000.00 USD to 3,000.00 USD per large turbine. Some states also offer property tax breaks (i.e., wind equipment may not be taxed like other buildings or capital equipment improvements). Wind plants and agriculture are compatible uses of land that can be good businesses for many farmers. This is a market that is expected to grow.

In an effort to help facilitate the transition of wind energy technology into commercial markets, DOE started the Wind Powering America program in 1999. The program has five focus areas, listed as follows.

1. State-level support: Holding workshops on clean energy technologies and their benefits, providing technical analysis and information necessary for planners to include wind and other renewable energy sources in the power generation mix, and ensuring that clean energy sources receive balanced consideration during deregulation negotiations (especially important on issues relating to operation and allocation of electricity transmission system resources and charges for ancillary services)

2. Rural economic development: Employing wind development in new business models, including land lease arrangements and other revenue-sharing approaches between developers and rural landowners, farmers, ranchers, and Native American Indian groups on tribal lands

3. 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

4. Power partnerships: Working with power generators and suppliers to encourage them to install clean generating capacity and to recognize their efforts, as well as working with large customers considering the purchase of clean power

5. Federal green power: Using wind and other renewable energy technologies to fulfill the requirements for purchasing electricity from clean energy sources for use by United States government-owned facilities

The Wind Powering America program has been working successfully and is an important way to bridge the obstacles for introducing wind technology in new regions and applications.

23.4.2 Turbine Cost Trends

Technology performance improvements resulting from R&D advances – complemented by increasing turbine production volumes, larger size projects, and improved construction methods – are reducing costs. Turbine installations are currently estimated to cost between 850.00 USD/kW and 1,220.00 USD/kW. These estimates are based on data from actual projects and include turbine, electrical system interconnection, and substation costs.

23.5 DEPLOYMENT CONSTRAINTS

Operational data from successful projects is helping to reduce electric utility company concerns about allowing connection of large wind plants to the grid. However, power transmission and distribution system constraints in regions with high-wind resources are expected to pose limitations to future wind energy growth unless new lines or system reinforcements are built. Several detailed power system studies are underway. One study in New England is analyzing high penetration of wind and biomass power plants operated in conjunction with the existing hydro- power systems. A second study is focused on grid systems needed to tap the vast wind resources in the upper Midwest.

Cost of wind energy is the primary constraint on commercial development, but costs are declining and traditional sources for electricity generation are becoming more expensive, especially when air pollution control costs become a factor. In high-wind areas, wind turbines can be the least-cost power generating option. However, further technology development and cost reduction is needed for wind to be cost effective in large regions with moderate winds.

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 is another consideration, but aesthetics is becoming less of an issue as land owners realize the income potential of harvesting wind energy. Considering the large land areas with excellent wind in the United States, avian and aesthetic concerns are not considered to be significant constraints.

23.6 ECONOMICS

23.6.1 Trends in Investment

Investment patterns in the wind-power projects in the United States are changing. To reduce the cost of energy, wind-power plant projects are growing in size, 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 newer 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 Florida Power and Light, Texas Utilities, Nebraska Public Power District, and Bonneville Power Administration (although they are only purchasing the power produced by wind plants). Other energy sector companies that are now delving into wind projects are Chevron, Texaco, Exelon, and Zilkha. Companies with electric power equipment manufacturing backgrounds that are now developing wind projects include ABB and Siemens. In addition, there are about 20 small companies developing projects across the country.

Equipment and component suppliers are increasing their investments in the wind energy business. To address the need for high-volume, low-cost components for wind turbines, the DOE Offices of Power Technologies and Industrial Technologies sponsored a technology forum, Supplying Advanced Materials and Components for Wind Power Systems, on 29 August 2001 in Salt Lake City, Utah. Forty-eight attendees from the aluminum, steel, chemical, fiberglass, plastic, and metal-forming and casting industries met with wind turbine manufacturers to identify potentially useful new materials and manufacturing processes through 2010. The keynote paper describing these trends is available on the Internet at www.oit.doe.gov/best-practices/energymatters/emextra/pdfs/wind_materials.pdf (the document is 885.7 KB).

23.6.2 Trends in Cost of Energy and Buy-Back Prices

Since 1980, the cost of electricity from wind systems at good wind sites without subsidies has been reduced from 0.35 USD/kWh (in 1980 dollars) to between 0.04 USD/kWh and 0.06 USD/kWh. Some projects at the best high-wind sites are now reporting even lower energy prices. Although costs have decreased significantly, researchers believe that further improvements could reduce costs an additional 30% to 50%. The DOE Wind Energy Program's goal is to advance the science and technology so that utility-scale, grid-connected wind-power systems can produce electricity for less than 0.03 USD/kWh at widely available wind sites with low-to-moderate wind speeds. DOE is launching a new development program to produce concepts, components, and full systems that will be cost effective, with out subsidies, at low-wind sites.

23.7 INDUSTRY

Nine companies in the United States are currently manufacturing turbines, and numerous businesses are building components, developing projects, and providing engineering services and related equipment. Information on U.S. firms is available on the American Wind Energy Association web site at www.awea.org.

Production of both small and large machines is expanding rapidly. During 2001, Southwest Windpower produced approximately 10,000 of its 400-W Air 403 turbines (Figure 23.3), which are distributed worldwide. This is a new production record for electric-producing wind turbines in a single year. Some of the larger European wind turbine manufacturers are establishing assembly plants and plan to manufacture components in the Midwest. The Danish firm NEG Micon has a large turbine assembly facility in Illinois. In addition, LM Glasfiber is building rotor blades in North Dakota. Projects are being developed in Europe and Asia with turbines manufactured under licenses by American companies. Enron Wind Corporation, a subsidiary of Enron Corporation, opened a wind turbine factory in Noblejas, Castilla-La Mancha, in Spain. The plant, began operation in June 2000, with an annual production capacity of 720 MW and employing 100 full-time employees. Bergey Windpower has established a joint venture, Xiangtan Bergey Windpower Co., Ltd., in the People's Republic of China, to build 7.5-kW and 10- kW turbines.

Enron Wind Corporation's parent company, Enron Corporation, has filed for bankruptcy, but this is not expected to impact its wind business. Enron Wind reported record profits on sales of more than 800 million USD of wind turbines during 2001. The company is likely to be sold, but it is expected to remain a U.S.-based manufacturer.

23.8 GOVERNMENT-SPONSORED RD&D

DOE research and development efforts are focused at the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC), in Golden, Colorado, with support from the Sandia National Laboratories in Albuquerque, New Mexico. The NWTC staff conducts research and wind turbine system and component certification testing at their state-of- the-art facilities. Both Sandia and the NWTC also conduct contracted research, development, and testing for the U.S. industry. The laboratory research is closely coordinated with industry cost-shared technology and turbine development contracts.

23.8.1 Priorities

Key elements in the DOE-sponsored Wind Energy Program, and current fiscal year funding, are shown in Table 23.2. The program funding for the current fiscal year 2002 is 38.6 million USD.

Figure 23.3 Commercial 400-W turbine – Southwest Windpower sold 10,000 during 2001

Key elements in the DOE-sponsored Wind Energy Program, and current fiscal year funding, are shown in Table 23.2. The program funding for the current fiscal year 2002 is 38.6 million USD.

23.8.2 &D Programs

1. Applied research

The applied research activity addresses wind energy engineering and technology issues with a broad range of scientific studies conducted at the national laboratories, universities, and in industry. This effort is aimed at improving understanding of wind characteristics, atmospheric physics, wind turbine structural dynamics, rotor aerodynamics, and electric power system integration issues.

Aerodynamics and structural research and design code validation is an area of emphasis. In mid- 2000, a series of wind tunnel tests were conducted that are now being analyzed and compared to field test data. Experiments were conducted by NREL in the wind tunnel at the National Aeronautics and Space Administration (NASA) Ames Laboratory in California. A 10-m in diameter, 19-kW, experimental wind turbine was tested in different configurations in the 80-foot by 120-foot section of the open throat wind tunnel. The NASA tunnel is normally used for testing full-scale models of subsonic aircraft. Extensive data sets generated from these tests are now being used by international research groups studying unsteady aerodynamics.

Wind tunnel and field tests on two 600-kW research turbines (see Figure 23.4) at the NWTC are being used to develop models for future low-wind-speed turbines. Testing on one machine is focused on long-term structural and fatigue loads induced by atmospheric turbulence. The second unit is testing control algorithms and rotor aerodynamics for low-wind-speed turbine applications. This research will provide better understanding of the basic scientific principles of the aerodynamic processes.

An important new area of study is on the potential of harnessing low-level atmospheric jets. Tests are being conducted to determine the potential for using turbine towers up to 80-m tall to reach nocturnal jets that appear to be prevalent in the large, flat areas of the Midwest. Preliminary data suggest that the turbulence near the jet may produce high loads,

Key Activities	Applied Research	Turbine Research	Cooperative Research & Testing
	Core research on aerodynamics, structures, materials advanced components, hybrid systems, environmental issues, and wind characteristics	Next generation and low wind speed large turbines, cold weather turbines, and small turbines for distributed generations applications	Wind Powering America Program, utility integration analysis, turbine field testing, and design verification and certification
Current Budget for Fiscal Year 2002 ($millions)	13.9	10.5	14.2

Table 23.2 Key activities and the associated funding for the DOE-sponsored Wind Energy Program

Figure 23.4 600-kW advanced research turbines at the NWTC near Boulder, Colorado

which need to be understood in order to design turbines for those regions.

2. Turbine research

The turbine research activity provides an opportunity for the U.S. industry, in partnership with the National Laboratories, to apply new technology and design tools (produced by applied research) to the development of advanced technology wind turbines. Through competitively awarded, cost-shared turbine development subcontracts, wind systems are designed for a variety of applications and in different turbine sizes, ranging from 5 kW to more than 1 MW.

The Wind Partnerships for Advanced Component Technologies project, or WindPACT, has focused on analyzing concepts that could be used in future machines. Rotor technology studies addressed scaling up to larger turbine sizes. Transportation of large blades is the primary constraint until manufacturing can be done at the project site. New, lightweight, high-strength blade materials, including carbon fiber, are being studied. Generators and drive system concepts being studied include direct drive systems, with no gearbox and a large-diameter ring generator with permanent poles; single stage gearboxes with several generators; and a bull gear design with multiple induction type generators attached. These new designs have the potential to reduce drive system costs by as much as 10%. Tall tower and self-erecting tower concepts are also being studied, along with ways to reduce the balance-of-station costs.

Under the Next Generation Turbine project, two machines are being field tested. A 500-kW Engineering and Manufacturing Development (EMD) model built by the Wind Turbine Company began operational testing in Southern California in December 2000 (see Figure 23.5). This unique machine has two independently hinged blades with a 48-m in diameter rotor. Enron Wind Corporation is continuing tests on a 1.5-MW EMD unit with new control systems that will accept a 77-m high energy capture rotor instead of the current 70.5-m rotor. In December 2001, NWTC issued a Request For Proposals to begin development of technology for a new, low-wind-speed turbine focused on large machines (greater than 100 kW) tailored for low-to-moderate Class 4 wind sites. This will increase the land area where wind should be cost effective by a factor of 20.

NREL is also completing development testing of a 100-kW, cold-weather turbine.

Figure 23.5 Wind Turbine Company's 500-kW, 48-m in diameter turbine under test at a Los Angles Department of Power and Water site near Fairmont, California

Figure 23.6 100-kW, cold-weather turbine built by Northern Power Systems under test at the NWTC near Boulder, Colorado

A prototype built by Northern Power Systems has been installed for certification tests at NWTC (see Figure 23.6). A second unit will be tested and connected to the grid in Kotzebue, Alaska.

Three additional small turbines are also being developed for both grid-connected and off-grid power generation. The three turbines are a 5-kW machine by Southwest Windpower, an 8-kW unit by Atlantic Orient Corporation, and a 50-kW machine by Bergey Windpower.

3. Cooperative research and testing

The cooperative research and testing activity includes support for industry, verification of advanced turbine performance in field tests, utility applications analysis, and support for the development of standards and turbine certification testing. Grants were awarded to industry, electric utilities, and state energy offices to encourage development of wind power in a variety of applications in ten states.

This program element also includes continuing development of international standards and the certification of American machines to those norms when necessary. The NWTC works closely with the International Energy Agency (IEA) to develop recommended practices, and with the International Electrotechnical Commission (IEC) to develop appropriate standards and testing procedures. In addition, the NWTC is accredited for certification of wind turbines for international markets. The NWTC certification test results can be used by the U.S. certification agent, Underwriters Laboratory (UL), or by others, as the basis for certifying the designs of U.S. industry machines for domestic and overseas markets. UL has certified, or is in the process of certifying, the design of the Enron 1.5-MW, the Southwest Windpower 400-W, the Atlantic Orient 50-kW, and the Northern Power 100-kW turbines. Accredited testing capability at the NWTC includes wind turbine power performance, structural loads, power quality, blade loads (static and fatigue testing), and noise certification.

23.8.3 Offshore Siting

Offshore installations of wind plants are being considered in New England, but no plants have been built to date.

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APPENDIX A

Attendees of the 47th Executive Committee meeting in Kristiansand, Norway.

APPENDIX B

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APPENDIX C

Currency conversions rates for IEA 2001 review

Country	Currency	rate/USD	rate/Euro	Fixed rates to Euro (1 Euro)
Australia	Euro	1.124	1.000	13.760 ATS
Canada	CND	1.590	1.415	
Denmark	DKK	8.350	7.432	
Finland	Euro	1.124	1.000	5.946 FIM
Germany	Euro	1.124	1.000	1.956 DEM
Greece	Euro	1.124	1.000	340.750 GRD
Italy	Euro	1.124	1.000	1936.270 ITL
Japan	JPY	131.040	116.626	
Mexico	MPS	9.160	8.152	
Netherlands	Euro	1.124	1.000	2.204 NLG
New Zealand	NZD	2.400	2.136	
Norway	NOK	8.970	7.983	
Spain	Euro	1.124	1.000	166.386 ESP
Sweden	SEK	10.460	9.309	
United Kingdom	GBP	.688	0.612	
United States	USD	1.000	0.890	

Source: Federal Reserve Bank of New York www.x-rates.com
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