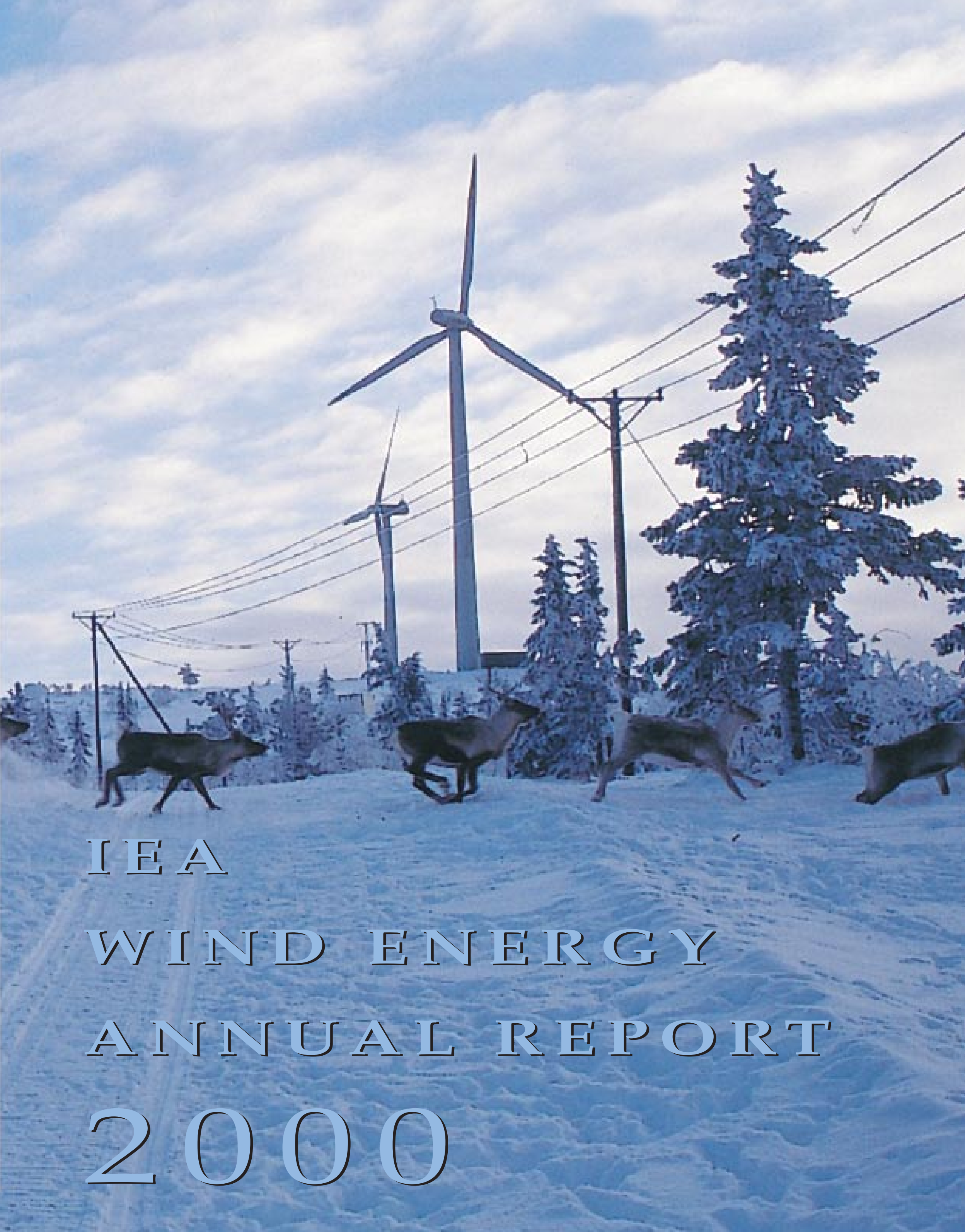
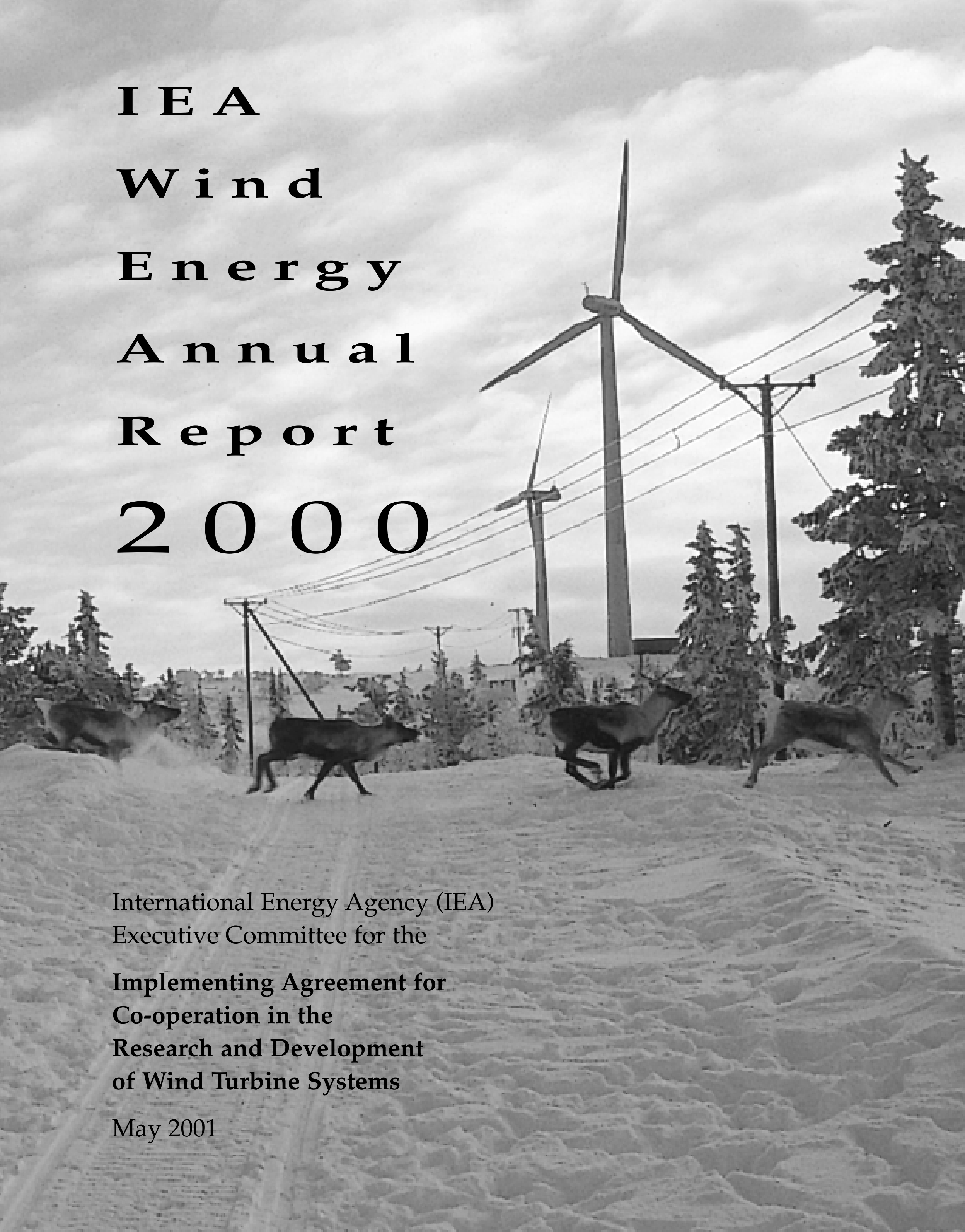


IEA WIND ENERGY ANNUAL REPORT 2000

International Energy Agency

R&D Wind



IEA Wind Energy Annual Report 2000

International Energy Agency (IEA)
Executive Committee for the

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

May 2001

NREL

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
United States of America

Cover Photo

These reindeer live in the vicinity of wind turbines at the Härjedälen site in Sweden.

Photo Credit: Gunnär Britse

The twenty-third IEA Wind Energy Annual Report reviews the progress during 2000 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 the National Renewable Energy Laboratory (NREL) in Colorado, United States, on behalf of the IEA R&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, Norway, Spain, Sweden, the United Kingdom, and the United States.

Jaap ´t Hooft
Chair of the
Executive Committee

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

CONTENTS

Page

MESSAGE FROM THE CHAIR

The year 2000 was another good year for wind energy. Worldwide electricity generation from wind now provides enough electricity to supply 75% of all Denmark's needs.

Much of the current market for wind energy is driven by the very low life-time emissions that the technology offers. But wind energy 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 increasingly recognized by governments, which has enabled sustained high growth at 30% per annum or above since reporting began in 1994. Wind continued to show growth at 30% both globally and in the reporting IEA countries this year. At the end of 2000, the global wind capacity reached 17.6 GW. The total installed capacity in the IEA member countries reached 15.4 GW, with the IEA countries now accounting for 88% of global installed capacity. The value of this global market in 2000 is estimated at around 4 billion US Dollars.

Germany and Spain sustained the very high rate of turbine installation seen for the last couple of years, putting in more new wind plant than ever before. This reflects the strong markets, offering fixed and generous tariffs for the energy produced. Denmark too had an exceptional year, installing nearly twice as much capacity as it has in recent years. Italy continued its rapid growth trend established over three years now, installing 145 MW to match Spain's overall growth rate of over 50%. New markets to show vigorous activity were Japan and Australia.

The price that wind power can generate electricity at commercially, continues to fall steadily. This is driven by more effective and cheaper machines and the use of larger machines. The average turbine continues to grow in size and capacity, reaching 800 kW in 2000, compared to 440 kW five years ago. Machines of 3 MW and above are now being developed by several companies, the first of which is expected to be erected in 2001 in Sweden.

The interest and level of commercial activity associated with offshore wind energy increased again during 2000. Projects were developed in the UK (4 MW), in Denmark (40 MW) and in Sweden (10 MW). The new market for large offshore machines has created much fresh thinking on both the foundations and installation methods. Offshore reliability has also been identified as an area needing continued research in order to achieve acceptable availabilities.

I hope you will find this IEA Wind Energy Annual Report both interesting and informative. This year we have expanded the Overview chapter based on the national reviews of the IEA R&D Wind member countries to provide a compressed analysis. We would appreciate your feedback on the annual report, which can be sent to the Secretariat listed in Appendix B.

Jaap ´t Hooft
Chair IEA R&D Wind

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 23 years have seen the development and maturing of wind energy technology. This process has only been possible 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 9 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 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 six Tasks, that are Annexes to the original Implementing Agreement. Several additional Tasks are being planned as new areas for cooperative research are identified. To date, 11 Tasks have been successfully completed and one Task has been deferred indefinitely. 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 7. A brief account of the status of Tasks follows here. To obtain more information about these activities, contact the Operating Agent for each task listed in Appendix B..

Task XI - Base Technology Information Exchange

Operating Agent: The Aeronautical Research Institute of Sweden (FFA)

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 ExCo. Work on this task began in 1987 and has been extended through December 2001.

In 2000, the 14th Joint Action Symposium on Aerodynamics was held in Boulder, Colorado. The 33rd Topical Expert meeting was held in Boulder, Colorado on Wind Forecasting Techniques. The 34th Topical Expert Meeting was held in Stockholm, Sweden on Noise Imission. In addition, the Operating Agent represented the ExCo at the Offshore Wind Energy MES conference, the IEA Renewable Energy Working Party workshop on long-term research needs, and the International Electrotechnical Commission TC88.

Task XV - Annual Review of Progress in the Implementation of Wind Energy by Member Countries of the IEA.

Operating Agent: Energy Technology Support Unit (ETSU), United Kingdom.

This task, initiated in 1995, has produced overviews for decision makers of the progress in commercial development of wind turbine systems in the IEA R&D Wind member countries.

In 2000, the ExCo voted to support this activity through contributions to the Common Fund. Now all members will contribute to supporting this important information-gathering and analysis activity. Annex XV will expire on May 31, 2001. The report on data collected in this activity is presented in this Annual Report of the IEA R&D Wind Agreement as Chapter 8, Overview. Future issues of the Annual Report will also contain an Overview chapter.

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. A standard turbine is undergoing tests at several different sites around the world. Preparation for testing includes drafting test plans, anemometer wind tunnel calibrations, and site calibration measurements. Anemometers from eight countries have been calibrated in ten wind tunnels. Site calibration measurements have been completed at NREL and RISØ.

Three standard turbines underwent tests in Canada, the United States, and Denmark in 1998. Testing continued through 2000. The ExCo voted to extend work on this Task and a final report is expected in 2001.

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 2000, the database contained more than 60,000 hours of data from 36 sites around the world. In addition, an advanced data selection system is available that allows interactive use of the Web site where the data are available.

TASK XVIII - Enhanced 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 use of the database can be expected for years to come. In 2000, the database was also made available on an Internet site. Access to the information is possible to parties who agree to inform the IEA Annex XIV participants about the experiences they gain with the database. The database has been extended and 18 organizations have received access to the database.

TASK XIX - Wind Energy in Cold Climates

Operating Agent: Technical Research Centre of Finland (VTT Energy)

In 2000, the ExCo approved Task XIX to supply information on the operation of wind turbines in cold climates. The participants will gather and share information on wind turbines in cold climates, they will establish 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. A work plan will guide the activities that will begin in 2001.

EXECUTIVE COMMITTEE ACTIVITIES

Officers

J. ´t Hooft (the Netherlands) served as Chair and F. Avia (Spain) served as Vice-Chair for 2000. At the 45th meeting, an additional Vice-Chair, P. Goldman (US) was elected. At the 46th meeting J. Lemming (Denmark) was elected to begin as first Vice-Chair in 2001.

Participants

In 2000, total membership continued to be 19 organizations participating. See Appendix B for an updated list of Members, Alternate Members, and Operating Agents. During the year, the Executive Committee invited representatives from China, France, and Ireland 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.

The 45th ExCo meeting was hosted by the Swedish National Energy Office (FFA) and Vattenvall AB in Visby, Sweden on May 23 to 24, 2000. There were 25 participants from ten of the contracting parties, five operating agent representatives of the tasks, the Secretary, and 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, XV, XVI, XVII, and XVIII; adopted the draft proposal for Annex XIX Wind energy in cold climates; and considered new proposals on wind energy forecasting, market development activities, and long-term R&D. The audit report of 1999 accounts of the Common Fund was approved. The Annual Report for 1999 was distributed to members.

On May 25, the ExCo visited the Slitevind company Smöjen project in a former limestone quarry; the Nordic Windpower AB Nordic 1000-kW wind turbine at Näsudden; and the HVDC light station at Näsudden.

The 46th ExCo meeting was hosted by ENEA in Naples, Italy on October 3 to 4, 2000. There were 26 participants from 12 of the contracting parties, five operating agent representatives of Tasks, a representative from IEA Headquarters, the Secretary, and several observers. The ExCo approved the budgets for the ongoing tasks and for the Common Fund. The ExCo also decided to have the work of Annex XV be financed from the Common Fund. The ExCo considered proposals on wind energy forecasting, life cycle analysis and environmental impact of wind turbines, the extension of Annex XVII, determining topics for long-term R&D, and contributing to IEA's market acceleration initiative.

On October 5, 2000, the ExCo visited Edison Energie speciali wind farm of 20 Enercon 500-kW turbines at S. Giorgio la Molara on Montefalcone and the IVPC operational office, spare parts facility and wind farms.

The 14th issue of the Wind Energy Newsletter was published in November 2000.

CHAPTER 1

The Implementing Agreement

The IEA co-operation in wind energy began in 1977 when The Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems was written. Referred to as IEA R&D Wind for short, this agreement has been signed by 17 countries and the European Commission. IEA R&D Wind currently governs the co-operation of 19 organizations, called contracting parties, designated by these 17 countries and the European Commission. Contracting parties participating in activities for 2000 are listed in Table 1.1.

The objectives of IEA R&D Wind are to exchange information 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, mostly government departments or agencies. Some countries have more than one member if each contracting party has one representative. Member countries also share the cost of administration for the governing body of

Table 1.1 Contracting parties to the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems—2000

Australia	Energy Research and Development Corporation
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 Electricity Corporation of New Zealand Ltd.
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 1.2 Participation per country in current Tasks. OA indicates Operating Agent.

COUNTRY	TASK					
	XI Technology information	XV Annual wind energy review	XVI Round robin test program	XVII Database on wind characteristics	XVIII Enhanced field rotor aerodynamics database	XIX Wind energy in cold climates
Australia	x					
Canada	x		x			
Denmark	x	x	x	OA	x	x
European Commission	x	x				
Finland	x					OA
Germany	x	x				
Greece	x	x	x		x	
Italy	x	x				
Japan		x			x	
Mexico	x					
Netherlands	x	x		x	OA	
New Zealand						
Norway	x	x		x		x
Spain	x					
Sweden	OA	x		x		x
United Kingdom	x	OA				
United States	x	x	OA	x	x	x

the Agreement, the ExCo. The ExCo meets twice each year to exchange information on their respective country R&D programs, to discuss work progress on various Tasks, and to plan future activities. Decisions are reached by majority vote.

The R&D Tasks performed under IEA R&D Wind are approved by the ExCo as Annexes to the original Implementing Agreement. (They are sometimes referred to as Annexes.) Each Task is managed by an Operating Agent, usually one of the contracting parties in the IEA R&D Wind agreement. 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. 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.

Current Tasks and participating countries are listed in Table 1.2.

All Tasks undertaken to date are listed in Table 1.3.

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

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. Continuing through June 2001.
Task XVI	Wind turbine round robin test program OA: the National Renewable Energy Laboratory (NREL), United States To be completed in 2001.
Task XVII	Database on wind characteristics OA: RISØ National Laboratory, Denmark. Continuing through 2001.
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.

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 1999 for the years 2000 and 2001. From 1 January 2000, a new Operating Agent, FFA, The Aeronautical Research Institute of Sweden, took over from The Technical University of Denmark.

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 once or twice a year on topics decided by the IEA R&D Wind Executive Committee.

Over the 21 years since these activities were initiated, we have published 34 volumes of proceedings from Expert Meetings (Table 2.2), 14 volumes of proceedings from symposia on Aerodynamics of Wind Turbines, five from symposia on Wind Turbine Fatigue, and two from symposia on Wind Characteristics.

The activities of Annex XI in 2000 follow.

- Represented IEA at the Offshore Wind Energy MES (OMEMES) conference
- Arranged topical expert meeting on Wind Forecasting Techniques
- Prepared a document on long-term research needs
- Participated in IEA Renewable Energy Working Party (REWP) workshop on long-term research needs
- Operating Agent Representative served as official observer of International Electro-technical Commission TC88
- Arranged a Topical Expert Meeting on Noise Emission
- Arranged a Joint Action Symposium on aerodynamics

The offshore conference OWEMES was partly sponsored by IEA. As a result of that, the operating agent was invited to participate in the paper selection committee and was also given the task to chair one of the sessions. The conference was held in Siracusa on Sicily and attracted 180 participants. The conference gave both a broad and an in depth description of an area under strong development.

The 33rd Topical Expert Meeting addressed Wind Forecasting Techniques. The National Renewable Energy Laboratory (NREL) hosted the meeting in Boulder, USA. In total, 20 persons participated in the meeting. At the end of the meeting, there was a discussion on the need further development, within this area. As a result, an ad hoc group was formed to write a proposal for setting up a new Annex to the IEA R&D Wind agreement. This proposal was discussed at the 46th ExCo meeting in Naples, Italy.

A discussion on Long Term Research needs was initiated by the IEA central office in Paris. As a result, an ad hoc group was set up, headed by the operating agent representative of Annex XI and the vice chair of the ExCo, to prepare a document focusing on R&D needs in wind energy. A preliminary version of the document was presented, by the ExCo chairman, at the IEA REWP meeting in Paris.

The 34th Topical Expert Meeting was held in Stockholm on Noise Immission. The meeting was attended by 16 persons, representing eight countries. The presentations clearly showed the difference between how guidelines and limits are set in different countries. Within the European Union, the Commission

Table 2.1 IEA R&D Wind List of Recommended Practices.

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	1984	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 wind 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

has made a proposal for common noise emission level descriptions and evaluation methods. It is primarily intended for traffic noise but can be expanded to include other sources of noise, such as wind power generators. The proposal suggests an equivalent annual average sound level (Lden) where the night level has a penalty of 10 dB(A) and the evening level of 5 dB(A). It should be emphasized that the proposal is not concerned with the specific values of the noise level limits, only with how they are defined.

The 14th Joint Action Symposium on Aerodynamics was held at NREL, Boulder, USA. The meeting was attended by 34 persons from eight countries. The meeting was arranged in conjunction with the NREL/National Aeronautics and Space Administration, Ames Scientific Panel Meeting and the meeting of Task XVIII Enhanced Field Rotor Aerodynamics Database. As a result of combining meetings there were many more participants in the IEA meeting than is usually possible. The final discussion was on long-term research needs in the aerodynamics area. The result of this discussion will be used in a new version of the above-mentioned Long Term R & D document.

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).

Author: Sven-Erik Thor, FOI, Sweden

Table 2.2 List of Topical Expert Meetings held since 1978

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
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

CHAPTER 3

Task XV - Annual Review of Progress in the Implementation of Wind Energy by the IEA Member Countries

This Task was initiated on June 1, 1995, and has been extended to May 2001. The Energy Technology Support Unit (ETSU), on behalf of the United Kingdom, is the Operating Agent for this Task.

3.1 OBJECTIVE

The objective of this Task has been to produce an annual overview of the progress in the commercial development of wind turbine systems in the IEA member countries participating in this Agreement in a form suitable for presentation to decision makers in government, planning authorities, the electricity supply industry, financial institutions and the wind industry.

The aim is to identify major trends in initiatives and attitudes that are likely to be of interest to decision makers rather than to produce detailed statistics of installations and their performance.

3.2 MEANS

The Member Countries of IEA R&D Wind decided in 2000 to change the way the work performed under this task will be supported. The task will expire June 1, 2001 and henceforth ETSU will perform the analysis under contract to the Common Fund to which all members contribute.

In addition, it was decided that the analysis would be published as a chapter in the Annual Report that is published with money from the Common Fund. As a result, this Annual Report for 2000 includes the summary of progress in the implementation of wind energy as Chapter 8. That Overview will not appear as a separate report. Member countries further agreed to supply information about deployment in a standard format, making summaries more uniform.

Author: Ian Fletcher, ETSU, United Kingdom.

Participants	
Denmark	The Ministry of Energy
European Commission	Directorate General XII
Germany	Forschungszentrum Jülich GmbH
Greece	The Ministry of Industry/Energy and Technology
Italy	Ente per le Nuove Tecnologie, l'Energia el'Ambiente (ENEA); and ENEL, Società per Azione
Japan	The Government of Japan
Netherlands	The Netherlands Agency for Energy and the Environment (NOVEM)
New Zealand	Electricity Corporation of New Zealand (ECNZ)
Norway	The Norwegian Water Resources and Energy Administration (NVE)
Sweden	The National Board for Industrial and Technical Development (NUTEK)
United Kingdom	Department of Trade and Industry
United States	The Department of Energy

CHAPTER 4

Task XVI - Wind Turbine Round Robin Test Program

4.1 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.

4.2 OBJECTIVES

The objectives of this program are to validate wind turbine testing procedures, to analyze and resolve sources of discrepancies, and to 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), United States of America.

The Operating Agent is the National Renewable Energy Laboratory (NREL) in the United States.

4.3 STATUS

This annex to the IEA R&D Wind agreement was approved with a start date of April 1996. After the program kickoff meeting, in April 1996, participants began detailed preparations for testing. These included drafting test plans, initiating anemometer wind tunnel calibrations, and initiating site calibration measurements.

ENEA participated in Annex activities from 1996 until 1998. Then the Operating Agent was verbally informed that funding and organizational changes prohibited further participation. ENEA has since withdrawn from the Annex.

Wind tunnel calibrations were conducted in cooperation with a European wind turbine standards program, MEASNET, in which anemometers from eight countries were being calibrated in ten wind tunnels. Final calibrations were 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. The principal investigator of this phase of testing, Dr. Kostas Papadopoulos, is planning to submit a second paper on this subject for publication in a peer-reviewed journal. NREL and Risø have completed site calibration measurements, which quantify wind speed differences between the anemometer tower and the wind turbine. Other participants plan to conduct this test at a later date.

The standard turbine is an Atlantic Orient Corporation (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 with both NREL and AWTS engineers having completed several operational tests of its turbine. 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 began in February 2000. The original plan to test the third turbine in Italy has been canceled due to funding and organizational constraints at ENEA.

Status meetings were held at Risø in June 1998 and at CRES in February 1999 and a third is planned for 2001. The Executive Committee has approved several extensions for the Annex to accommodate 1) the delayed production of the European test turbine, 2) change in test sites from ENEA to CRES, and 3) longer than expected testing schedules. Final reports are expected to be completed by October 2001.

Some comparisons of test results have begun. However, detailed investigations are not planned until tests at AWTS, CRES, and NREL are completed in early 2001.

Author: Hal Link, NREL, United States

Figure 4.1 AOC 15/50 turbine under test at CRES.

CHAPTER 5

Task XVII – Database on Wind Characteristics

5.1 INTRODUCTION

In 1996, the European Union, EU-DG XII (JOULE) project 'Database on Wind Characteristics' was started. That project, concluded in1998, resulted in a unique database of quality-controlled well-documented field time series measurements of the wind. The project also provided tools for easy access and simple analysis through an Internet connection using the World-Wide-Web.

As a follow-up to the JOULE project, the IEA R&D Wind agreement added Annex XVII Database on Wind Characteristics to its list of approved tasks. Task XVII was joined by Sweden, Norway, the United States, The Netherlands, Japan, and Denmark the active participants that fund the work of the task. Task XVII was initiated on 1 January 1999 for an initial period of two and one half years.

The main purpose Task XVII is to provide wind energy planners, designers, researchers, and the international wind engineering community in general with actual wind field time series observed in a wide range of different wind climates and terrain types. Recently, the scope has been widened to include also wind resource measurements as well as structural response time series associated with wind turbines erected at sites where wind field time series is available.

5.2 OBJECTIVES

The objective of Task XVII is to maintain and extend the database and also to make people aware that it is available. The work is organized in three work tasks.

(a) Maintain the database in order to ensure that the data, as well as the hardware and software will be on-line and available;

(b) Extend the database developed in the JOULE-project;

(c) Publicize the database and the possibilities for its use.

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

5.3 STATUS

Presently, the database contains more than 60,000 hours of meteorological time series from 36 sites in Europe, Egypt, the United States, and Japan. These data represent a wide variety of wind climates, terrain types, and wind turbine wake situations. The time series are stored in a common file format with the temporal resolution ranging between 1 and 40 Hz. Therefore they are mainly intended for investigations of design wind loads and phenomenological studies. In addition, an advanced data selection system is supplied that fully utilizes the interactive nature of the World Wide Web. Tools are also provided for simple data analysis (f. ex. analyses of wind speed gusts, wind direction gusts and studies of wind shear), for data presentation (on-line plot facility), and for down load of time series, for further processing.

The wind resource data are stored as 10-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 2000, within each of the defined work tasks, are summarized below.

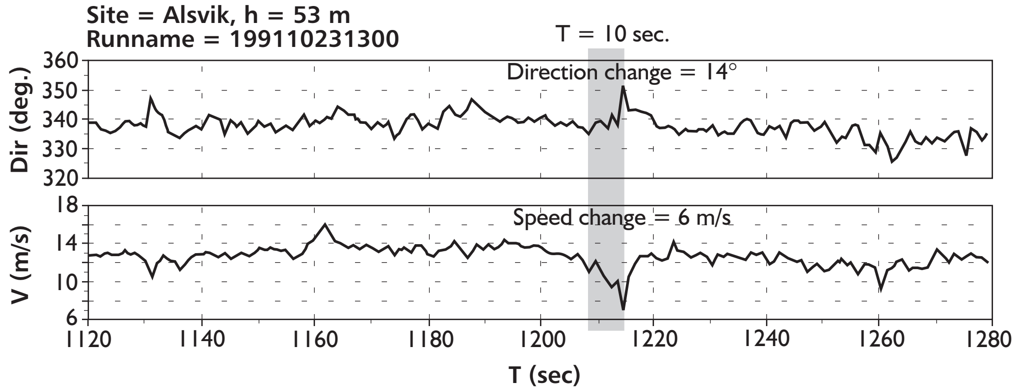


Figure 5.1 Example of simultaneously extreme wind speed (down) gust and wind direction change identified using database search and analysis tools.

5.3.1 Maintenance

The maintenance of the database includes both routine software updates and routine hardware updates. During 2000, the old server (200 Mhz) was replaced by a new state-of-the art server (700 Mhz). The JukeBox was replaced by a huge fast hard disc with a capacity of 45 Gb, which increases online time history plotting speed considerably and decreases the access time in general. The old server as well as the JukeBox will be used as hardware backup in the future.

5.3.2 Extension

This work includes development of the software facilities as well as implementation of meteorological data from new sites and extension of available data from already existing sites. The efforts to upgrade the database facilities and extend the amount of available wind field time series are described below.

Database Utilities:

- Export facilities from the database format to tables in Paradox/Access data-base formats have been implemented. This new facility enables the users to extract selected statistics from the main database for arbitrary post processing with standard database tools;
- A new query form for searching "additional statistics" has been included, and all query forms have been updated with links to an on-line plot package;
- A multi-user class software system has been defined and implemented. The system allows licensed users to be categorized into user classes which, among other things, allows the database to be used as "host database" for (confidential) data;
- A new database structure, intended for wind resource data, has been defined and implemented in the database framework;
- A new database structure, suited for implementation of wind turbine structural load time series, has been defined and implemented in the database framework;
- Two higher order statistical moments (skewness and kurtosis) have been implemented in the database and are currently under implementation in the search profiles;
- Facilities for evaluation of turbulence spectrum (power spectrum), cross correlation functions and probability density functions has been implemented as part of the integrated plotting package (DANAP);

- The ServerPlot facility (on-line time history plot) has been released in an updated version. The new version allows small gif pictures (approximately 30 kB) to be generated fast on-line with full resolution;
- The Website has been extended with a new Web page titled "List of content." This facility is meant to help the user navigate through the database facilities. New links to related institutions and companies have also been added;
- Detailed user statistics have been made available on the Web-server showing the number of visitors, downloaded documents and active users each month.

Database Bank Implementation:

- Sprogø data (527 hours of high wind data from an off-shore/coastal terrain site in Denmark);
- Tjæreborg data (150 hours of data from a flat Danish terrain);
- Zeebrugge measurements (104 hours of data from a coastal terrain (pier) in Belgium);
- Marglarp data (41 hours of 20 Hz recordings from a flat terrain in Sweden);
- Utlängan data (90 hours of 20 Hz recordings from a flat terrain in Sweden);
- Näsudden data (124 hours of 20 Hz recordings from a flat terrain in Sweden);
- Abisko data (130 hour of 20 Hz recordings from a flat terrain (frozen lake) in Sweden);
- Sky River wind field data (300 hours of data from a complex site in California, U.S.A);
- Sky River structural response data (140 hours of structural load measure ments from a Vestas V39 wind turbine erected nearby the meteorological tower from where the wind field record ings originate). While these are the first structural measurements in the database, the wind turbine response signals are defined in a preliminary manner;
- Toboel wind field data (3,000 hours of data from a flat pastoral site in Denmark). These records contain a 400-year wind event (recurrence period 400 years) in Denmark—the storm 3-12-99;
- Middelgrund data (2074 hours of wind data from an off-shore site in Denmark);
- Tsukuba data (1,355 hours of wind data from a Japanese site);
- Tarifa data (more than 660 hours of sonic wind data from a complex site in Spain);
- Wind field data from Hurghada (desert, Egypt), Gedser Syd (off-shore, Denmark), Horns Rev (off-shore, Denmark) and supplementing data from Cabauw (flat homogeneous terrain, The Netherlands) are under final implementation.

5.3.3 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 Task XVII has a high priority. Initiatives taken in 2000 follow.

- Presentation of a paper on extreme gusts at off-shore locations (based on statistical analysis of data originating from the database) at the OWEMES seminar at Sicily 13 to 15 April 2000;
- Presentation of "Database on Wind Characteristics" on Advanced Topics in Wind Turbine Aerodynamics, PhD course, 16 to 25 August 2000, DTU, Denmark;
- Distribution of the database leaflet at the OWEMES seminar at Sicily 13 to15 April 2000 and at the Wind Energy Symposium,

38th AIAA/ASME Aerospace Sciences Meeting and Exhibition, 10 to13 January 2000, Reno, U.S.A.;

- Demonstration of the database and its capabilities at the Danish national event "Vinddag 2000" held at Risø 29 November 2000.
- Mailed letter to 26 Japanese universities/ institutions/companies;
- Preparation of an IEA brochure on the database;
- Preparation and printing of a revised version of the database leaflet;
- Issuance of four electronic newsletters;
- Conducted opinion poll on "Database on Wind Characteristics" among Dutch manufactures and other potential users;
- Established an electronic discussion club for users of the database;
- Established links from different home pages to the database (IEA, WasP, Risø, DTU);
- "Database on Wind Characteristics" has been utilized in a number of ongoing research projects (the JOULE project NewGust, the JOULE project ENDOW, the JOULE project ADAPTURB, a project on siting of wind turbines in complex terrain and a national Danish project on non-Gausian turbulence). Moreover Risø, DTU, Tech-wise A/S and NEG Micon have obtained funding for a national project in which the database plays an prominent role;
- Risø and DTU have obtained national funding for a research project on extreme wind direction gusts in which the database will be used.

The database is available on the Web server (http://www.winddata.com/) and the use is free of charge for users from IEA Task XVII participating countries.

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

CHAPTER 6

Task XVIII – Enhanced Field Rotor Aerodynamic Database

6.1 INTRODUCTION/OBJECTIVE

IEA R&D Wind Task XVIII is an extension of the IEA R&D Wind Task XIV project in which five parties (DUT, ECN, NREL, RISØ, IC) from four countries (the Netherlands, Denmark, United Kingdom, and the USA) cooperated 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.

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 Task XIV, is a major step forward in understanding the aerodynamic behavior of wind turbines.

Until October 1999, the Task XIV database was stored on CD-ROM and on an ftp-site, which was protected by means of a password. The CD-ROM and/or the password are available for outside parties under the condition that they inform the Task XIV participants about experiences gained with the database. In October 1999, the database has also become available on an Internet site. The conditions to obtain the database from the Internet site remain similar to the conditions described above. By April 2001, permission to use the database has been granted to 17 individual institutes and to a group of institutes which jointly perform a EU-JOULE project. Furthermore, students use the database.

Task XVIII was defined on the basis of the recommendations formulated at the end of Task XIV. The main objectives of Task XVIII are:

- Maintenance of the Task XIV database. In order to reach this objective the feed back from the above mentioned users of the database is essential.
- Extension of the Task XIV database with new measurements.

The participants in Task XVIII are:

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

6.2 CHARACTERISTICS AND STATUS OF THE TEST FACILITIES

1) Wind turbine at ECN, the Netherlands
D = 28 m; Two blades; Blades with twist and taper; Instrumented at three radial stations, measured simultaneously. The tests are completed. Much data have been collected, both for standstill as well as rotating conditions. The data are stored in the Task XIV database.

2) Wind turbine at RISØ, Denmark
D = 19 m; Three blades; Blades with twist and taper; Instrumented at three radial stations, measured simultaneously. Much

data have been collected and stored in the Task XIV database. The tests are completed.

3) Wind turbine at NREL, United States
D = 10 m; The experiments are carried out in different phases. Phase II: Three bladed; Blades without twist and taper. Phase III and IV: 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 bladed; Blades with constant chord, twisted. Instrumented at 4 (or 5) radial positions, measured simultaneously; Much data have been collected. The phases II, III and IV are completed and data are stored into the Task XIV database.

4) Wind turbine at Mie University, Japan
D = 10 m; Three blades; Blades with twist and taper; Instrumented at 4 radial stations, partly measured simultaneously. At the end of 2000, most measurements were performed, but they still needed to be made available for Task XVIII.

5) Wind turbine at Delft University, the Netherlands

D = 10 m; Two blades; Blades without twist and taper; Instrumented at four radial positions. Until 1999 these stations could not be measured simultaneously. From 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 database. Also some measurements with boundary layer manipulators have been performed which are made available to the database.

6) Wind turbine at CRES, Greece
D = 19 m; 3 blades; Blades with twist and taper; Instrumented at three radial positions. The instrumentation is not finished yet and at the end of 2000 it was not expected that the data would arrive in time to be stored into the database.

6.3 STATUS OF THE DATABASE

At the end of 2000 the following measurements were stored into the database:

- Power curves, delivered by NREL, RISØ and Mie University;
- 2D airfoil coefficients, delivered by ECN, NREL, and RISØ;
- 2D pressure distributions delivered by NREL;
- Rotating airfoil coefficients, delivered by ECN, NREL and RISØ;
- Time series, delivered by DUT, ECN, NREL, IC and RISØ. 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.

DUT and Mie University still need to deliver their 2D and rotating airfoil coefficients. Further, DUT and Mie University still have to supply a number of time series.

6.4 EXPERIENCES OF USERS OF THE DATBASE

Until October 1999, the Task 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 Task XIV participants about experiences gained with the database, for example by means of relevant project reports. This feedback gives the Task XVIII participants the possibility to improve the quality of the database, to get insight into the research which has been performed with the measurements, and to defend against possible criticism.

In October 1999, the database also became available on an Internet site. On this site, a registration form has to be completed by users which asks them to share their experiences with the Task XIV/XVIII participants. The request to share experiences is based on an honors system agreement and no obligations can be imposed. The Table 6.1 lists the institutes which received access to the database.

Furthermore the CD-ROM has been supplied to the EU-JOULE project group: 'VISCEL', coordinated by CRES (Greece).

In November 2000, a questionnaire was distributed to the users of the database, with the following questions. Have you used the database recently? If yes, for what purpose have you used it? Do you have any references? What were your experiences? Do you think you will use the database in the future? If no, why not? Do you have any comments on the content and the access of the database? Are you interested in updates of the database?

Users have responded. Some of the main observations are as follows.

1. Generally speaking it can be concluded that the experiences were positive, but it also has to be concluded that recent use of the database was limited. This was partly attributed to lack of time. Almost all users were interested in updates and wanted to be informed about future developments.
2. The communication is complicated by the fact that access to the database is given to persons instead of to institutes. When persons move to other positions, contact often get lost, although sometimes they use the database at their new jobs.
3. The database is mainly used in university environments, and as such the emphasis is on more fundamental research items and on validation of advanced CFD

Table 6.1 Users of Enhanced Field Rotor Aerodynamic Data Base

INSTITUTE	ACCESS TO DATABASE	CD-ROM/ INTERNET
Garrad Hassan and Partners (United Kingdom)	Dec. 1997	CD-ROM
Carlos III University (Spain)	Jan. 1998	CD-ROM
FFA (Sweden)	Dec. 1997	CD-ROM and Internet
Rzeszow University (????)	May 1998	CD-ROM
University of Illinois (United States)	Feb. 1998	CD-ROM
University of Glasgow (United Kingdom)	Dec. 1997	CD-ROM
NASA-Ames (United States)	Feb. 1999	CD-ROM
University of Quebec (Canada)	Feb. 1999	CD-ROM
University of Northern Arizona (United States)	Dec. 1998	CD-ROM
NEG-Micon (Denmark)	Feb. 1999	CD-ROM
School of Aerospace Engineering Georgia Institute of Technology (United States)	May 1999	CD-ROM and Internet
Universidad de Malaga (Spain)	March 2000	Internet
CITA (France)	Sep. 2000	Internet
Vrije Universiteit Brussel (Belgium)	April 2000	Internet
Asade (Spain)	Oct. 2000	Internet
University of Applied Science Kiel (Free Republic of Germany)	Dec. 2000	Internet
Monash University (Australia)	Oct. 2001	
Students (Greece, Denmark, Holland)	Continuous	Internet

codes. Applications to industrial related aerodynamic research is still rare.

4. The NREL data are the most popular. This is partly because many of the users are subcontractors to NREL, but also because NREL has measured the inflow conditions in most detail.

6.5 ACTIVITIES TO BE PERFORMED

The following tasks still have to be performed:

1 The storage of the measurements which are mentioned in section 6.3, into the database

2. The final report which will be an extension of the Task XIV final report referenced below. It will contain an updated description of the database and the facilities and other information. Meanwhile the facilities of all participants have already been reported.

3. Finalization of the Internet site. The applications of the measurements will be reported, links with external Internet sites will be established and dissemination will be enhanced.

Reference:

J.G. Schepers et al., Final report of IEA-ANNEX XIV. Field Rotor Aerodynamics, ECN-C-97-027, Netherlands Energy Research Foundation, 1997.

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

CHAPTER 7

Task XIX – Wind Energy in Cold Climates

7.1 INTRODUCTION/OBJECTIVE

Wind energy production in cold climates has been discussed withing the IEA R&D Wind implementing agreement for some time. For example, it is a topic mentioned in the strategic plan for 1998 to 2003. Wind energy is increasingly used in cold climates under arctic conditions and technology has been adapted to meet these challenges. As the turbines incorporating special technology are being demonstrated, there is a need to gather the experiences in a form that can be used by developers, manufacturers, consultants, and financiers.

To supply information on the operation of wind turbines in cold climates, Annex XIX to the IEA R&D Wind implementing agreement was approved in principle by the ExCo in 2000. The resulting Task XIX will begin 1 March 2001 and continue for three years. The participants will work to achieve the following objectives.

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

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

7.2 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.

Three main activities will be carried out under this agreement.

7.2.1 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 account of energy demand, grid infrastructure, wind conditions, general climate conditions, extremes and variations in temperature levels, type and rate of icing, site accessibility, safety aspects, other demands related to infrastructure, and special off-shore conditions. The classification procedure will be based upon existing information or recommend ways to obtain new data.

7.2.2 Technology and Operations Classification

To help those evaluating bids or proposed specifications for sites classified according to the Site Assessment and Classification system mentioned above, technical and operational features will also be classified. The technical features will include materials specifications, temperature control, lubricants, and ice detection. Operational strategies will include operation within specified temperature ranges and ways to stop the turbine if icing occurs. This effort will also identify methods for predicting ice accretion and methods to prevent it from affecting wind turbine.

7.2.3 Operation and Performance Experiences

In order to determine how much electricity production is lost due to extraordinary climatic effects, the project would monitor production and failure events related to operations and maintenance under cold conditions. It would develop power performance measurement techniques to be used in cold climate conditions. It would develop methods to monitor icing events during operation. It would monitor availability and reliability of standard and specially adapted technology during extreme events. It would gather experiences regarding construction of wind turbine facilities under cold climate conditions. And it would assess the reliability of anemometers, ice detectors and other instruments.

7.2.4 Extraordinary Operational Events

In addition to the overall monitoring, specific sites representing different conditions will be chosen for detailed monitoring of extraordinary events such as icing, storms, and voltage losses.

7.2.5 Dissemination of Results

The findings that will include guidelines for assessing and deploying wind energy under cold climate conditions will be published for the members of IEA R&D Wind, and they will be presented at various international conferences.

7.3 STATUS

A kickoff meeting was held in Helsinki on 22 September 2000 where the work plan was updated with national activities for each participant to carry out. Work will begin in 2001.

Author: Jonas Wolff, VTT, Finland

CHAPTER 8

Overview

8.1 THE INTERNATIONAL CONTEXT

The basis of this overview chapter is the national reviews of the IEA R&D Wind Implementing Agreement Member Countries presented in Chapters 9 through 23.
As has been done previously under a separate task (Annex XV), 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.

8.1.1 A Solution to a Problem

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. The following benefits make wind energy increasingly attractive to existing and new markets.

- Very low lifetime emissions of harmful gasses (especially CO_2), 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 an opportunity for industry, through turbine and component supply and assembly, provision, and installation of turbines and infrastructure and ongoing plant servicing.

The principal value of wind energy for most countries actively involved in implementing wind energy to date, is the control or reduction of greenhouse gas emissions. The top down policies start by setting targets for CO_2 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.

Generally the countries with most installed wind capacity have a strong national commitment to environmental goals, but lack a strong hydro-resource (DE, United States, DK, Netherlands). 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, NOR). For many countries wind energy offers one of the better opportunities and has formed a strong part of government forward thinking.

8.1.2 National Policies

Government policies and strategies vary because of both their circumstances and how aggressively they pursue environmental goals. However 2000 has seen several examples of increased commitment to renewables, especially wind energy. In particular, some countries are increasingly looking at supply obligations with green certificate trading and penalties as a means of implementation in a competitive and economic environment.

Please refer to Appendix C of this Annual Report for the exchange rates used in this analysis.

Australia (AU)

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

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 have also pursued wind/diesel technology for off-grid systems and have the Atlantic Wind Test Site at North Cape, for wind/diesel systems.

Denmark (DK)

The present strategy is based upon the Government's action plan "Energy 21," and setting ceilings for CO_2 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 the 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.

Finland (FI)

Finland sees a limited resource, which is predominantly offshore. A policy introduced in 1997 described wind energy as capable of reaching some percent of total power consumption after 2015. The role of all renewables is recognized, but the largest expectations are on bioenergy. The action plan for renewable energy resources from 1999 strives to increase the share of renewables to 3 Million tonnes of oil equivalent (Mtoe) /yr by 2010 and 6 Mtoe/yr by 2025. The corresponding targets for wind energy are 500 MW in 2010 and 2,000 MW in 2025.

Germany (DE)

Germany has become increasingly concerned with the environment and this change is reflected in changing policy. It also now seeks to maintain a strong technology position and to improve exports. In the short term, improvements in thermal power stations and energy efficiency measures are expected to produce reductions in CO_2 emissions, with renewables making a significant contribution in the medium to long term. Government targets for wind energy are not specified, but the two federal states of Lower Saxony and Schleswig-Holstein do publish targets. It is in these two states that most of the development to date has occurred.

Greece (GR)

Greece recognizes a high wind energy potential, and the government wishes to exploit wind energy to replace expensive imported fuel in decentralized energy production. It also aims to actively involve Greek industry in creating new jobs. The Greek electricity market is undergoing deregulation, with the liberalization coming into force in February 2001. The new law maintains support for renewables in the competitive framework, but no effect on wind energy development has yet been observed.

Italy (IT)

Italy has progressively changed its position in favor of renewables. A white paper of August 1999 stated the a main goal of doubling the renewables contribution to the energy balance by 2010. Specifically, 3.4 million tons per year of avoided CO_2 emissions should come from wind power. This equates to about 2,500 MW or 200 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.

Japan (JP)

The process of establishing wind energy in a new country requires initial demonstration projects, often needing substantial support from government. Japan have just such a program for the construction and operation of large-scale test plant, through NEDO. In 1998, the Government developed a plan to stabilize CO2 emissions at 1990 levels by 2010, with renewable energy increasing from 1.1% to 3.1%. Wind energy has a target of 300 MW.

Mexico (ME)

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.

The Netherlands (NL)

For the Netherlands, reducing CO_2 is a key objective. By 2000, emissions should have reached 1990 levels. The policy is now to stabilize emissions by first limiting energy demand as much as possible and then to meet the remaining demand with renewable energy. For renewable energy, the target is set to a 10% contribution in 2020. A wind target of 2,750 MW is derived from that.

New Zealand (NZ)

Other countries, although nominally promoting sustainability, do so less aggressively and are instead driven much more by economics. The position with New Zealand is somewhat similar to Australia's with government policy for energy to ensure the continuing availability of energy services at the lowest cost to the economy as a whole, consistent with sustainable development.

Norway (NOR)

In a year with above average rainfall, Norway could be self sufficient with electricity from renewables, almost all of which is hydro. More typically now, with the increase in energy demand, Norway depends on importing some electricity, mainly from Sweden and Denmark. There are limited opportunities for new hydro projects and in 1998, the Norwegian government stated an overall goal to reach 3 terawatt hours per year (TWh/yr) of electricity from wind energy by 2010. However, the current market incentives and subsidizing scheme are probably insufficient to fulfill this ambition.

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 for 10 years, to large-scale implementation. The high priority and payments given to wind could well continue. During the last year a target has been adopted for renewables. This is a 12% contribution to the national primary energy demand by 2010. This is also attributed a target installed capacity of 8,974 MW.

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. About 95% of the electricity supply in Sweden comes from non-fossil fuels such as hydro-power and nuclear power. A long-term transformation program to develop an ecologically sustainable energy supply system was agreed upon in parliament in 1997. No long-term production volume goal has yet been set, but 0.7 TWh/yr should result from the present investment subsidy program by 2002. The authority responsible for transforming the Swedish power supply is SNEA, which was formed in January 1998.

United Kingdom (UK)

The Government published a policy in February 1999, with a number of key policy themes, including the new Renewables Obligation for England and Wales and the analogous Renewables (Scotland) Obligation. This puts an obligation on all electricity supply companies to procure a rising percentage of their power from renewables with the aim of reaching 10% of UK electricity from renewable sources by 2010. Other policy elements include exemption of electricity generated from renewables from the Climate Change Levy (a tax on business use of energy), development of a proactive strategic approach to planning in the regions through regional targets and capital grants for early offshore wind and energy crops projects.

The United States (US)

The Department of Energy (DOE) is organizing an initiative to help support a dramatic increase in the deployment of commercial wind systems and to sustain the growth of wind energy with a target to provide at least 5% of national electricity by 2020. To encourage uptake state and federal government agencies are expanding renewable energy use, including wind systems. The federal government also offers a tax credit based on energy production from wind plants.

8.1.3 National Targets

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

8.2 THE WIND ENERGY MARKET

8.2.1 Wind Sector Turn-over

The value of this market globally during 2000 is estimated at approximately four billion US dollars (USD). This figure is based on an average total project cost of 1,000 USD/kW installed. This excludes the routine maintenance of all the installed capacity. Germany alone reports a total sector turnover in 2000 of 3.66 billion DEM (1.9 billion USD). This covers both manufacturing and servicing the existing 6 gigawatts (GW) of capacity, with Germany accounting for 40% of the new capacity installed world-wide in 2000, though much of this was imported.

8.2.2 Installed Capacity Growth

High sector growth sustained

Wind continued to show growth at 30% both globally and in the reporting IEA countries. This is a very strong performance, though a little down from last year's record growth of 42% in the IEA countries and 37% globally. The IEA countries now account for 87% of global installed capacity and growth has now been sustained at 30% per annum or above since 1994. At the end of 2000, the global wind capacity reached 17.7 GW. The total installed capacity in the IEA countries reached 15 GW (15,440 MW).

Growth markets

Germany and Spain sustained the very high rate of turbine installation seen for the last couple of years, putting in more new wind plant than ever before. Their

Table 8.1 Wind and renewables electricity genertion targets

COUNTRY	NATIONAL TARGET FOR RENEWABLES	NATIONAL TARGET FOR WIND ENERGY
Australia	An additional 2% of electricity from renewables by 2010 meeting the end target of 9,500 GWh/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 offshore..
Finland	To increase generation from renewables by 50% over 1995 levels, by 2010 (3 Mtoe/a).	Anticipate 3% of new renewables to be wind energy giving 500 MW, by 2010.
Germany	To reduce CO_2 emissions by 25% from 1990 levels by 2005.	No national targets. Lower Saxony has a target of 1,000 MW by 2000 and Schleswig-Holstein 1,200 MW by 2010.
Greece		300 MW by 2012.
Italy	Double the renewables contribution to the energy balance by 2010.	3.4 million tons per year of avoided CO_2 emissions should come from wind power. This equates to about 2,500 MW by 2010 or 200 MW 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	For renewable energy the target is set to a 3% contribution in 2000 and 10% in 2020.	Annual savings of fossil fuels of 12 petajoules in 2000 and 45 petajoules in 2020. This requires 750 MW of wind by 2000 (target missed) and 2,750 MW by 2020. About 1,250 MW of offshore are anticipated to meet the 2,750 MW target.
New Zealand	None	None
Norway	In addition to the wind target, from 1998 to 2010 to achieve 4 TWh/yr of renewables (and industrial waste heat) fired central and district heating systems by 2010.	3 TWh/yr from wind energy in 2010 (approx. 1,100 MW).
Spain	Achieve 12% of primary energy demand from renewables by 2010.	8,974 MW installed capacity, with an average yield of 21.5 TWh/yr
Sweden	Maintain greenhouse emissions at 1990 levels.	0.7 TWh/yr by 2002 (=0.5 TWh incease compred to 1997.
United Kingdom	To increase the electricity supplied from renewables to 5% by 2003 and 10% by 2010, subject to the cost to the consumer being acceptable.	None
United States	25,000 MW of non-hydro renewables generation by 2010.	10,000 MW by 2010, 5% of electricity supply by 2020 (approx. 80,000 MW).

Table 8.2 Global installed wind capacity (MW)

COUNTRY/REGION	CAPACITY AT YEAR END 1999	NEW CAPACITY	CAPACITY AT YEAR END 2000
Australia	13.0	20.0	33.0
Canada	123.9	13.1	137.0
Denmark	1,750.0	588.0	2,338.0
Finland	38.0	0.0	38.0
Germany	4,445.0	1,650.0	6,095.0
Greece	109.0	105.0	214.0
Italy	282.0	145.0	427.0
Japan	70.6	50.5	121.1
Mexico	3.0	0.0	3.0
Netherlands	409.0	38.0	447.0
New Zealand*	37.0	0.0	37.0
Norway	13.0	0.0	13.0
Spain	1,539.0	795.0	2,334.0
Sweden	220.0	21.0	241.0
United Kingdom	344.0	64.0	408.0
United States	2,455.0	99.0	2,554.0
Ireland*	68.0	50.0	118.0
Portugal*	60.0	40.0	100.0
France*	23.0	56.0	79.0
Austria*	42.0	36.0	78.0
Turkey*	9.0	11.0	20.0
Egypt*	15.0	48.0	63.0
Morocco*	—	54.0	54.0
India*	1,095.0	125.0	1,220.0
China*	182.0	158.0	340.0
Costa Rica*	46.0	5.0	51.0
Rest of World*	120.0	13.0	133.0
TOTAL	13,511.5	4,184.6	17,696.1

*Data from *Windpower Monthly*

growth rates were 37% and 52% 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, although this is becoming an issue of increased significance in Germany now.

Denmark had an exceptional year, installing nearly twice as much capacity as it has in recent years, to achieve an overall growth of 34%.

Italy continued its rapid growth trend established over three years now, installing 145 MW to match Spain's overall growth rate at 51.4%.

New markets to show vigorous activity were Japan and Australia. Japan installed two large wind farms totaling 50 MW, which nearly doubled its total installed capacity. Australia installed 20 MW which, as a fledgling market, much more than doubled its total capacity. This large increase is due to the planned introduction of a Renewable Energy Certificate market in 2001. The prospects for large grid-connected developments are excellent with announcements made on the planned completion of up to120 MW in 2001 and up to 180 MW in 2002.

UK saw some growth (19%), which was especially welcome having had very poor years in 1999 and 1998.

Steady

Sweden and the Netherlands saw similar new installed capacity to previous years, rather than continued growth.

Down turn

This year was slow for the United States after the encouraging up turn of activity in 1999. The 1999 boom was precipitated by a flurry of projects against the scheduled expiry of the tax credit at the end of June 1999, now extended to the end of 2001. In 2000, 99 MW of new plant was installed, giving 4% growth. Much more new plant is expected during 2001.

No new machines were installed in Finland, Norway, Mexico, or New Zealand.

Figure 8.1 below shows the growth of wind power across the IEA countries since 1994.

8.2.3 Offshore

The interest and level of commercial activity associated with offshore wind energy increased again during 2000. Projects were developed at Blyth in the UK (4 MW) and at Middelgrunden, off Copenhagen in Denmark (40 MW) and at Utgrunden in Sweden (10 MW).

Interest in the offshore siting of turbines is, in the main, limited to those countries where there is a shortage of suitable sites on land (SW, JP) or where population density precludes extensive on-land development because of visual intrusion (DK, NL, UK, DE). In addition to the new capacity above, Denmark has two demonstration offshore wind farms of 5 MW in operation, the Netherlands has four 500-kW machines, and Sweden has one 220-kW and five 500-kW machines.

Both Denmark and the Netherlands have announced sizeable targets for offshore deployment. A target of up to 4,000 MW by 2030 has already been set by Denmark and of 1,250 MW by 2020 in the Netherlands. In Germany too there are plans for around 100 MW in the North and Baltic Seas. In the UK, the government has now outlined a capital grants program for offshore wind energy, enabling early developments to compete for grants up to 40%. In combination with the Renewables Obligation, this will provide a strong financial basis for development. Further details were expected to be announced in the spring of 2001.

Sweden is also very active and has a very large number of large offshore projects in different planning and study phases.

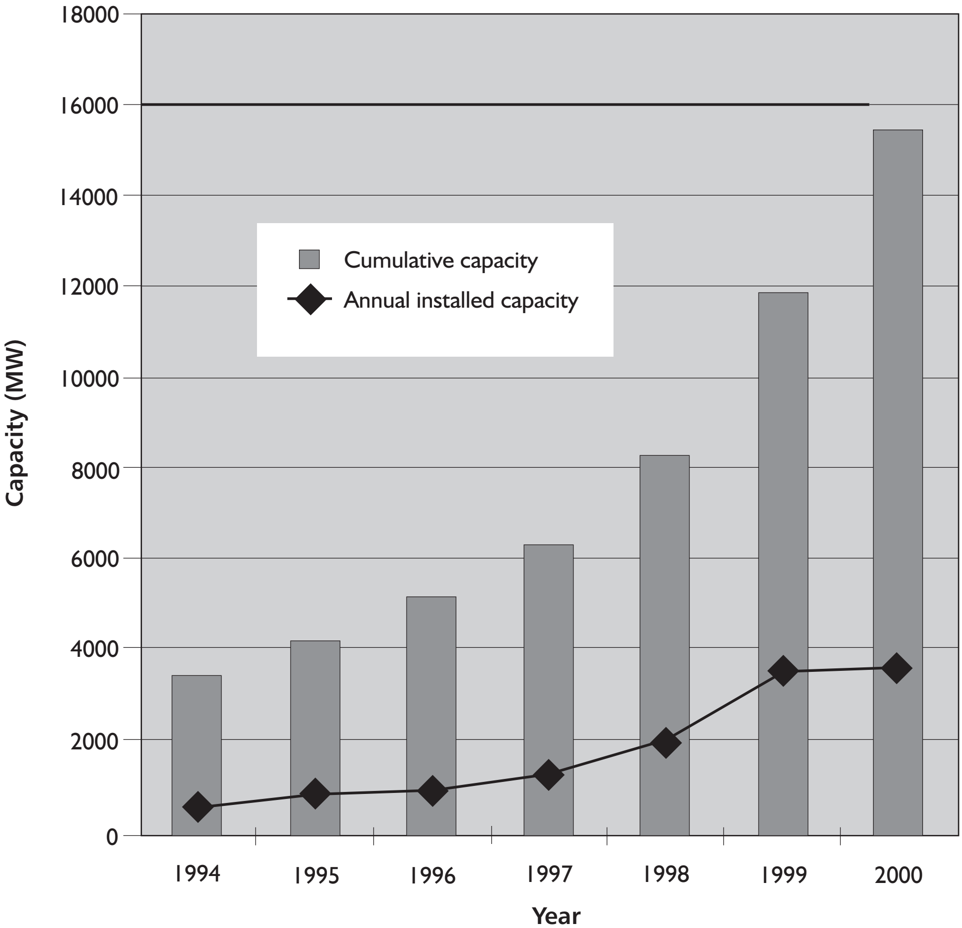


Figure 8.1 Annual installed and cumulative installed capacity in IEA countries

In Spain, there are early plans for two offshore wind farms, with monitoring in place at one.

8.2.4 Energy Contribution from Wind Power

Electricity generated by wind

More electricity was generated in the IEA countries in 2000 than in any previous year. This was approximately 26 GWhrs, up 17% from last year and providing electricity equivalent to 75% of all Denmarks needs. Globally, it is estimated that around 30 GWhrs of electricity were generated from wind in 2000.

Wind speeds

The Netherlands reported a 92% wind index against the 30 year average, ie it was 8% less windy during 2000 than the long term average.

8.3 MARKET DEVELOPMENT

8.3.1 Support Initiatives and Market Stimulation Instruments

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 can be either fixed, provide an incremental amount over the value of the electricity alone, or be established competitively. A competitive bid-in system has been used in the UK, Ireland, and France, with contracts awarded to the lowest bidders. The primary emphasis here is price reduction and convergence with the market price for electricity and has seen substantial wind energy cost reductions. Other mechanisms include tax incentives and "green electricity" trading which is also at premium prices, but directly to consumers.

Table 8.3 summarizes the main market stimulation instruments in the participating countries. The table makes an important differentiation between the basic types of mechanism. These can be either 'Investment support' which contributes to the build cost of wind turbines, 'Production support' which increases the value of the electrical output of turbines, or 'Demand creation' which directly creates a demand and subsequently increases the value of wind energy. Investment support has the potential disadvantage of installing wind turbines, but then not maximizing their output. The three mechanisms described immediately below are all examples of production support which do maximize generation. Obligations on electricity suppliers or users to buy a proportion of electricity from renewable resources are examples of demand creation.

Mechanisms for high deployment

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

In Denmark, since 1993 the payment for wind-generated electricity has been related to the utilities' production and distribution costs (tariffs). A law has obliged the power utilities to pay wind turbine owners a kWh rate of 85% of the utility's production and distribution costs. Additionally, until now, the Government has reimbursed wind-turbine owners CO_2 tax and added direct subsidy.

The "Electricity feed law" (EFL) in Germany became effective in 1991. Since then, the utilities have been obliged to pay 90% of the average tariffs per kWh that private consumers had to pay, with taxes of 15% excluded.

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

Shifting the burden of taxation

In the Netherlands eco-tax on energy carriers such as gas and electricity (except that generated from renewables) was mostly fed back to the tax payers through reduced income tax. This is then neutral to the tax payer but shifts the burden from labor to energy. Such measures can also be seen as the attribution of a value to the external costs of energy production.

Green certificates

As a means of both monitoring and meeting generation targets and encouraging competition, some countries are introducing green certificate trading (NL,UK, DK, IT). Certificates are issued against electricity generated by renewable sources, which can then be traded nationally. In the Netherlands some electricity companies have started trading internationally, but this has not been officially recognized by the government.

Green Electricity tariffs

In a number of countries, customers are being offered "Green Electricity" usually at slightly higher rates, ie 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 (AU, CN, DE, FI, NL, UK, US). In the Netherlands, distribution companies offered Green Electricity at about the same price as brown, supplying about 600 GWh across 600,000 customers. In Northern Ireland, a single wind turbine was built purely against green electricity demand, whilst one of the two UK off-shore turbines will supply certificates to the Dutch utility Nuon, and Scotland installed a 13-MW wind farm outside of any support mechanism, but probably in anticipation of the Renewables Obligation.

Japanese green funds

The Tokyo Electric Power Company established a "Green Power Fund" for people who wish to make a social contribution. A single donation is 500 Yen per month. The scheme supports wind and photovoltaic (PV) projects and is non profit making. A similar new company called the Japan Natural Energy Company also started in 2000.

New incentive in UK

During 2001, a new mechanism will be introduced in the UK, to support renewables. It hopes to increase the rate of deployment whilst exploiting market forces to control costs. Public electricity suppliers will become obliged to either supply a progressively increasing amount of electricity from renewables, buy an equivalent number of green certificates, or pay a penalty charge. The penalty sets the level of incentivisation and is currently proposed at 3.0 p/kWh, which is additional to the value of the electricity.

Other market drivers in the US

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 the 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 rose from 2.20 USD per thousand cubic feet to 6.60 USD over the year. This price makes wind energy more cost competitive and also increases its attractiveness because of its 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 10 years.

Autonomous systems

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.

8.3.2 Constraints on Market Development

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

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

Table 8.3 Market stimulation instruments used in participating countries

	AUSTRALIA
Investment support	• There are various grants avaliable 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 two percent in the use of electricity from renewables and specified waste sources by 2010.
	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.
Demand creation	• Now substantial support through Green Power purchase.
	DENMARK
Investment support	• Low voltage connection paid by owner, Grid reinforcement costs paid by distribution companies.
Production support	• Since 1989 production subsidies for energy produced by private generators and utilities • Until April 2001, buy-back rates fixed relative to 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 certifictes is set at 0.1 DKR/kWh.
Demand	• Renewable energy quotas will be announced by Government, in which consumers will be obliged to a steadily increasing share of electricity from renewables. This is part of the measures for reaching future CO_2 reduction targets.
	FINLAND
Investment support	• Investment subsidies - up to 30% total investment costs depending on technical innovation.
Production support	• Production subsidy for wind and other small local energy production.
Demand creation	• “Green Power Tariff” offered by utilities and some private generators also selling green energy directly to customers.
	GERMANY
Investment support	• Grants under the ‘250MW Wind’ demonstration program. • Individual states may offer capital subsidies or soft loans.
Production support	• The EEG law (Erneuerbare-Energien-Gesetz) came into force on April 1, 2000. This replaces the EFL law with a fixed tariffof DEM 0.178/kWh for 5 years, then DEM 0.121/kWh. • The first offshore installations, installed before 2006 and more than 3 nautical miles from the coast, will receive the higher DEM 0.178/kWh rate for 9 years.
	GREECE
Investment support	• 40% capital investment subsidies and possible 40% soft loan.
Production support	• Premium price for energy since end 1995.

Table 8.3 Market stimulation instruments used in participating countries—continued

	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	• Premium price for renewable and assimilated energy sources.
Demand support	• There is a forthcoming decree under consideration that would substantially improve the position of wind energy. Priority would be assured in displacement over the transmission system, large importers or producers of electricity become obliged, starting from the year 2002, to produce a 'quota' from new renewable energy plants. The percentage is 2% initiallly and will be increased in subsequent years.
	JAPAN
Investment support	• 100% wind measurements • 50% construction costs for public sector projects over 1,200 kW • 33% construction costs for private sector projects over 1,500 KW • 50% design costs
Production support	• Some finance at preferential rates and tax incentives for profitable companies. • Buy-back price negotiated between generator and utility.
	MEXICO—None at present
	NETHERLANDS
Investment support	• Up to 1996 a subsidy per m^2 swept rotor area and wind turbine capacity, up to a maximum of 35% of the investment costs. • Income from "Green Funds" subject to lower interest rates on capital borrowed. • From January 1997 40% deduction of capital investment from company profits. • From January 1996 accelerated depreciation on wind turbine investment.
Production support	• Up to 1998 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 support	• "Green Label" scheme introduced for 1998, which also applies to historical projects. • Exemption from Regulatory Energy Tax for end users of renewables.
	NEW ZEALAND—None at present
	NORWAY
Investment support	• 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 about 20% of investment costs, of which one was fulfilled. The other two are still in the planning stage). • Investment tax exemption for up to 7% of costs.
Production support	• Since the end of 1998 a production support for generators has been 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 ørc/kWh.
	SPAIN
Investment support	• In 1994 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 through the national energy agency IDAE,
Production	• 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.

Table 8.3 Market stimulation instruments used in participating countries—continued

	SWEDEN
Investment support	• Investment subsidy of 15% (program limited to 60 MSEK/year).
Production support	• No annual cost for using the electricity net (max. size = 1,500 kW). • Until November 1, 1999: Premium tariff based on household tariffs plus environmental bonus (15.1 öre/kWh) plus a small addition against local grid value. Maximum size = 1,500 kW. • After November 1, 1999: Environmental bonus (16.2 öre/kWh) plus temporary subsidy (9 ore/kWh) plus a small addition against local grid value. Maximum size = 1,500 kW.
	UNITED KINGDOM
Investment support	• Investment subsidies of up to 40% are expected, specifically to support early offshore wind farms.
Production support	• Premium price for energy produced. Contracts awarded after competitive bidding.
Demand creation	• Regional obligations, placed on the electricity supply companies are in the process of being introduced, expected to come into force 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	• Federal subsidies of USD 0.017/kWh, adjusted annually for inflation, in form of tax credits for investor-owned utilities and production incentive payments for municipal (tax exempt) power producers. • Wide range of individual state incentives (e.g. waiving of sales or property taxes).

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.

Resource

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. In the Netherlands many of the better resource sites are now taken up, and exploitation of lower wind speed sites is now also encouraged.

Political stability

The high dependence of markets on government policies is an ever present concern. Overall, the sector benefits from the global market, smoothing the effects of single market policy changes. During 2000, in Denmark legislation on reform changing from fixed prices to a market-based system with green certificates, caused uncertainty on the future buy-back rates.

8.3.2.1 Institutional Constraints

Planning Policy

For several countries where the existing market stimuli make wind power attractive, the main constraint on the rate of development is the difficulty of obtaining land use planning consent. Objections are often on the grounds of environmental concern, in particular the visual impact of wind farms (DK, DE, IT, NL, NO, SW, UK, US). In the majority of the countries, land use planning is often a local matter which takes account of broad national guidelines. However, planning consent decisions and any imposed conditions on wind farm developments can be highly subjective because of variations in their interpretation.

In the Netherlands, about 2/3 of all initiatives fail at an early stage because of difficulties in getting building permits and the necessary policy changes in the municipalities that do not want wind energy "in their backyard." In the UK, planning consent remains the biggest impediment and although deployment did increase this year, the planning success rate has not changed. Scotland has a better planning record and has seen further positive moves in new planning guidelines.

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 April a publication supported by the provinces and the Foundation for Nature and the Environment, indicated locations suitable for a further 1,695 to 1,840 MW across the country.

In the UK, government has implemented a proactive strategic approach to planning through the introduction of regional targets for renewables based on resource assessments. Also in the UK a new development is the application for planning for wind farms of over 50 MW size. This changes the consent route to go directly to the Department of Trade and Industry (DTI) rather than through local planning, though local planners are still consulted. Decisions are expected during 2001.

In the UK 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.

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, but not immediate, problem. Denmark has already achieved a 12% contribution from wind energy nationally, with no major integration problems.

In Spain though, the main constraint is currently the capacity of the grid for power transmission from the low populated areas where development is occurring, to the population centers. Concerted action between the developers and the utilities is expected to solve this problem. For Greece too, grid limitations are the major constraint to rapid market growth. Grid reinforcement is considered of high priority, especially in high wind potential areas (Evia and Lakonia). In Germany, the wind power contribution shows considerable regional variations. Schleswig-Holstein has 18% from wind, whereas North Rhine-Westphalia has just 0.8%. On a still smaller scale there may be higher contributions and in some cases grid connection presents a technical challenge and can be limited.

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. Whilst the requirement for certification does not prevent projects from being developed, it does have an impact on the development of manufacturing industry, particularly in new markets. New entrants to the industry can more readily develop a national turbine manufacturer through joint ventures with the well established European manufacturers, than through new machine development.

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

8.3.2.2 Environmental Constraints

The benefit of low greenhouse gas emissions from renewable sources of electricity, including wind, continues to increase in importance as governments seek to limit climate change. Public opinion polls in several countries (UK, NL, DK) have shown that the environmental advantages of wind power are recognized and, in general, the majority of the public are supportive of wind energy installations. In many countries, although the non-polluting benefits of wind renewable energies such as wind are recognized, they are not assigned a monetary value and so are not included in any economic appraisals or electricity prices directly. All the countries actively pursuing wind development are conducting environmental impact assessments which typically address the following topics.

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 as the primary issue in planning.

Noise immissions

The assessment of noise levels from turbines at nearest 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 immissions as a technical problem which can be solved through good engineering practice. By way of example, in the UK a best practice guide on noise measurement and assessment was published in 1996. This document has provided a de-facto standard which developers and regulators have now accepted. 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 titled, Measurement of Noise Immission from Wind Turbines at Noise Receptor Locations, last edition 1997.

Effects on bird life

Concern remains about the possibility of bird strikes in all countries, although the incidence is low. The problem of birds varies greatly from site to site and the vast majority of wind power plants report no problems. Some bird strikes were reported in Spain and the US in the early 1990's. These farms were on bird migratory routes, but the species involved were not migratory. Bird strikes since 1992 have been minimal and studies carried out in several countries suggest that turbines have a very low effect on bird life compared to other human activities. Germany has also seen concern about the effects of shadows from moving turbine blades on wild life including birds.

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 ecosystems has been reported from the installation of wind farms.

8.4 TECHNOLOGY AND INDUSTRY

8.4.1 New R, D&D Developments

New turbines

During 2000, a Swedish consortia (ABB plus ScanWind) developed and sold its first 3.5-MW machine to the utility Vattenfall. It is a 3-bladed, 90 m rotor diameter machine, including a direct-drive, high voltage, permanent magnet generator called Windformer and made by ABB. The first installation is expected late in 2001 on the Swedish island of Gotland.

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 of capacity 5 to 6 MW and with 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 to 4-MW turbine with a 110 m rotor diameter.

Some more radical concepts have received support from both private sector and government. The Wind Turbine Company from the US is testing a scaled prototype hinged-blade, down-wind turbine. In New Zealand, a prototype called the Vortec has been developed, which funnels air through a large venturi surrounding the turbine, to augment the wind speed.

The new Swedish 1-MW Nordic Windpower wind turbine was installed and commissioned in August 2000. It is a light-weight, flexible two-bladed, up-wind design, developed from the Nordic 400.

Offshore foundations and installation

The new market for large offshore machines has created much fresh thinking on both the foundations and installation methods. Whilst foundation types might loosely be categorized as either gravity or pile type, there are many different options being considered against very 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 has also been identified as an area needing big improvements in order to achieve acceptable availabilities (NL, DK, UK, SW).

Offshore environment

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.

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 (non-firm), or penalties in the case of under-supply. Several R&D programs recognize that the value of wind power is increased if the output can be more accurately predicted, and have started research in this area (including US, UK, NL, DK). The possibilities of aggregation of the output from several geographically distributed wind farms is also being examined (UK).

Blades

It is increasingly becoming the case that manufacturers are having to take back their blades for disposal at the end of their useful life. This has caused them to seek economic and environmentally friendly means of disposal and has led to the use of crushed blades in Belgian cement. The Netherlands too started a project to research possibilities of producing large blades from ecologically friendly materials.

In the UK, research was initiated on new blade designs for larger blades needed offshore. Improved lightning protection for offshore blades is a new area of interest too, because of the higher probabilities of strike and increased difficulties of repair or replacement.

Direct drive

Most turbine manufacturers have opted for drive trains with gear boxes, although several notable exceptions have pioneered direct drive technology (Enercon, Genisys of Germany, Lagerwey of the Netherlands, and Jeumant of France). The German company Enercon has been particularly successful and although turbine weights are comparable to other manufacturers, the company claims lower maintenance costs over the life time of the machine. The largest commercial example of this technology is currently seen in the Enercon E66, 1.8-MW machine.

Autonomous systems

There are plans to install two additional wind turbines on King Island, Tasmania that will dramatically increase the proportion of wind generation in the wind diesel power system. Each turbine is to be about 600 to 850 kW and will increase the installed capacity to more than 1.4 MW. This will be made possible with a 400-kW pumped sea water hydro storage scheme (as opposed to the original fresh water storage) and a 200 to 800-kWh battery and inverter system. An inventory has been prepared by MURE of Western Australia showing that there are over 250 possible diesel generator sites, of which many may be suited to conversion to hybrid wind diesel power systems.

The Denham, Australia wind diesel flywheel hybrid power system, completed in 1999, is operational but its final optimization will not be complete until the first quarter of 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 tonne Enercon designed flywheels.

Government programs

All countries provide underlying support through national and regional R, D&D programs. Whilst the budgets for such programs vary greatly, they are all mainly aimed at assessing the technical, environmental, and economic prospects for wind technology. Programs are normally run in collaboration with the power utilities and the industry for technology development.

8.4.2 Operational Experience

Availability

In general, the installed turbines have performed well with few operational difficulties. Most commercial plants operate with availabilities of between 97% and 99% and load factors between 0.2 and 0.4, depending on the wind speeds at the sites and degree of plant optimization. From statistics taken on the German Scientific Measurement and Evaluation Programme, the average availability for 2000 was around 98%. This corresponds to an average down-time of 150 hours for each machine.

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

The vast majority of long term operation has been in the United States. Globally, a maximum of 11% of current installed capacity has been operational for 10 years

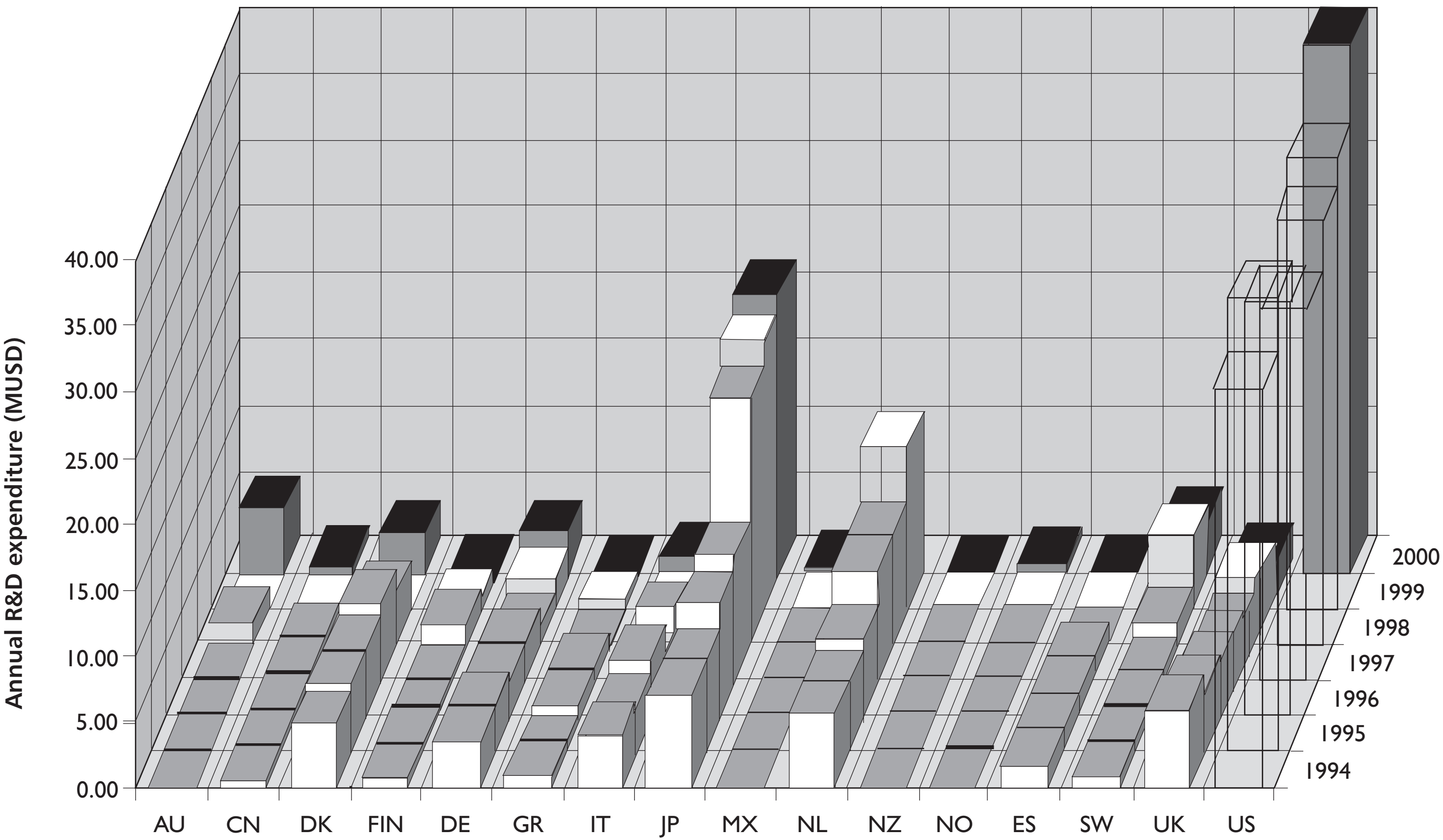


Figure 8.2 Funding for national R&D programs 1994 to 2000

Table 8.4 Years of turbine operating experience

COUNTRY	OPERATING FOR 15 YEARS (1985)	% OF CURRENT	OPERATING FOR 10 YEARS (1990)	% OF CURRENT	CURRENTLY OPERATING (2000)
United States	1,039	41%	1,525	60%	2,554
Denmark	50	2%	310	13%	2,338
Netherlands	6	1%	57	13%	447
Germany	3	0%	60	1%	6,095
World	1,097	6%	2,023	11%	17,606

and just 6% for 15 years. The real figures are slightly lower for 10 years of operation and likely to be considerably lower for 15 years of operation, since these calculations assume that all of the turbines are still operating. This is certainly not the case in the United States, but statistics on individual turbines are not available.

Table 8.4 gives an indication of the long-term operational experience to date. The countries selected as those with a long wind power history.

Reliability

Overall reliability can be considered high, reflected in the availabilities achieved, detailed above. Figure 8.3 below shows the distribution of failure causes in Germany in 2000, recorded on the scientific monitoring and evaluation program. 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. 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.

8.4.3 Costs

Capital costs

Because of the commercial nature of wind farms there is very little firm cost data available, though most countries provide estimates. For complete wind farms the estimates of average cost vary according to country, between about 1000 to1200

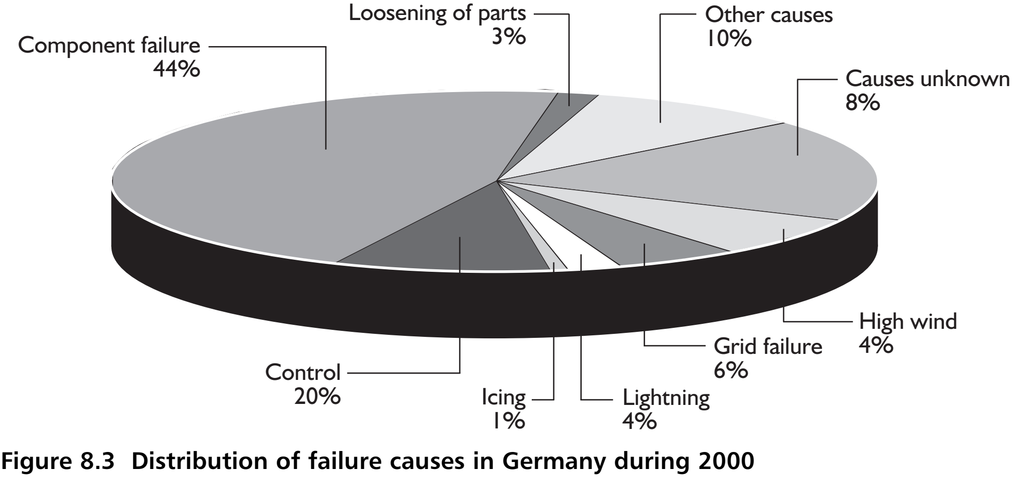


Figure 8.3 Distribution of failure causes in Germany during 2000

USD/kW of installed capacity, but with 1000 USD more typical. The cost of the turbine and tower alone varies between about 700 to 900 USD, with 770 USD typical. These costs show a split of roughly 77% for machine and 23% for balance of plant comprising primarily of foundations, electrical infrastructure, and roads.

Offshore costs are much more difficult to determine at this early stage. The UK reported a total cost of 4 million £ (6 million USD) for the Blyth 4-MW project developed in 2000.

Generation costs

Figure 8.4 below shows the wide variation in both the price paid to wind energy generators and to generators using conventional sources (base). Whilst the diagram shows prices rather than costs and does not indicate the availability of additional capital grants, it does demonstrate that wind energy requires a price higher than conventional generation. The high prices available in Denmark, Italy, and Spain have successfully enabled wind energy development. Whilst Japan too has a high price, it is determined through agreements with utilities against individual projects and not universally available. The difficulty in Finland and Norway is clear, with such low conventional electricity costs.

8.4.4 Development in Industry

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 direct 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.

In Denmark technology development in manufacturing industry focused on

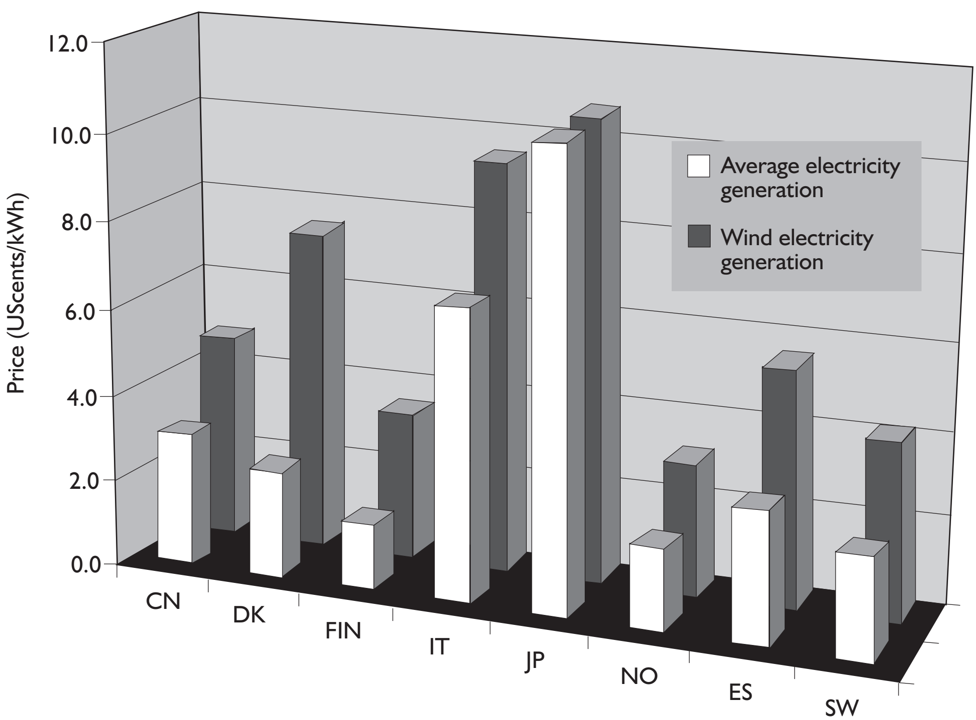


Figure 8.4 Wind and base electricity generation costs

refining the MW class of wind turbines, including upgrading with larger rotors and generators. The optimization of rotors, to maximize energy capture, increase capacity factor, and adjust to the local wind regime, has resulted in larger rotors (per unit of installed capacity). The Netherlands reports that since the mid-eighties the installed swept area per unit of power has changed from 1.7 to 2.5 m^2/kW.

Manufacturing industry

Spain has been expanding its home industry with new component factories opening during 2000. Manufacturers are now also looking to export markets, initially in North Africa (Tunisia, Morocco, Egypt).

Some of the larger European manufacturers are establishing assembly plants in the US and plan to set up component manufacturing in the Midwest. NEG Micon has opened a large turbine assembly facility in Illinois and Vestas is considering similar options. Enron's 1.5-MW machine will be the first of its size class to be produced in the United States. Enron expects to install 350 wind turbines in the United States by the end of 2001.

Turbine size

The average turbine continues to grow in size and capacity, though the size of machines typically deployed does vary between the various markets. For the reporting countries (excluding Canada and the US), the average new turbine deployed grew from 440 kW in 1995 to 805 kW in 2000. The most recent offshore installations (DK, UK) have both used 2-MW turbines. The most competitive projects have tended to use machines in the 660-kW to 750-kW class. These machines are being further stretched to 900 kW, forming the core machines for many markets in the next couple of years.

Germany has consistently exploited large machines. Here MW class machines are popular and the average turbine installed in 2000 had a higher capacity than anywhere else at 1,100 kW. 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 MW machines will be substantially exploited here in the near future, with the average new machine being around 600 kW in 2000.

Offshore

The Government of the Netherlands decided on the location of the 100-MW demonstration project, which will also include two foundations for testing large machines. The site is 10 km off the coast near the village of Egmond aan Zee. The development will also be used for extensive environmental, economical, and technical monitoring to inform larger future developments. Denmark continues to progress its plans for a 150-MW installation at Horns Rev, now expected to be commissioned autumn 2002. In Denmark, the state also determines the areas suitable for offshore development, whereas in the UK offshore sites are initially selected by the developers. There is growing interest in offshore investment in the UK, which has attracted new companies to the industry. The oil sector in particular is now forming partnerships with wind industry developers to exploit this resource.

Author: Ian Fletcher, ETSU, UK

Table 8.5 Capacity and output data for member countries (1996 to 2000)

COUNTRY	INSTALLED CAPACITY (MW)	OFFSHORE CAPACITY (MW)	NO, OF TURBINES	ANNUAL INSTALLED CAPACITY (MW) 1996 (MW)	1997 (MW)	1998 (MW)	1999 (MW)	2000 (MW)	ELECTRICITY GENERATED GWHRS/YR	NATIONAL DEMAND TWHRS/YR
Australia	33.0	0.0	80.0	0.0	1.1	5.8	3.3	20.0	42.0	180
Canada	137.0	0.0	220.0	0.2	3.0	48.0	50.4	13.1	*280.0*	545
Denmark	*2,338.0*	50.0	*6,143.0*	169.0	300.1	308.0	302.0	*588.0*	*4,240.0*	*35*
Finland	38.0	0.0	63.0	0.9	4.6	5.6	20.6	0.0	79.0	79
Germany	6,095.0	0.0	9,369.0	428.0	534.0	792.0	1,571.0	1,650.0	8,400.0	486
Greece	214.0	0.0	481.0	0.0	3.0	11.5	67.5	105.0	*460.0*	40
Italy	427.0	0.0	819.0	48.4	28.5	79.7	102.0	145.0	500.0	286
Japan	121.1	0.0	234.0	4.0	6.5	14.4	39.0	50.5	76.0	817
Mexico	3.0	0.0	10.0	0.3	0.5	0.6	0.0	0.0	7.5	216
Netherlands	447.0	2.0	1,297.0	47.0	44.0	39.0	45.0	38.0	*750.0*	95
New Zealand	37.0	0.0	n/a	3.5	0.0	0.0	33.3	0.0	*14.0*	n/a
Norway	13.0	0.0	23.0	0.0	0.0	5.4	3.7	0.0	32.5	120
Spain	2,334.0	0.0	4,697.0	96.5	205.0	407.0	705.0	795.0	4,162.0	196
Sweden	241.0	13.0	517.0	38.0	17.0	52.0	46.0	21.0	448.0	145
United Kingdom	408.0	3.8	862.0	36.8	84.5	13.0	18.0	64.0	*895.0*	*388*
United States	2,554.0	0.0	n/a	7.2	11.0	147.0	565.0	99.0	*6,000.0*	3,680
TOTAL	15,440.1	68.8	24,815.0	879.8	1,242.8	1,929.0	3,571.8	3,588.6	26,386.0	7,308

Figures in italics are estimated.

CHAPTER 9

9.1 INTRODUCTION

Australia has an abundance of renewable energy resources. In particular, the wind resources of Australia are excellent for wind generation and more than comparable to those of 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 2000, a number of wind farms over 50 MW were announced.

The 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.

A 1998 National Greenhouse Gas Inventory released by the Australian Greenhouse Office in 2000 showed that Australia's emissions in 1998 were 16.8% above 1990 levels. Although not directly comparable with Australia's Kyoto target, this figure confirms that Australia will face a difficult task in containing emissions growth to the Kyoto target of 8% above 1990 levels by 2010. Electricity generation contributes about 37% of total net greenhouse emissions.

The large increase in wind generation in 2000 is due to the planned introduction of the Renewable Energy Certificate market in 2001 that will assist Australia to meet its greenhouse gas emission targets.

Australia currently has over 39,000 MW of generation capacity that produce more than 171,000 GWh of electricity per year. Currently, 10.5% are from renewable sources, mostly hydro, and the remainder is from thermal sources, predominantly coal and some natural gas. Wind energy currently produces about 0.02% of total electricity generation.

9.2 NATIONAL POLICY

9.2.1 Strategy

Current policy on renewables, including wind, have their basis in the 1992 National Greenhouse Response Strategy, which was developed to launch a program of action addressing climate change. The strategy was later refined following production of the paper, "The Development and Use of Renewable Energy Technologies," produced in 1996 as part of the development of a National Sustainable Energy Policy. A discussion paper titled, "Sustainable Energy Policy for Australia," was subsequently released in 1996 to stimulate public consideration of a sustainable energy policy. At that time, the electricity industry was being reformed, and the objective of energy policy was to provide for efficient, open, and competitive energy markets with market signals to enable the emergence of new technologies, including the renewables.

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 National Greenhouse Strategy was developed in 1998 to provide a strategic framework for limiting Australia's greenhouse emissions, consistent with the Kyoto Protocol. The greenhouse strategy demonstrates Australia's commitment to carrying its fair share of the burden in the worldwide efforts to combat global climate change, while recognizing the national interest in protecting jobs and maintaining the competitiveness of Australian industry.

Within the greenhouse strategy, the renewable energy industry is seen as strategic for Australia because of the potential environmental benefits; contribution to economic growth; and in the long term, enhancement of energy security. It is recognized, however, that renewables require assistance to foster their development within an industry currently dominated by low-priced electricity generated with coal in a de-regulated electricity market.

The strategies for the development of renewables in Australia are unchanged during 2000 and currently include the following goals.

- Establish a mandated target for the uptake of renewable energy by specifying a proportion of renewables in new-generation requirements.
- Generate support for green electricity schemes and accreditation of green energy products.
- Fund the development, commercial ization and demonstration of renewable energy and greenhouse technologies
- Support education and training standards
- Identify and remove barriers to the development of a renewables industry.

9.2.2 Progress Toward National Targets

Significant progress toward the development and growth of a renewable industry has been achieved in 2000 with a real commitment to the development of a renewable industry as a means of limiting the increase in national greenhouse emissions.

In 2000, Australia has conducted the following activities, which illustrate this progress.

- Established the Renewable Energy (Electricity) Act 2000 and the Renewable Energy (Electricity) (Charge) Act 2000.
- Commenced comprehensive monitoring and reporting of progress in relation to the National Greenhouse Strategy.
- Released a Renewable Energy Action Agenda Discussion Paper titled, "New Era—New Energy," that aims to provide a starting point for the development of the Action Agenda for the Renewable Energy Industry.

The Government—through the Australian Greenhouse Office, Renewables Target Working Group, 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 will be implemented through the Renewable Energy (Electricity) Act 2000 and the Renewable Energy (Electricity) (Charge) Act 2000, supported by the Renewable Energy (Electricity) Regulations. The regulations are still being developed with an expectation of completion in April 2001.

The Renewable Energy (Electricity) Act specifies a number of interim yearly targets from 2001 to 2010, as shown in Figure 9.1, that describe the timetable for the growth of the renewable energy market. The interim targets will ensure that there will be consistent progress toward achieving the 9,500-GWh target by 2010 and that all investment does not occur in the final years of the scheme. The measure currently expires in 2020 and will give the investment certainty until 2010 for all retailers and large buyers that will be required to maintain the 9,500 GWh of new renewables between 2010 and 2020.

The measure will be implemented using a system of tradeable certificates called Renewable Energy Certificates (RECs), which will be earned on the basis of one REC per MWh of eligible renewable generation. Penalties for liable parties who fail to meet their purchase obligation

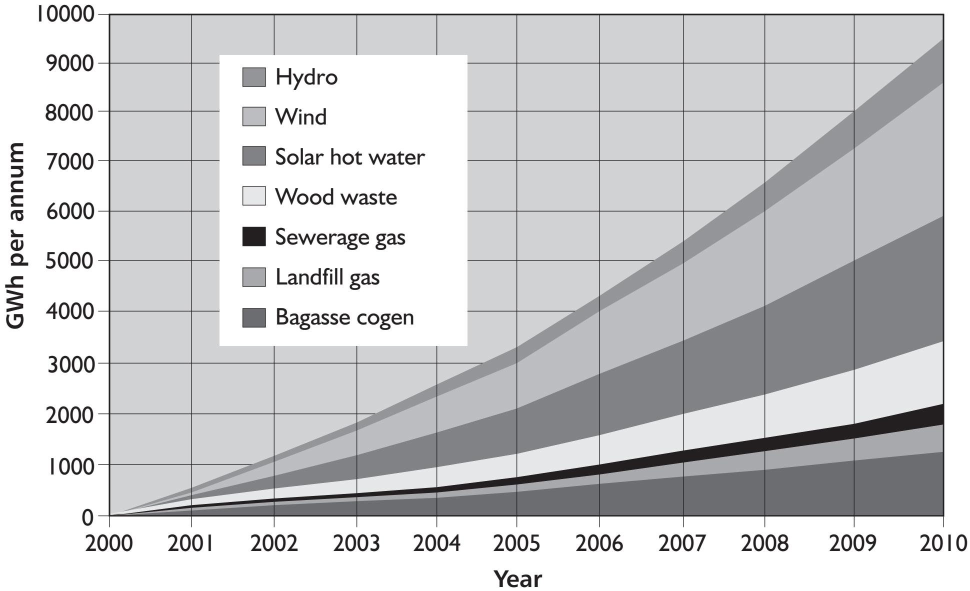


Figure 9.1 Possible contribution to renewable generation target by source

are to be capped at 40.00 AUD/MWh. The measure is designed to allow the market to find the least-cost response for meeting the target and to develop innovative responses that would not be as likely to occur under a centrally-administered scheme.

A Green Electricity Market (GEM) is being developed by the Australian Electricity Industry to establish a new electronic trading platform for trading green electricity rights, including the RECs. GEM will support the REC market using an Internet-based registry and exchange, which will allow members to trade the value attached to the "green nature " of electricity produced by renewable generation sources. This green nature value can then be separated from the actual electricity, allowing the electricity to be sold to the wholesale market while the green nature value is traded on the new exchange. There is potential for this type of market to become global.

Industry estimates of the contribution from wind energy toward achieving the national target vary. One possible scenario is shown in Figure 9.1, which could necessitate the installation of up to 900 MW or more of wind turbines by 2010. Individual targets for each renewable energy source have not been established in the measure.

Table 9.1 Targets for new renewable electricity generation

YEAR	TARGET FOR ADDITIONAL RENEWABLE GENERATION (GWH)
2001	300
2002	1100
2003	1800
2004	2600
2005	3400
2006	4500
2007	5600
2008	6800
2009	8100
2010-2020	9500

An effective reporting and monitoring framework for the National Greenhouse Strategy (NGS), previously released in 1998, has been established to monitor Australia's emissions relative to its Kyoto target of limiting growth in greenhouse gas emissions to 8% above 1990 levels from 2008 to 2012. The reporting requirements incorporate and include information on emissions projections, emissions performance monitoring, and progress toward implementing NGS measures and evaluating their effectiveness.

As part of the Emerging and Renewable Energy Action Agenda, a Renewable Energy Action Agenda Discussion Paper titled, "New Era—New Energy," was released in 2000. The paper sets out the current status of Australia's sustainable and renewable energy industry, the energy markets, market drivers, and impediments to growth. The vision for the industry is described as "Renewable Energy Industry—4 Billion AUD in Annual Sales by 2010." The Action Agenda describes five key strategies for achieving the industry's vision: continuing market development, building community commitment, building industry capability, establishing the policy framework, and encouraging a culture of innovation. Actions critical to achieving the vision have been identified, and a number of initiatives are described.

9.3 COMMERCIAL IMPLEMENTATION

9.3.1 Installed Wind Capacity

The installed capacity of wind turbines (>25 kW in size) reached over 32 MW at the end of 2000. Approximately 28 MW are grid-connected, and the remainder are in remote wind-diesel power systems. This increase in wind power capacity for 2000 includes 22 MW added to the national total from two grid-connected wind farms. The prospects for future large grid-connected developments are excellent, with announcements made on the planned completion of up to120 MW in 2001 and up to 180 MW in 2002. 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.

See Table 9.2 and Table 9.3 for further details on each installation and the planned installations. The two wind farms completed in 2000 were Windy Hill and Blayney.

Stanwell Corporation has completed the installation of 20 Enercon E40 turbines at the Windy Hill site near Ravenshoe in Queensland. The 12-MW project commenced in November 1999 and was commissioned in September 2000.

In October 2000, the New South Wales (NSW) Energy Minister officially opened the 18 million AUD Blayney wind farm, the biggest in NSW. Blayney uses 15 Vestas V47-660 wind turbines that are the most powerful turbines in the country, making it one of the largest and most efficient operations in Australia. With a 10-MW capacity, the farm will produce enough power to supply the annual electricity needs of 3,500 average Australian homes. The wind farm is owned and operated by Eraring Energy and designed and built by Pacific Power, with electricity retailer Advance Energy purchasing the energy. The wind farm is located on private grazing land. The development of the wind farm was assisted and supported by the NSW Government's Sustainable Energy Development Authority.

Tourism and education are other major spin-offs causing the farm to become a country landmark, such as the Parkes Telescope. Economic benefits will spread throughout the central west including Bathurst, Orange, and Cowra.

In addition to the Blayney Wind Farm, Eraring Energy also owns a 5-MW wind farm at Crookwell, NSW, which was the first grid-connected wind farm in Australia.

Figure 9.2 Blayney wind farm, New South Wales

A number of wind farms were also in various stages of development at the end of 2000 as summarized in Table 9.2 and in Table 9.3.

Stanwell Corporation has commenced the planning and approval process for the second stage of the Windy Hill wind farm on the Atherton Tablelands in Queensland. The plan is for an additional 13 MW of turbines at the site.

Toora wind farm, also being developed by Stanwell Corporation, has received initial approval for the approximately 20 MW of development. The estimated completion date for this site is late 2001.

In Western Australia, a number of private companies—as well as the State Government-owned utility, Western Power —undertook work in relation to wind energy developments. A combination of

Table 9.2 Planned Australian wind turbine installations

SITE	DEVELOPER	STATE	ESTIMATED CAPACITY-MW	PLANNED COMPLETION
Codrington	Pacific Hydro	VIC	18.20	2001
Albany	Western Power Corporation	WA	21.60	2001
Toora	Stanwell Corporation	VIC	20.00	2001
Exmouth	Western Power Corporation	WA	0.06	2001
Lake Bonney	Babcock and Brown	SA	120.00	2001–2003
Woolnorth	Hydro Tasmania	TAS	10.50	2002
Windy Hill (Stage 2)	Stanwell Corporation	QLD	13.00	2002
Woolnorth	Hydro Tasmania	TAS	120.00	2002 – 2006
Cape Nelson Cape Sir William Grant Yambuk Cape Bridgewater	Pacific Hydro	VIC	140.00	2003
Uley Basis	Babcock and Brown	SA	60.00	2002
King Island	Hydro Tasmania	TAS	1.20	2002
Geraldton	Private Company	WA	104.00	2002
Geraldton	Private Company	WA	5.40	2002
		TOTAL	633.96	

Table 9.3 Australian wind turbine installations at end of 2000 (over 20 kW)

COMMISSIONING	LOCATION	NO./KW	TOTAL MW
1987	Breamlea, VIC	1 x 60	0.060
1988	Flinders Is., TAS	1 x 55	0.055
1988	Salmon Beach, Esperance, WA	6 x 60	0.360
1991	Coober Pedy, SA	1 x 150	0.150
1992	Ten Mile Lagoon, Esperance, WA	9 x 225	2.025
1996	Coconut Is., QLD	1 x 25	0.025
1996	Flinders Is., TAS	1 x 25	0.025
1997	Armadale, WA	1 x 30	0.030
1997	Kooragang, NSW	1 x 600	0.600
1997	Thursday Is., QLD	2 x 225	0.450
1998	Crookwell, NSW	8 x 600	4.800
1998	Huxley Hill, TAS	3 x 250	0.750
1999	Epenarra, NT	1 x 80	0.080
1999	Murdoch, WA	1 x 20	0.020
1997 & 1999	Denham, WA	3 x 230	0.690
2000	Blayney, NSW	16 x 660	10.600
2000	Windy Hill, QLD	20 x 600	12.000
		TOTAL	32.720

renewable energy legislation, introduced by the Commonwealth Government and a State renewable energy policy, has seen increased interest in wind farms by private developers in Western Australia.

Three wind farm projects were announced by private companies, ranging in size from 5.4 MW to 104 MW and all close to the city of Geraldton, approximately 400 km north of the state capital, Perth. These projects are currently in the approval stage, although land agreements have been signed and wind monitoring completed for at least two of these.

Other areas of the state are also seeing private development interest. Of these, sites between Geraldton and Perth have seen the installation of wind monitoring equipment and the beginning of environmental studies and approvals.

Western Power Corporation continued construction work on three wind farm projects. One project was a 21.6-MW wind farm at Albany in the state's south coast. Two additional projects were in the midwest area of the state—a 690-kW wind diesel/flywheel storage project at Denham and a 60-kW mini wind farm at Exmouth.

The Albany wind farm involves the installation of 12 Enercon E66 1.8-MW wind turbines at a coastal site 15 km from the city. This project was approved in July 2000 and is on schedule for operation by July 2001. At the end of 2000, most of the civil engineering construction was completed and the electrical connection begun. Construction of the steel towers in Perth was also underway.

Western Power is also undertaking a feasibility study for a new wind farm at Geraldton and investigations on the installation of more wind turbines at Esperance in the South East of Western Australia. Western Power also continues supporting the Australian Cooperative Research Centre for Renewable Technologies, which includes wind research and numerous small wind turbine community projects.

With partner Enercon Power Corporation, the Australian Enercon agent, Western Power announced in 2000 a wind energy

SUPPLIER	OWNERSHIP	OWNER	APPLICATION	2000 GWH*
Westwind	Private	N/A	Grid Connected	0.16
—	Private	N/A	Wind Diesel	0.15
Westwind	Government Utility	Western Power	Wind Diesel	0.40
Nordex	Local Government	Government	Wind Diesel	0.25
Vestas	Government Utility	Western Power	Wind diesel	3.90
—	Government GenCo	Ergon Energy	Wind Diesel	0.04
—	Private	N/A	Wind Diesel	0.04
Westwind	Private	N/A	Grid Connected	0.03
Vestas	Government Retailer	Energy Australia	Grid Connected	0.90
Vestas	Government GenCo	Ergon Energy	Wind Diesel	1.40
Vestas	Government GenCo	Pacific Power	Grid Connected	10.00
Nordex	Government GenCo	Hydro	Wind Diesel	2.30
Lagerway	Government	N/A	Wind Diesel	0.04
Westwind	Research	N/A	N/A	0.01
Enercon	Government Utility	Western Power	Wind Diesel	0.70
Vestas	Government GenCo	Pacific Power	Grid Connected	10.00
Enercon	Government GenCo	Stanwell Corp.	Grid Connected	12.00
			TOTAL	42.32

development joint venture called the Wind Energy Corporation.

The 18.2-MW Codrington wind farm, Victoria's first commercial wind farm, is under construction by Pacific Hydro on the state's south coast. Installation and commissioning of the 14 1.3-MW AN Bonus turbines is expected in mid-2001.

Hampton Wind Energy Park is being developed as a model of smaller wind farm projects for Australia. The privately owned farm by Hickory Hill Wind Energy is to consist of two 660-kW Vestas turbines. Planned to fit the niche between the kilowatt class machine installations and the larger project developed by Generation Company using megawatt class machines, projects similar to this project could be developed and operated by local farmers and community groups similar to what has occurred in Europe.

Pacific Hydro has commenced the first stage of the approval process for 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. The projects—located at Yambuk, Cape Sir William Grant, Cape Nelson, and Cape Bridgewater—have been granted Major Project Facilitation Status by the Commonwealth Government. This large-scale development is expected to lead to increased local manufacturing. Australian content is set to rise from the current 40% to possibly 95%.

Hydro Tasmania continues to seek development approval for a 130-MW wind farm and Transmission Line connection in the northwest of Tasmania. Development has been hampered by the assessment of the project at three levels of Government. Meanwhile, construction planning for the first 10.5 MW of the development is well underway with construction expected to commence in late 2001 and commissioning in 2002 of the six 1.75-MW Vestas turbines.

Two additional wind turbines are to be installed in Hydro Tasmania's Huxley Hill wind farm on King Island, Tasmania, in an innovative project that will dramatically increase the proportion of

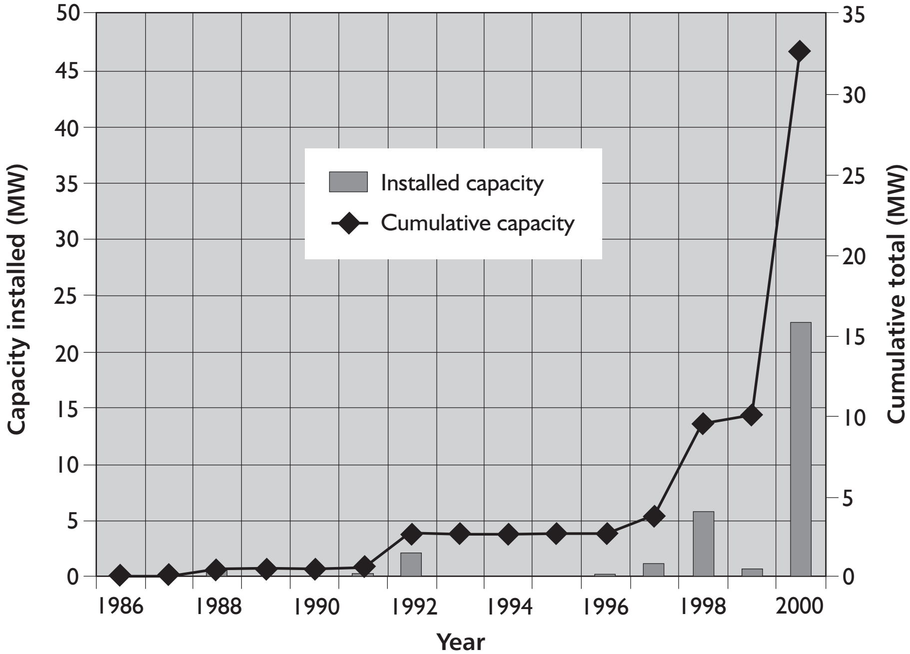


Figure 9.3 Yearly installed capacity of wind generation in Australia

wind generation in the wind-diesel power system. The project has a grant form the Australian Greenhouse Office to perform the R, D&D. Work has commenced on the environmental approvals and preliminary design following a late re-design. Each turbine is to be about 600 to 850 kW and will increase the installed capacity to more than 1.4 MW. This will be made possible with a 400-kW pumped sea water hydro storage scheme (as opposed to the original fresh water storage) and a 200 to 800-kWh battery and inverter system, plus a new integrated control system.

Babcock and Brown, in conjunction with a local developer, plan to construct a 100 to 120-MW wind farm near Lake Bonney in the southeast of South Australia. Construction is expected to commence in 2001 on the first stage consisting of 41 turbines.

9.3.2 Rates and Trends in Deployment

See Figure 9.3 for the yearly and cumulative total capacity of wind turbine installations over the last 14 years.

9.3.3 Contribution to National Energy Demand

Australian generation capacity totaled 39,383 MW at 30 June 1998. Total electricity generated in 1997 and 1998 was 179,095 GWh. The states of New South Wales, Victoria, and Queensland account for 81% of Australian electricity consumption. Overall, coal-fired generation meets 89.7% of Australian electricity needs, with the balance coming from hydro at 8.7%, natural gas at 1.4%, and internal combustion at 0.3%. Wind energy currently forms 0.02% of total electricity generation.

9.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

The most influential market stimulant in Australia is 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 an investment of between 2 billion AUD and 4 billion AUD in

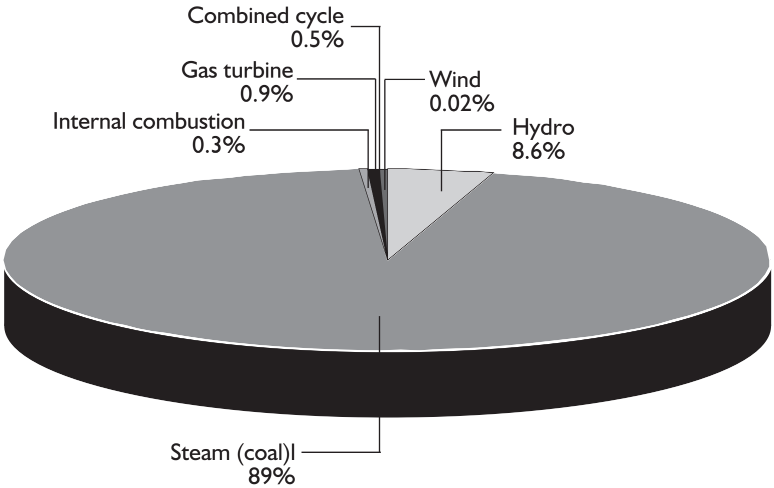


Figure 9.4 Contribution of wind to national energy demand

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.

- 10 million AUD Renewable Energy Showcase. One million AUD was allocated to the development of an innovative wind-diesel power system at Denham, Western Australia.
- 29.6 million AUD for the Renewable Energy Commercialisation Program over four years commencing in 1999. These are grants to assist the commercialization of renewable technologies. One million AUD has been allocated to the devel opment of the hybrid generation and storage power system on King Island, Tasmania, and 225,000 AUD has been allocated to the Exmouth Advanced mini wind farm in Western Australia.
- 100,000 AUD over two years commencing in 1999 for the Sustainable Energy Industry Association of Australia (SEIAA) to support a range of industry develop ment activities including training and accreditation support for sustainable energy service providers and vendors, plus a survey of the sustainable energy industry.
- 21 million AUD in funding from the Government through REEF to provide specifically for the R&D and commer cialization of renewable energy technologies. The value of the fund rises to approximately 30 million AUD when matched by private-sector capital. The fund promotes better access to venture capital funding for commercializing R&D.
- 321 million AUD available over four years, commencing 2000 to support remote power generation, the utilization of photovoltaic systems on residential buildings and community-use buildings, and additional support for the further development and commercialization of renewable energy in Australia. The Renewable Remote Power Generation Program (RRPGP) will provide support for conversion of diesel-based electricity supplies to renewable energy technologies and increase the uptake of renewable

energy technology in remote areas of Australia.

These programs are being delivered by the Australian Greenhouse Office and AusIndustry. Additional Government support for this sector is available through the Cooperative Research Centre for Renewable Energy.

The Commonwealth 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.

The national greenhouse strategies are being implemented through the Commonwealth Government agencies, including the Australian Greenhouse Office (AGO) and the Australian Cooperative Research Centre for Renewable Energy (ACRE). A summary of these agencies follows.

- The AGO, established in 1998, is the key Commonwealth agency on greenhouse matters. The AGO is responsible for both the coordination of domestic climate change policy and for managing the delivery of the National Greenhouse Strategy (NGS) programs.
- The Australian Cooperative Research Centre for Renewable Energy (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 industries. 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 Sustainable Energy Development Authority of NSW and Sustainable Energy Authority of Victoria, are also providing support for renewable energy industries in their states. These include the following.

- 5 million AUD is available from Sustainable Energy Development Authority (SEDA) between 1998/1999 and 2000/2001 to promote investment in the commercialization and use of sustainable energy technologies. The Renewable Investment Program is making up to 1 million AUD available as a grant or loan to complying projects within NSW. SEDA was created to bring about a reduction in the levels of green house gas emissions and other adverse by-products of the production and use of energy in New South Wales. SEDA's Green Power scheme was widened in 1998 to encompass all of Australia. SEDA has been instrumental in getting the wind farm projects of Crookwell and Blayney off the ground.
- SEAV.
- The state Government of Western Australia is providing 1 million AUD annually for five years, commencing in 1999 from a sustainable energy development fund to support the establishment of new renewable energy resources, which is to administered by the Alternative Energy Development Board.

9.5 DEPLOYMENT AND CONSTRAINTS

9.5.1 Wind Turbines Deployed

The majority of wind turbines < 20 kW are owned by Government Utilities and Generation Companies (GenCo's) as shown in Table 9.4. As expected, the proportion of wind-diesel power systems is decreasing as the construction of grid-connected wind farms accelerates due to a mandated 2% new renewables target.

New South Wales (NSW), Queensland (QLD), and Western Australia (WA) have been the most active in the installation of wind turbines over the last decade,

Table 9.4 Deployment by ownership and application

OWNERSHIP	TOTAL NUMBER	TOTAL MW	APPLICATION
Research	1	0.02	N/A
Government GenCo	45	28.00	Grid Connected
Government Utility & GenCo	26	4.53	Wind Diesel
Private	2	0.09	Grid Connected
Private	2	0.08	Wind Diesel
TOTALS	76	32.72	

followed by Tasmania, as shown in Table 9.5, Victoria is expected to catch up in the next few years if installations are constructed as planned.

9.5.2 Operational Experience

An estimated, 42.3 GWh of energy was produced by wind generation in 2000 and is double that produced in 1999. Estimates of the energy generated are shown in Table 9.2. (Caution should be applied to use of these estimates, as actual production figures are not reported in Australia.) There are no reports from any of the current installations available at the time of this report.

9.5.3 Main Constraints on Market Development

Market development constraints consist mainly of 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 to be set by the following sources.

- Spot price on the national or state electricity markets (varies due to dependence on market price).
- Value of the renewable energy certificate (varies due to dependence 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).

The spot price for electricity has risen in the national electricity market over the last year to typically 25.00 to 35.00 AUD/MWh, and the indications are that it will continue to rise in the long term as demand starts to

Table 9.5 Deployment by state

STATE	TOTAL NO.	TOTAL MW
NSW	25	16.00
NT	1	0.18
QLD	23	12.48
SA	1	0.15
TAS	5	0.83
VIC	1	0.06
WA	20	3.13
TOTALS	76	32.72

reach the capacity to generate and distribute electricity. Higher typical spot prices have been observed in states not connected to the national grid.

There is no precise data available on the contribution from the certificate or green power. 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 the wind farm. In the longer term, carbon trading credits may also increase the return.

The level of current wind energy development, mainly embedded generation, has not been constrained to date by the provision of a grid connection. Although, developments now in the pipeline, some of which are listed in Table 9.3, could not be classed as embedded generation. These installations require dedicated or shared access transmission lines to connect to the grid. Some of these developments are appearing to be constrained and will require planning and coordination between wind farm developers, electricity transmission companies, large electricity consumers, and state governments. Coastal Victoria is leading Australia in the incorporation of potential wind farm areas into their land planning processes. Active promotion of these areas has generated extensive interest from wind farm developers and other stakeholders. Other areas of Australia are now making efforts to either allow for future wind turbines and/or promote wind developments in their regions.

Lack of Australian standards relating to wind turbines (particularly noise) and guidelines for wind farm development continue to be an issue.

New South Wales is developing a wind atlas for that state (see Section 9.8.2). Other than this, Australia does not have any wind atlas information available for use by prospective developers of wind installations for either small or large machines. Most data is either old, in an inappropriate format, or produced for a developer and commercially confidential.

The wind resource is not the only factor governing the choice of a wind farm because wind farm developers currently can make predictions using limited wind monitoring and wind flow modeling. However, a wind atlas does give an indication of the magnitude of the wind resource and wind farm development potential that should be brought to the attention of local, state and commonwealth governments.

9.6 ECONOMICS

9.6.1 Trends in Investment

No trend information is available.

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

Most of this information is commercially sensitive and confidential in Australia for existing wind farms. It is expected that as the market for renewables is established, data should become available for new wind farms. Some information is becoming available from Government Authorities. The Green Energy Market may provide valuable information in the future.

9.7 INDUSTRY

9.7.1 General Information

A survey conducted in 2000 by the Sustainable Energy Industry Association of Australia (SEIAA) found the following information.

- The total value of the industry is on the order of 8 billion AUD and is increasing at 28% per year.
- Total economic effect is between 18 billion AUD and 26 billion AUD.
- Employment within the industry was more than 22,000 and growing at 12% per year; the flow on effect was about three times this number.

- Exports contributed to about 13% of revenue and exports averaged over 38% of revenue.

There is no reliable data available at this time on the proportion due to the wind industry.

There is a small, but viable, industry in Australia manufacturing turbines in the battery charger sizes, and there is a growing industry involving the manufacturing of 5 to 20-kW turbines for export. See Section 9.8.2. Estimates of the size of this industry are not available.

Australia has no significant manufacturing capability in large wind turbines. A number of European manufacturers have a commercial presence and are considering the possibility of establishing joint ventures or licences for the manufacturing of some wind turbine components, including generators and blades. Turbine towers are being manufactured in Australia on a project-by-project basis. The establishment of large turbine component manufacturing and assembly plants requires a guaranteed production of 30 to 50-MW per annum of a particular turbine model. An Australian plant, if developed, could supply the markets of Australasia, Pacific, and Asian regions as well as the Australian market.

Export continues to Japan of Lagerwey BV 750-kW wind turbine generators manufactured in the Siemens Ltd facility in Latrobe Valley, Victoria. Further developments in relation to Commonwealth Government support, Victorian Government initiatives, the favorable exchange rate, and international prices could see this manufacturing capability maintained and possibly expand.

9.7.2 Industry Development and Structure

The industry is still in the formation stage in its development.

9.8 GOVERNMENT SPONSORED R,D&D

9.8.1 Priorities

The funding for Australian Greenhouse Office programs is being allocated to renewable energy R, D&D projects that

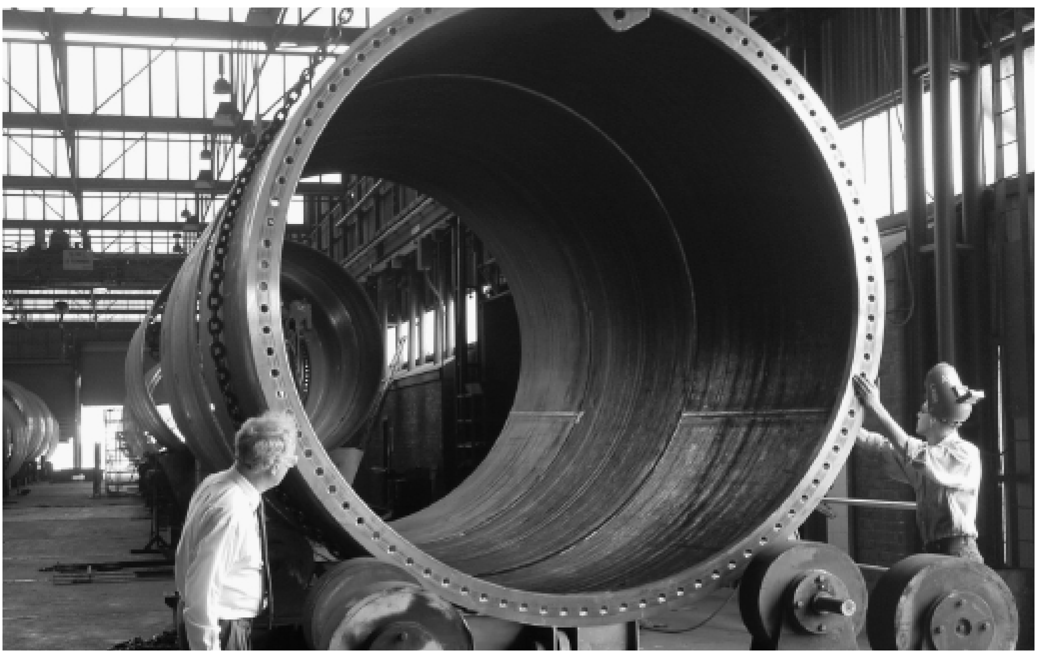


Figure 9.5 Manufacturing towers for Enercon turbines, Western Australia

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 9.4.

9.8.2 New R,D&D Developments

A draft inventory has been prepared by MURE of Western Australia in conjunction with the Australian Greenhouse Office and ACRE. Initial results showed over 250 possible diesel generator sites, of which many may be suited for conversion to hybrid wind-diesel power systems.

The Denham wind-diesel flywheel hybrid power system, completed in 1999, is operational but its final optimization will not be complete until the first quarter of 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 tonne 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 the fluctuations in the wind. This then allows diesel generators to be kept off-line, reducing fuel consumption and engine wear. This project was supported by a 1 million AUD grant from the Australian Greenhouse Office. Research work into this system was conducted for PowerCorp and Western Power by Curtin University of Technology, Murdoch University, and Northern Territory University in conjunction with ACRE.

Figure 9.6 Denham wind-diesel power system with flywheel storage, Western Australia

Another project being undertaken by Western Power with a 225,000.00 AUD grant from the Australian Greenhouse Office is the installation of three Westwind 20-kW turbines designed and manufactured in Australia. Exmouth lies in a cyclonic zone, and these small turbines on tilt-up towers can be lowered in strong winds.

The turbines for the Exmouth project are being developed separately for ACRE by a combined effort by Westwind (manufacturer); Murdoch University (monitoring); University of Newcastle (blade design); University of Technology, Sydney (generator design); Northern Territory University (controller); and Western Power (customer). The turbines being developed range from 5 to 20 kW and use a unique, permanent magnet, low-speed, high-torque generator; a blade pitching mechanism; a tailfin arrangement; and a 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/PV/diesel/battery hybrid power system with an 80-kW Lagerwey wind turbine.

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

Hydro Tasmania, has been offered a grant of 1 million AUD from the Australian Greenhouse Office Renewable Energy Certificate 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, a pumped storage mini-hydro system, several demand-side load management systems, and an integrated renewable energy control system.

Monitoring towers have been set up at 22 sites across New South Wales in a project being arranged by the Sustainable Energy Development Authority. Information on the wind resource at the quality necessary to assess wind generation potential is scarce and not readily available. This program will provide an understanding of the seasonal and yearly variations sufficient to prepare a Wind Atlas for the New South Wales. The aim is to generate publicly

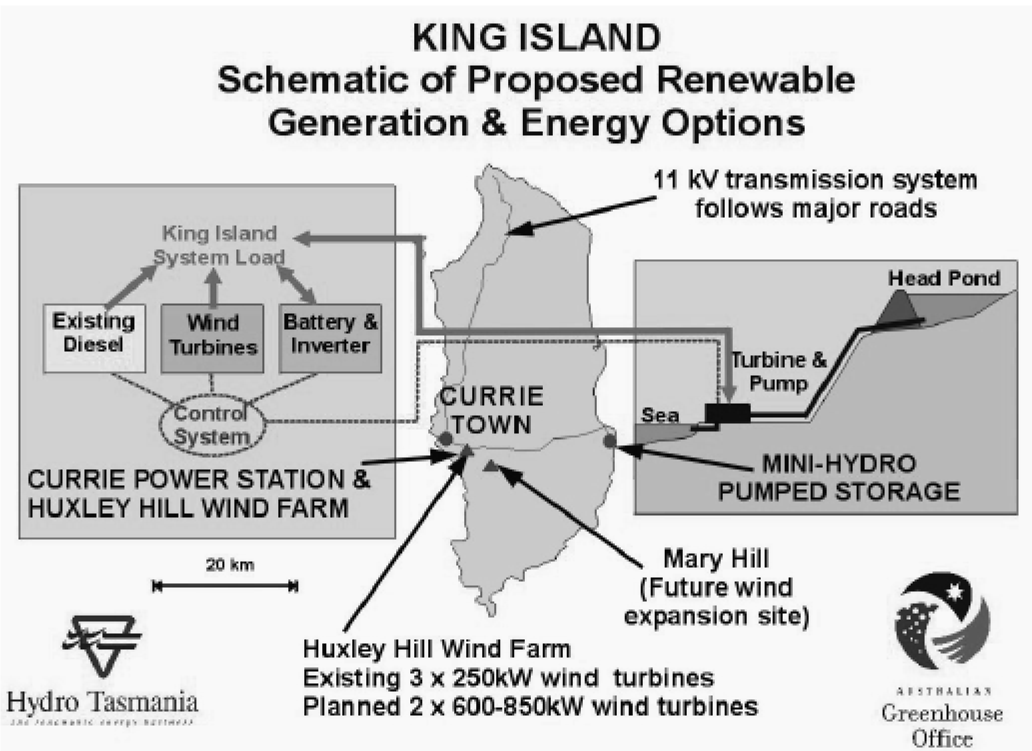


Figure 9.7 Schematic of King Island wind-diesel hybrid power system with mini-hydro pumped storage, batteries, and inverter

available information and identify potential sites over a two-year period, commencing in 2000.

A prototype gyromill has been tested for harvesting the winds in the jet stream that are prevalent across the center of Australia. This new type of wind generation, being developed by the University of Western Sydney, would operate in the upper atmosphere at an altitude of 4.5 km. Further testing is proposed in a trial wind farm at Woomera in South Australia.

9.8.3 Offshore Siting

There is little interest currently in the development of offshore wind farms.

9.9 REFERENCES

www.hydro.com.au
www.energy.com.au

Author: Robert Stewart, Hydro Tasmania, Australia.

CHAPTER 10

10.1 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 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.

10.2 NATIONAL POLICY

10.2.1 Strategy

The main elements of the WERD Program are: Technology Development, Resource Assessment, Test Facilities, and Information/ Technology Transfer. Field trial projects are selected to evaluate the performance of the new technology under special environmental conditions or for specific applications.

10.2.2 Progress Toward 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.

10.3 COMMERCIAL IMPLEMENTATION

10.3.1 Installed Wind Capacity

- Canadian Hydro Developers: 20.6 MW at Cowley Ridge, Alberta, comprised of Kenetech wind turbines. The first stage, consisting of 18.6 MW with 360-kW turbines was completed in 1994. Five 375-kW machines were added in 2000.
- Vision Quest Windelectric: 12.9-MW in Southern Alberta. The operation consists of two sites, with 600 and 660-kW Vestas turbines.
- AXOR Group: 100 MW, officially opened in September 1999. This project (Le Nordais), consisting of 133 750-kW NEG-Micon turbines, is located in the Gaspe area of Quebec. There are also three 750-kW NEG-Micon turbines owned by Hydro-Quebec, which will be used mainly as a test site for future developments, in the same area.
- Various other installations exist with a total capacity of about 2 MW.

The total installed capacity in Canada at the end of 2000 was 137 MW.

10.3.2 Rates and Trends in Deployment

No specific targets for wind energy deployment have been set at this time.

10.3.3 Contribution to National Energy Demand

The national electrical energy demand in Canada in 2000 was 545 TWh. Total installed generation capacity at the end of 1998, the most recent year for which statistics are available, was 110 GW, which includes hydro, coal, nuclear, natural gas, oil-fired, wood-fired, tidal, and wind power. The installed wind capacity was 137 MW by the end of 2000 and an estimated 280 GWh of wind energy was produced that year.

10.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

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.

As well, the government has legislated the extension of the use of flow-through share financing currently available for non-renewable energy and mining projects to include intangible expenses in certain renewable projects, by creating a new Canadian Renewable and Conservation Expense (CRCE) category in the income tax system. 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 first exploratory well of a new oil field.

The federal government has established a Green Power Purchase program, which allows developers of wind turbine and other renewable energy sites to sell power through power transmission lines to facilities owned by the government, at premiums negotiated through a competitive process. As a result of these incentives, wind power producers have built sufficient plant to sell wind power to private consumers, in addition to the federal government.

In 2000, 21 new wind turbines, for a total of 12.4 MW, were installed in Alberta, a provincial capacity increase of 55% in one year. Arguably, the strongest contributor to the rapid growth was a significant increase in the average cost of power generation in the province. This occurred for two reasons. First, demand for natural gas rose dramatically, causing fuel prices for gas-fired electricity plants to skyrocket. Second, increases in electricity demand left Alberta with a shortage of electrical energy in 2000 and placed further upward pressure on costs. In this context, wind energy became the cheapest source of new generation in many areas, leading to a large increase in demand for this type of power. In fact, further wind turbine installations in this province appear imminent.

10.5 DEPLOYMENT AND CONSTRAINTS

10.5.1 Wind Turbines Deployed

The wind turbines deployed in 2000 include 56 Keneteck 360-kW and 375-kW wind turbines, 136 NEG-Micon 750-kW machines, four Vestas 600-kW and 16 Vestas 660-kW wind turbines, one Tacke 600-kW unit, and a handful of turbines with capacities of 150 kW or less.

10.5.2 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.

The Tacke TW600 wind turbine, located near Tiverton, Ontario has been operating well. In 1999, production was 1,335 MWh, with an availability factor of 98.5%.

10.5.3 Main Constraints on Market Development

The main constraints for wind energy development in Canada are the lower cost of conventional energy and a surplus of generation capacity in many areas. However, in a few jurisdictions these factors are changing.

10.6 ECONOMICS

10.6.1 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. Another federal program, operated through the National Research Council, provided about 300,000.00 CAD toward wind energy R&D in 2000.

In addition, the Canadian government has established the Technology Early Action Measures (TEAM) program, which provides funds for activities falling under the Climate Change initiative. These 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, 3.5 million CAD has been accessed to leverage projects sponsored by WERD. In 2000, approximately 300,000.00 CAD of these funds was accessed.

10.6.2 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 similar process is underway, though full competition is not scheduled to commence until after November 2001. 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.

10.7 INDUSTRY

10.7.1 Manufacturing

- Dutch Industries (water pumps), Regina, Saskatchewan
- Koenders, (water pumpers and aerators) Englefield, Saskatchewan
- Wenvor-Vergnet of Guelph, Ontario is developing 25-kW single and three-phase wind turbines for grid-connected, remote communities and stand alone applications.
- Novelek Technology of New Brunswick is finalizing the development of 10-kW and 25-kW inverters for the commercial wind turbine market.
- Polymarin Huron Composites Inc, Huron Park, Ontario, is manufacturing blades for 25-kW to 750-kW wind turbines and is presently commencing pilot production of blades for the 1-MW to 2-MW range.

10.7.2 Industry Development and Structure

Industries that are related to wind turbine manufacturing and deployment activities include control systems manufacturers, inverter and tower manufacturers, wind resource assessment firms, and wind farm developers.

10.8 GOVERNMENT SPONSORED R,D&D

10.8.1 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.

10.8.2 New R, D&D Developments

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

- 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.

10.8.3 Offshore Siting

This item is not applicable at this time.

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

CHAPTER 11

11.1 INTRODUCTION

Denmark has a long tradition of implementing vigorous energy policies with broad political support that involve a broad range of actors: energy companies, industries, municipalities, research institutions, NGOs, and consumers. A continuous effort since the beginning of the 80s has led to an installed wind energy capacity of approximately 2340 MW by the end of 2000 and a wind energy production covering 12% of Denmark's electricity consumption. The following presents the development and status of wind energy in Denmark as of the end of 2000.

11.2 NATIONAL POLICY

11.2.1 Strategy

Denmark has had several energy strategies over the last 20 to 25 years, and the aim of these strategies has shifted from securing the energy supplies after the crisis of 1973-74, to plans pursuing a sustainable development of the energy sector. The present "Energy 21," published in 1996, is the fourth of the energy strategies and lays down the energy-policy agenda for the time period up to 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 (certification schemes and R, D&D programs) have been used as tools in the strategies. The policy instruments used in 2000 are shown in Table 11.1.

Energy 21 generally considers new large wind turbines as one of the cheapest technologies for reducing CO_2 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 to be 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 in step with the development of technology.

Table 11.1 Policy instruments used in 2000 to promote wind turbine technology and installations

DEMAND PULL INSTRUMENTS	TECHNOLOGY PUSH INSTRUMENTS
Incentives	Incentives
• Taxation	• R&D programs
• Production subsidies	• Test station for wind turbines
• Programs for developing countries	• International cooperation
Other regulation and policy instruments	Other regulation and policy instruments
• Resource assessment	• Approval and certification scheme
• Local ownership	• Standardization
• Agreements with utilities	
• Regulation on grid connection	
• Buy-back arrangements	
• Information programs	
• Spatial planning procedures	

For this reason, Energy 21 expects 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 effected, among others, by renovation of wind turbine areas as well as by the removal or replacement of existing wind turbines in accordance with regional and municipal planning.

In 1999, an electricity reform was introduced, and a number of new bills for the Danish electricity sector were approved by Parliament. The reform contributes to ensuring the fulfilment of the long-term, international environmental commitments from 2008 to 2012. The agreement covers the first four years from 2000 to 2003, and is a framework for CO_2 emissions from the electricity sector and for the development of renewable energy.

For 2000 to 2003, a ceiling has been established for the total electricity sector's CO_2 emission: 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 CO_2 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 the state the sum of 40.00 DKK/ton CO_2.

The rising share of electricity consumption will in the future be covered by electricity produced from renewable energy sources when a more competition-based market mechanism, that can ensure the cost-effective development of renewable energy production, has been introduced.

This requires 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. A quota will be laid down requiring 20% of the electricity consumption be covered by RE at the end of 2003. Because wind power is the most developed, and one of the cheapest ways to save CO_2, a major part of the renewable energy is going to be wind power. The Government intends to continue its promotion of the employment and export opportunities by continued research and development.

11.2.2 Progress Towards National Targets

Because Denmark is a densely populated country, 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 wind turbine plans. The Danish Energy Agency has analyzed this local planning and estimates the 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 two utility associations, Elkraft and Elsam, together with the ministry's Energy Agency and Environmental Protection Agency.

In the plan of action, eight areas available with water depths up to 15 m are included. 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. (Hub heights of 55 m and rotor diameters of 64 m are anticipated.) This should be compared to inland conditions of 2,000 to

Table 11.2 Estimated wind turbine capacity and production in Denmark

	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%

2,500 hours. The total capacity for electricity production is estimated in Table 11.2.

In Energy 21, the targets for installed wind energy are 1,500 MW of wind power by 2005 (12% of electricity consumption) and 5,500 MW of 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 the off-shore development is just beginning.

11.3 COMMERCIAL IMPLEMENTATION

11.3.1 Installed Capacity

During 2000, new installed capacity reached a record of approximately 585 MW. By the end of 2000, the total installed capacity of wind turbines was approximately 2,338 MW. By February 2001, final statistics for 2000 were not yet available. The accumulated wind turbine capacity of private and utility wind turbine installations is shown in Figure 11.1.

11.3.2 Rates and Trends in Deployment

The deployment rate in Denmark in numbers and electrical capacity are shown in Table 11.3. The deployment has been almost constant since 1996, adding approximately 300 MW of wind power capacity onshore annually. The average size of the installed wind turbines has grown gradually, from 760 MW in 1999 to 825 kW during the first nine months of 2000.

11.3.3 Contribution to National Energy Demand

ThThe total electricity production in 2000 is estimated to be approximately 4,242 GWh, which is approximately 12% of the total electricity demand in Denmark, estimated as 34,870 GWh. The wind's energy index, which describes the energy in the wind of a normal year, was 95% in the

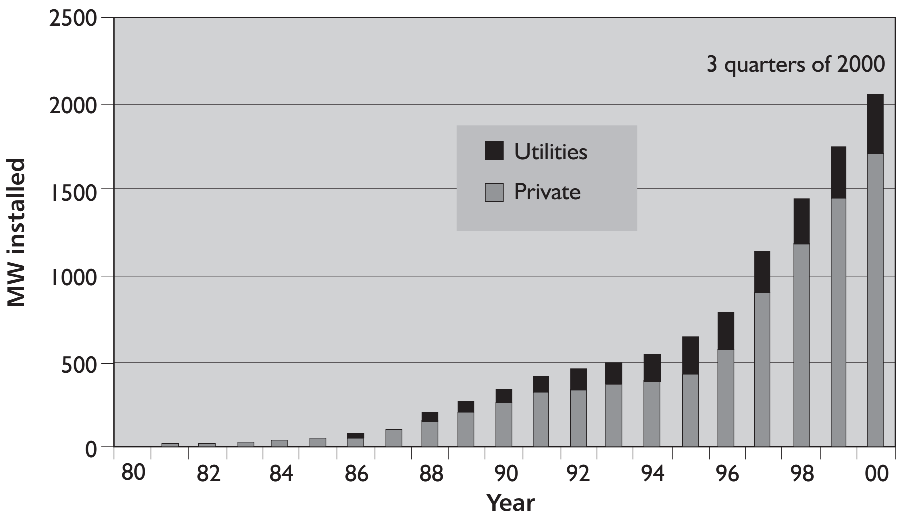


Figure 11.1 Accumulated wind turbine installations in Denmark 1980–2000

Table 11.3 Installed wind turbine capacity and development in size (Year 2000 only third quarter included), Source: E&M Data for the Danish Energy Agency

YEAR OF INSTALLATION	NUMBER	POWER (KW)	AVERAGE POWER (KW)
Before 1990	2,601	258,169	99
1990	385	81,913	213
1991	372	74,136	199
1992	217	45,230	208
1993	142	36,399	256
1994	135	48,604	360
1995	191	92,017	482
1996	400	205,853	515
1997	536	300,445	561
1998	462	312,925	677
1999	426	323,926	760
2000	406	335,649	825

year 2000 (E&M-Data). The development in the wind energy index is shown in Figure 11.2.

11.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

11.4.1 Main Support Initiatives and Market Stimulation Incentives

The utilities are obliged 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). A law has obligated the power utilities to pay wind turbine owners a kWh rate of 85% of the utility's production and distribution costs (85% of 0.37 DKK to 0.45/kWh in 1998). Up to now, the Government has reimbursed wind-turbine owners the 0.10 DKK/kWh CO_2 tax and added 0.17 DKK/kWh in direct subsidy. As a result, in 2000 the average selling price of electricity from private wind turbines was approximately 0.60 DKK/kWh.

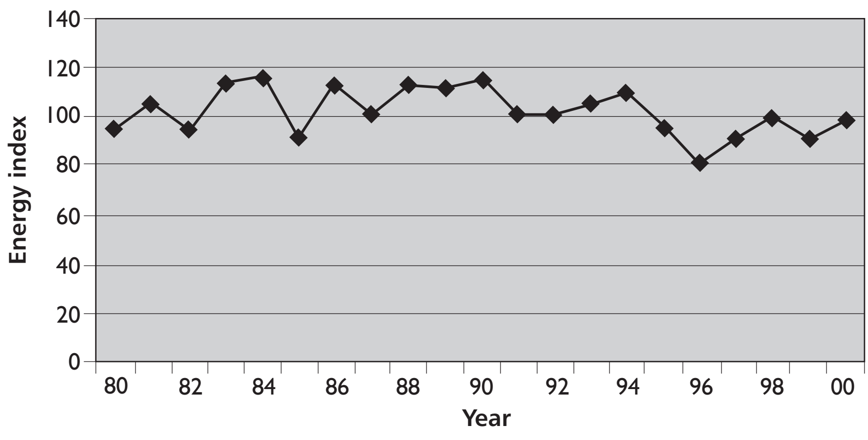


Figure 11.2 Energy in the wind energy index in Denmark 1980–2000

An electricity reform was introduced in the spring of 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 the 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 amount of 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. The approval is expected to be issued in the near future. For existing or temporary wind turbines, the price will be reduced from 0.60 to 0.43 DKK/kWh in the near future, depending on age and accumulated production. In addition to regulation, limiting private wind developments have been withdrawn.

Favorable taxation schemes have been used to stimulate private wind turbine installations, and the taxation schemes have changed over time. Today, income from wind turbines, by and large, is 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 which, as a minimum, describes production and installation of the turbine. Today all manufacturers have an ISO9000 quality assurance system.

A set of rules have been developed and adopted in "Teknisk Grundlag for Typegodkendelse og Certificering af vindm.ller i Danmark" (Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark), most recently revised in 2000. Several recommendations are affiliated to the Technical Criteria. In the future, the recommendations are to be replaced by IEC or CENELEC standards, and the Technical Criteria are to be harmonized on a European level. In the year 2000, guidelines for the application of power curve measurements carried out in accordance with IEC 61400-12 in relation to the Danish approval scheme were issued. Furthermore, recommendations for generator concepts for wind turbines and a draft for the recommendation for technical approval of offshore wind turbines have been prepared this year.

Since 1979, Risø has been authorized by the Danish Energy Agency to issue licenses or type-approvals for wind turbines, including the tests and measurements required for the approvals. Today, the market for these services is liberalized, and private enterprises can be authorized to perform type approvals, certifications, tests, and measurements. This market is open for international competition, and several foreign enterprises are active. See Table 11.4.

During the last years, large efforts have been spent on establishing a new test site for multi-MW 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 on the northwest coast of Jutland has been preferred. In late 1999, VVM-studies (evaluation of the effect on the environment) were carried out for two proposals: H.vs.re, with room for five test stands, and a combination of R.jens. Odde and R.nland. The studies recommend H.vs.re as the site with the least problematic effects. In May 2000, the Minister of

Table 11.4 Bodies authorized by the Danish Energy Agency to provide services under the Danish scheme for certification and type-approvals for wind turbines (December 2000)

SERVICE	AUTHORIZED BODY
Type approvals of wind turbines	Det Norske Veritas Germanischer Lloyds
Production and installation certification	Germanischer Lloyds Certification GmbH Det Norske Veritas Certification of Mgt. Systems Bureau Veritas Quality Insurance
Basic tests	Risø, Test & Measurements Tripod Consult Aps Windtest Ingenieurbüro für Windenergie
Power curve measurement	Risø, Test & Measurements DEWI, Wilhemshafen WindTest, Kaiser-Wilhelms-Koog GmbH Tripod Consult Aps Windconsult GmbH Ingenieurbüro für Windenergie
Testing of systems and concepts	Risø, Test & Measurements
Blade testing	Risø, Sparkaer blade test centre
Noise measurement	DEWI, Wilhemshafen WindTest, Kaiser-Wilhelms-Koog GmbH Wind Consult GmbH DELTA Akustik & Vibration + bodies approved by DELTA

Environment and Energy issued a directive, allowing Risø to develop a test site at H.vs.re 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.

11.5 DEPLOYMENT AND CONSTRAINTS

11.5.1 Wind Turbines Deployed

Wind turbines are typically installed in clusters of three to seven machines. Clusters of wind turbines are preferred in the spatial planning by local and regional planning authorities. In a few places, larger wind farms are allowed. Denmark's largest wind farm on land (in capacity) is Rejsby Hede with 42 600-kW machines. The largest offshore wind farm is the Middelgrunden wind farm outside Copenhagen harbour with 20 2-MW wind turbines, installed in year 2000.

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

Local ownership of wind turbines has been promoted politically by the Government and the Parliament. The reason is that wind power's environmental advantages are on a global or national level, whereas wind power's environmental disadvantages are on a local or neighborhood level, associated with the presence and operation of wind turbines. Such local disadvantages can lead to a lack of public acceptance of wind farms. Local ownership of wind turbines (i.e., allowing local farmers, co-operations, or companies to benefit from the wind turbines) can secure local acceptance of projects. Co-operations spreading ownership of a wind turbine between 20 to100 families in the vicinity of the wind turbine have been especially stimulated.

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

Table 11.5 Status for wind turbines in Denmark (3rd quarter of 2000 included). Source: E&M-Data for the Danish Energy Agency based on reports from manufacturers

OWNER TYPE	TURBINES ADDED	MW ADDED	TOTAL TURBINES	TOTAL MW
Private individuals	266	224.0	2761	1227.0
Private cooperations	70	55.0	2339	484.0
Power utilities	70	57.0	779	330.0
Municipalities, industries, others	0	0.0	114	25.0
Total	406	336.0	5,993	2,066.0

interest rates have decreased, prices for wind power electricity have slightly increased, and laws for facilitating structural changes in the farming sector have unintendedly opened up new possibilities for farmers.

The contribution and the total capacity of wind power as of the first three quarters of 2000 are listed in Table 11.5.

11.5.2 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 responsible for recording operational experiences. The results are published in the association's magazine, "Naturlig Energi." On a voluntary basis, 2,830 turbines, with a total installed capacity of 700 MW, regularly report operational data to this database.

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 the gearbox 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 the gearbox, might be replaced halfway through the total design lifetime, which is dealt with as a re-investment.

Operation and maintenance costs include such elements as service, consumables, repair, insurance, administration, and lease of site. The Danish Energy Agency, E&M-Data, and Ris. National Laboratory have developed a model for annual operation and maintenance costs. The model is based on statistical surveys and analyses in 1991, 1994, and 1997. The model includes a large reinvestment after the tenth operational year on 20% of the cost of the wind turbine. This reinvestment is distributed over the operational years ten to 20. See Table 11.6.

Table 11.6 Annual operational and maintenance costs as a percent of investment in the wind turbine. Source: Danish Energy Agency, E&M-Data and Risø National Laboratory

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
500–600 kW	1.0	1.9	2.2	3.5	4.5

In an ongoing project, both the technical and the economical lifetimes of wind turbines are investigated. The work is concerned with machine sizes of 55, 150, 225, 300, 500, 600, 660, and 750 kW, and it is based on empirical data from a major questionnaire inquiry, which has been sent to approximately 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 11.7. The first part of this table shows the costs of reparation and maintenance, while the second part presents the total O&M costs, which includes costs such as insurance, service, administration, and site rental. It is normally expected that O&M costs increase over time. Nevertheless, the empirical costs on the 55 kW machines are actually decreasing after ten years of operation as observed in Table 11.7.

11.5.3 Main Constraints on Market Development

Since the mid-90s, the Danish market's significant size has remained remarkably constant. The main constraints are spatial planning; the legislation in 1999 on the electricity reform, which has caused uncertainty on the future buy-back rates for private investors; and the regulations on offshore wind power.

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

The Danish Government has supported several studies and appointed a governmental committee to investigate the regulatory conditions for offshore wind power installations. The committee has reported twice, in 1987 and 1995.
Beyond selecting the sites for the small demonstration farms and the new large-scale farms, all interest in Danish waters have been mapped. A set 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. According

Table 11.7 O&M costs in DKK/kW after machine size and year. Source: Danish energy Agency, E&M-Data and Risø National Laboratory.

OPERATION 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 OPERATION AND MAINTENANCE COST (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	—	—

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

The bill also outlines the procedures for the approval of electricity production from water and wind, and pre-investigation of such within the national territorial waters and within the economical zone belonging to Denmark. Permission will be given for a specific area, and if the constructions are expected to have environmental impact, an environmental assessment must be carried out.

To ensure optimal development in the best areas, a central tender procedure will be established. But also an "open door" procedure will be followed, allowing approval of projects without previous call for tenders, especially for smaller projects closer to the coast.

11.6 ECONOMICS

11.6.1 Trends in Investment

The ex-works cost of wind turbines has decreased significantly with the latest 600 and 750-kW generation of machines (44 to 48 m rotor diameter). For 600-kW machines installed in 1997 and 1998, the ex-works cost was typically 3.1 to 3.5 million DKK, and for 750-kW machines installed in 1998, the cost was 3.4 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 on this market, and different financial packages have been developed. Typical projects are financed over ten years.

Additional costs depend on local circumstances, such as soil conditions, road conditions, and proximity to electrical grid sub-stations. Additional costs on typical sites can be estimated to approximately 20% of total project costs. Only the cost of land has increased during recent years. Based on information from 65 new 660 to 1000-kW wind turbine projects, the average cost of a 1000-kW wind turbine project is estimated in Table 11.8.

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

The production cost for wind generated electricity per kWh 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

Table 11.8 Cost of a 1000-kW wind turbine project. Source: E&M-Data, Nov 2000.

COMPONENT	AVERAGE KDKK (000)
Turbine ex works	5,294
Foundation	251
Grid connection	389
Electrical installations	55
Communication	14
Land	70
Roads	69
Consulting	29
Finance	32
Other	17
TOTAL	6,221

station based on condensation. The estimated cost is shown in Figure 11.3.

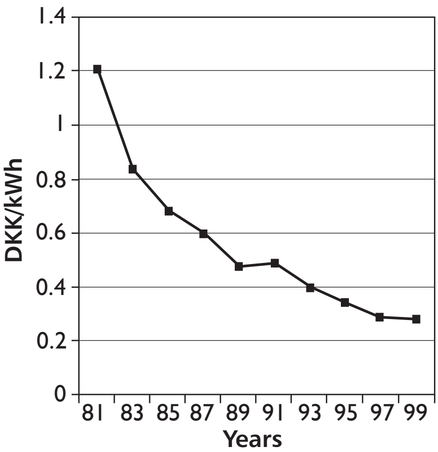


Figure 11.3 Estimated costs of wind generated electricity in Denmark. Based on 20 years' depreciation, 5% interest rates and siting in roughness class 1

The average consumer (4,000 kWh/year) electricity price from power distribution utilities varies somewhat from west to east from 0.531 to 0.535 DKK/kWh. These costs are comprised of subscription, grid and PSO tariff, commercial, and prioritized power. For private consumers (connected to the 400/230-Volt distribution grid), a number of taxes are added to this price. On the top, a 25% Value Added Tax (VAT) is added. In 2000, the consumer price for Danish low-voltage customers was 1.46 DKK/kWh.

With new regulation for the year 2000, the whole payment for wind-generated power will come from the electricity consumers. In 2000, the average selling price of electricity from private wind turbines was approximately 0.60 DKK/kWh. The price the distribution companies pay after a transition period will be the actual market price on conventional electricity. In addition, the producers of wind electricity will receive green certificates, which 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 and 0.27 DKK/kWh.

At the same time, a transition period is 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 DDK/kWh is laid down (corresponding to the present 85% rule) until either a well-functioning market for renewable energy has been established or a fixed period of ten years has been reached. In addition, wind turbines will continue to get the so-called "CO_2 10-.re."

Depending on the size and the age of the turbines, an additional price subsidy of 0.17 DDK/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 from 600 kW and upwards, 12,000 full-load hours have been given. Turbines between 200 kW and 600 kW get 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 DDK/kWh for a ten-year period, plus the value of the certificates. Special rules for owners of small-scale technology and for owners of turbines, which are decommissioned in favor of new wind turbines, will be established.

11.7 INDUSTRY

11.7.1 Manufacturing

Danish-based manufacturers of large commercial wind turbines in the 150 kW to 2 MW range are: Bonus Energy A/S, NEG Micon A/S (including Wind World), Nordex Energi A/S, Vestas Wind Systems A/S, af 1997 A/S, and Wincon West Wind A/S. Gaia Wind Energy A/S makes machines for delivering electricity to households in the range of 5.5 kW, 11 kW, and 22 kW. 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.

11.7.2 Industry Development and Structure

Industrial development in 2000 focused on refining the megawatt generation of turbines. This includes, among other things, upgrading the turbines with larger generators and larger rotor diameters. The wind turbine types on the Danish market are shown in Table 11.9. For most of the types, a number of versions with different tower heights can be supplied.

The sales of the Danish wind turbine manufacturers have increased from 1,905 MW in 1999 to 2,100 MW in 2000, which is a growth of 10%. Although significantly less than last year's growth of 56%, the development corresponds well with the industry's anticipated growth of 10% to 20% annually. Machines of 600 MW have been sold to the Danish market, hence the export turbines in 2000 is expected to be 4,500 MW, bringing the total global wind turbine capacity up to approximately 18,500 MW. Danish wind turbine manufacturers have maintained a market share of approximately 50%.

Service and maintenance of the more than 5000 wind turbines in Denmark is carried out by the manufacturer's service

Table 11.9 Wind turbines (>100 kW) on the Danish market. Energi-og Miljødata (EMD), Nov. 2000

MANUFACTURER	TYPE	NOMINAL POWER (KW)	EXTRA GENERATOR (KW)	ROTOR DIAMETER (M)	POWER REGULATION
BONUS	600 MK IV	600	120	44.0	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	1,000	250	60.0	Stall
NEG MICON	NM1500C/64	1,500	375	64.0	Stall
NEG MICON	NM2000/72	2,000	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	250	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	Pitch
VESTAS	V52	850	0	52.0	Pitch
VESTAS	V66	1,750	0	66.0	Pitch
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

departments, but also a handful of independent service companies have been established. These are companies such as DWP M.lleservice A/S and DanService A/S. Some of the electricity companies service their own turbines.

Other industrial service enterprises have created important businesses in servicing the wind power industry. For example, companies are specialized in providing cranes for installations of wind turbines as well as providing transport of turbines, towers, and blades domestically and for export. The major Danish consultancies in wind energy utilization are BTM Consult Aps, E&M Data, ElsamProjekt 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.

11.8 GOVERNMENT SPONSORED R,D&D

11.8.1 Priorities

The Danish Government has two sponsored programs. The first is the Ministry of Environment and Energy's Energy Research Programme (EFP). During recent years, a part of the research program has been allocated to energy issues in Eastern Europe and the former Soviet Union. The Energy Agency makes the administration of the program. Practically all projects are initiated through the annual call for proposals, issued by each Research Committee. The deadline for project proposals is normally in the beginning of September. Projects normally run over two or three years and funding is given at 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 were supported with total amount of 11.98 million DKK. In total, 21 projects were proposed, asking for 49.3 million DKK in support to projects with a total budget of 79 million DKK.

The Ministry of Environment and Energy also runs a program for development, demonstration and information of renewable energy (UVE), and the Energy Agency makes the administration of the program. The program so far has been renewed every three years, and currently projects are initiated through a standing call for proposals. There is no deadline for project proposals, but they are debated at regular meetings by the Technical Advisory Committee. Projects are always shorter than three years. In 2000, projects were supported by the Danish Energy Agency with a total of 9.6 million DKK.

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 Energy Research Program. This ensures a good co-ordination of the activities within the two programs.

As a part of its 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 of the Test Station for Wind Turbines are negotiated each year, and the budget for the Test Station task at Risø was 5.8 million DKK in 2000.

In addition to the Government R&D programs, the system operators (ELTRA and Elkraft System) have PSO-subsidized R&D programs concerning new and environmentally friendly energy technologies. Prioritized issues include efficiency, costs, and reliability of the wind turbines; regulation and forecasting of production; and environmental impact and maintenance. Call for proposals have been issued with 15 October 2001 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. The 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 IEA R&D Wind since its establishment.

Danish universities, research centers, power utilities, and manufacturing industries participate in the European Union's RTD programs. However, no quantitative data is currently 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.

11.8.2 New R, D&D Developments

In 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 energy research program but puts more emphasis on long-term R&D. The key areas for future R&D projects follow.

- 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 follow.

- Contribute to the 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 from a long-term perspective and establish the basis for new political initiatives.
- Contribute to achieving political goals other than those affiliated with energy issues, such as the country's economical development, environmental improve ments, 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 wind development offshore. In 1999, new R&D projects included wind resources and forecasting offshore, integration of large offshore wind farms in the electricity system, and development of large wind turbines. This year, the call has emphasized R&D on components (e.g., gears), design conditions, electricity system integration, and environmental impact. Project titles in the 2000 round of the research program for wind power include the following.

- Aeroelastic Research Programme 2001-2002
- Turbine dynamics and gear loads.
- 3-D wind simulator for determination of extreme and fatigue loads.
- Improved design basis for large wind turbine blades made of composites.
- Electrical design and control—a simulation platform for modeling, optimization, and design of wind turbines.

Descriptions (in Danish) of the projects are available at the Danish Energy Agency's Web site located at www.ens.dk.

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

- To promote the technical possibilities for utilization of wind power in Denmark through research, development, and demonstration of new and better wind power technology.
- To support the optimal utilization of the available sites.
- To participate in removing barriers for sustainable utilization of wind energy.
- To strengthen the Danish contribution in international co-operation.
- To stimulate Danish industrial development and export.

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

In 2000, the Test Station for Wind Turbines consisted of the following activities.

- Information activities.
- International co-operation with other test stations for wind turbines.
- Secretariat for the Danish certification and type-approval scheme.
- Spot-check of type-approved turbines.
- Inspections of major break-downs of turbines.
- International standardization.
- Development of test methods for wind turbines.
- Development of test methods for blades.

11.8.3 Offshore Wind Energy

In the years to come, utilization of the Danish offshore wind resources will have a high priority in the Danish energy research and development programs. Today two demonstration farms are in operation: Vindeby's 4.95 MW turbine and Tun. Knob's 5-MW turbine, as well as a commercial 40-MW wind farm 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 harbor in shallow water (3 to 5 m deep)—has been under construction in 2000, and the foundations were transported to the site during the first part of October. The farm comprises 20 2-MW Bonus wind turbines, which are installed in a row with a distance of 2.5 diameters. The wind turbines are connected by a 30-kV grid, and the energy is transported to the power plant, Amagerværket, by a 30-kV cable. All wind turbines were erected in December, and the first turbine went into operation on 27 December 2000. The wind farm and the construction phase are shown in Figures 11.4 and 11.5. Studies financed by power utilities, the Danish Energy Agency, and EU/JOULE indicate a substantial cost reduction for new 100 to 200-MW offshore projects: 56% reduction compared to Vindeby. A more accurate assessment of the offshore wind climate and predictions 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

Figure 11.4 The Middelgrunden wind farm. ***Photo by Jens H. Larsen and Mads Eskesen. Published with the permission of Københavns Miljø og Energikontor***

Sea, south of the island of Læs. in "Kattegat," south of the island of Om. in "Smålands Havet," and south of Lolland Falster ("R.dsand" and "Gedser" in "Osters.en" (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 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 year 2000. Also, the economical prospects looked good in comparison with onshore installations. It was recommended that steps be taken for a first phase of a 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.

Figure 11.5 The Middelgrunden wind farm under construction. ***Photo by Jens H. Larsen and Mads Eskesen. Published with the permission of Københavns Miljø og Energikontor***

In 2000, the power companies and the Danish Energy Agency have 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 shall be erected between 2001 and 2008.

In 2000, Elsam/Eltra applied for permission to develop a wind farm at Horns Rev at the West Coast of Jutland. SEAS, on behalf of E2, has applied for a project at R.dsand, south of Seeland. Environmental Impact Assessments have been carried out for two projects.

Both wind farms are planned to consist of 80 wind turbines and a capacity of 150 MW. The plan for the Horns Rev farm assumes the farm to become operational in 2002. The farm is located 14 km from the coast at Blåvandshuk. The turbines are expected to have a total height of 100 to 110 m and a rating of 2 MW, and the farm will occupy an area of 20 km^2.

Authors: Peter Hauge Madsen, Risø National Laboratory, Denmark and Jørgen Lemming, Danish Energy Agency, Ministry of Environment and Energy, Denmark

CHAPTER 12

12.1 INTRODUCTION

The year 2000 was disappointing for wind energy in Finland, as no new installations came through. This was partly anticipated after the doubling in capacity the year before, but the low electricity prices has stalled the whole energy sector and there is not much interest in new power production investments at all.

12.2 NATIONAL POLICY

12.2.1 Strategy

Finland's 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 on this strategy as part of its target for renewable energy deployment, while recognizing the Kyoto protocol on the reduction of 1997 greenhouse gas emissions and the EU White Paper endorsed by the Commission in 1997 and the Council in 1998.

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

The share of renewable energy sources in power production would increase by 8.3 TWh (2,010 MW) from the level in 1995. The major part, 75%, would be generated from biofuels. Achieving the targets would reduce greenhouse gas emissions by about 7.7 million tons of CO_2 equivalent. The vision for 2025 is to add 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 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.

12.2.2 Progress Toward National Targets

The Action Plan for Renewable Energy is so far only endorsed by the Ministry of Trade and Industry and apparently it has been difficult to defend the budget required. Unless more stable and consistent subsidy systems are developed, the ambitious national targets will be far from reached.

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

12.3 COMMERCIAL IMPLEMENTATION

As already stated, no new installations were made in the year 2000, leaving the installed capacity at 38 MW. The gross wind energy production amounted to 79 GWh. The development in capacity and gross production is presented in Figure 12.1.

There is a drive towards offshore siting. Some semi-offshore installations at "artificila" islands made of gravel in low-waters are already built. In the future, installation on small rock cliffs and islands barely over the water level will also progress.

The gross power consumption in 2000 reached 79 TWh, with an increase of 1.7% from 1999. Domestic production covered 86% of the electricity need. Wind, therefore, stands at about 0.1% of the national consumption.

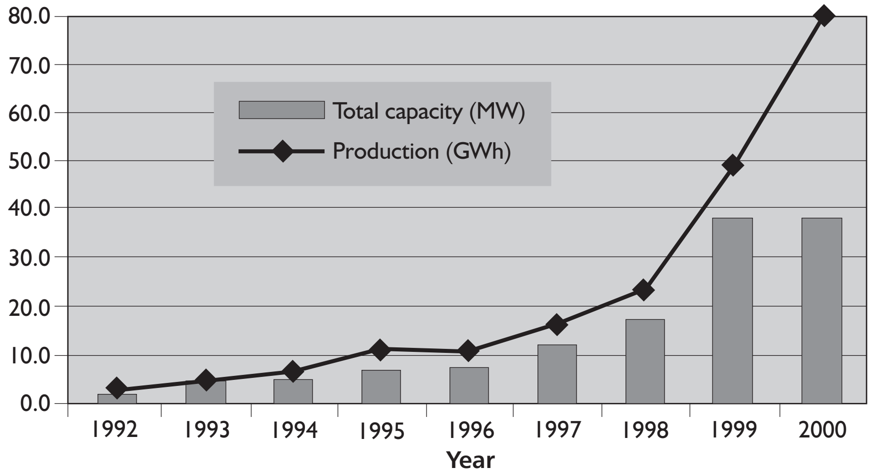


Figure 12.1 Development of wind energy production and installed capacity in Finland 1992 to 2000

12.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

12.4.1 Main Support Initiatives and Market Stimulation Incentives

The Action Plan for Renewable Energy Sources states that the investment subsidy should remain the primary support mechanism. For wind energy, installation of 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. The budget for investment subsidies in 2001 has been raised somewhat. In addition, a price premium of 42.00 FIM is awarded per MWh. 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.

12.4.2 Un it Cost Reduction

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

12.5 DEPLOYMENT AND CONSTRAINTS

12.5.1 Wind Turbines Deployed

So far, all turbines are imported, mainly from Denmark but also to some extent from Germany. The most recent and largest wind turbines have for a long time been preferred, mainly due to difficult siting in the complex coastal landscape.

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

12.5.2 Operational Experience

In general, there has been great satisfaction concerning the operation of the turbines. There are incidents of breakage in seals and bearings, but the overall availability among the reporting turbines remains high. The turbines operating at extreme climates report higher downtimes.

12.5.3 Main Constraints on Market Development

Since 1997, the electricity market has been fully liberalized, down to the household consumers. Thus, all wind energy installations are “merchant” producers that have to find their customers in a competitive market. Current market prices are low and, despite the 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.

Wind energy deployment is slow, but there is always 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.

12.6 ECONOMICS

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

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

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

12.7 INDUSTRY

A new Finnish manufacturer, WinWinD, will present its first prototype during spring 2001. The turbine will have a rated power of 1 MW, will operate at variable speed, and will introduce a one-stage planetary gearbox and a permanent magnet generator. The aim is to develop the concept into a 3.5-MW turbine for offshore applications.

For some time, the Finnish industry has also been able to produce main components, such as gearboxes and induction generators, as well as materials like steel plates and glass-fibre for the main wind turbine manufacturers. The total turnover of this “sale of components” is estimated to have reached almost 1 billion FIM in 2000. 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.

A blade heating system for wind turbines operating under icing conditions was released as a commercial product in 1998. It has been developed mainly for the domestic market but also for export—the first delivery to Sweden was made in 1998.

12.8 GOVERNMENT SPONSORED R, D&D

Since 1999, there has not been a national research program for wind energy. Individual projects can receive funding from the National Technology Development Agency (Tekes) according to the general priorities and requirements for technical R&D. The benefit to industry is stressed,

Figure 12.2 Two of the turbines at Olostunturi

as is the industry's direct financial contribution to individual research projects. Priority is given to product development and the introduction of new products.

New development is comprised mainly of the new domestic turbine mentioned above. Another topic of interest is the actual performance of turbines under local conditions.

There is a drive toward offshore locations of turbines. The foundation and installation of turbines in the icing waters requires careful design of the support structure. Also, the electrical connection, the physical cable laying, and the cost-effective network design will need development not yet started.

Author: Jonas Wolff, VTT Energy, Finland.

CHAPTER 13

13.1 GOVERNMENT PROGRAMS

13.1.1. Aims and Objectives

The actual program, the "4th Program for Energy Research and Technology," has been carried out by the Federal Ministry for Education, Science and Technology (BMBF) since 1996 and by the Federal Ministry for Economics and Technology (BMWi) since 1 December 1998. The development of wind power (Research and Technology, "250-MW Wind"- Program, ELDORADO) is included in this program.

The program consistently follows the goals of the former programs to conserve limited resources, to improve the security of the German energy supply, and to protect the environment and the climate. Two general objectives are emphasized, which are as follow.

1. Creation of the necessary prerequisites;
2. Contribution to the modernization of the national economy, to maintain the German technology position and to improve the exports.

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

13.1.2 Strategy

The strategy of the 4th Program follows three aims, which follow.

1. Improvement of the performance and reliability of existing techniques,
2. Development and demonstration of technological concepts for the future,
3. Support of basic research for the issues above by financing projects with industry and research institutions.

In the short and medium-term, the main contributions to decrease energy consumption and to reduce CO_2-emission are expected from the improvement of thermal power stations and a further use of rational energy.

In the medium and long-term, renewable energies are expected to contribute significantly to the German energy supply and to reduce CO_2-emissions: Technically rather advanced, but not in all cases economically competitive, is the utilization of heat (solar thermal, heat pumps, biomass) and electricity (wind power, waste combustion, biomass, photovoltaic). Hydro power contributes approximately 4% to the German electricity generation.

The full range of strategy measures covers various technologies. For this report, the item "Renewable Energies and Rational Use " is of special interest.

R&D of Renewable Energies is supported by the government. This includes photovoltaics (including the new, 100,000 PV-roofs program), wind power (including the "250-MW Wind"- Program), biomass, geothermal energy, and other renewables as well as an application system for southern climatic conditions.

R&D fields of Rational Energy Use/Saving of Fossil Energy for Consumers are supported including solar thermal power, solar thermal heating of buildings, heat storage, and energy-saving industrial processes.

13.1.3 Renewable Energies Act, EEG

The Erneuerbare Energien Gesetz (EEG), created by the new government, has been active since 1 April 2000 (see Section 13.1). It supports the development of renewable energies by law. The preamble says that the aim of the act is to enable a sustained development of energy supply and to increase the contribution of renewable energies to the electricity supply. This is considered of interest to 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 by the year 2010.

According to the association of German utilities (VDEW), renewable energy—including hydro power—covered 0.9% of the total primary energy consumption and 6% of the electricity consumption in 1999. In 1998, these renewables covered 0.8% and 5.7%, respectively. About two-thirds of the 6% renewable electricity were generated by hydro power, and the share of wind power electricity in 1999 was one-fifth. The share of wind power electricity shows a clearly growing tendency.

13.1.4 Targets

The "4th Program for Energy Research and Energy Technology" was related to the political target of the German government to reduce the CO_2-emission by 25% from 1990 levels 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 CO_2-emission by 20% by the year 2005, compared to 1990 levels.

Government targets for wind energy in Germany are not specified. 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 possible. In the year 2000, wind power electricity reached approximately 1.8% of the German electricity consumption.

Within the government's "250-MW Wind"-Program, a total rated power of 348 MW (250 MW refers to the wind energy conversion system (WECs) power at 10 m/s wind speed) corresponds to a yearly electricity production (including the early, smaller WECs) of about 0.13% of the total electricity actually consumed.

Two German federal states published these specific targets: Lower Saxony with 1,000 MW by the year 2000 (the status as of 31 December 2000 was 1,758 MW) and Schleswig-Holstein with 1,200 MW by the year 2010 (the status as of 31 December 2000 was 1,178 MW).

13.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

13.2.1 Installed Wind Capacity

By 31 December 2000, the number of installed wind turbines was 9,369, with a total rated power of 6,095 MW. A total of 1,665 MW and 1,495 turbines were installed in 2000.

The total number of turbines in operation by 31 December 2000 within the "250-MW Wind"-Program was 1,403 (15% of all WECs), corresponding to a total of 336 MW (5.5% of the total rated power). The development of wind power in Germany is shown in Table 13.1. The distribution of wind power for the 16 German states is given in Table 13.2.

The total rated power of wind turbines by the end of 2000 in the three coastal federal states of Lower Saxon, Schleswig-Holstein, and Mecklenburg-Vorpommern was 3,393 MW, which was 56% of the total installed wind power in Germany, corresponding to 5,331 WECs or 57 % of all WECs in Germany. In 1999, these states contributed 57% of the nation's total wind power.

13.2.2 Comparison with Conventional Public Electricity Consumption

The total public electricity consumption, including grid losses, in Germany for 1999 was 486 TWh. This number was 482 TWh in 1998. Because 2000 data is published in

Table 13.1 Development of wind power in Germany; "250 MW Wind" and total, by December 31, 2000

DATE	NUMBER OF WECs		RATED POWER (MW)		WIND ELECTRICITY PRODUCTION (10^9kWh)	
	250 MW WIND	TOTAL	250 MW WIND	TOTAL	250 MW WIND	TOTAL
12/31/1989	15.0	256.0	1.4	20.0	0.0003	—
12/31/1990	187.0	506.0	30.8	60.0	0.0160	0.04
12/31/1991	439.0	806.0	72.2	111.0	0.0890	0.13
12/31/1992	738.0	1211.0	121.3	183.0	0.2010	0.28
12/31/1993	1058.0	1797.0	183.9	334.0	0.3020	0.50
12/31/1994	1317.0	2617.0	225.5	643.0	0.4620	0.90
12/31/1995	1466.0	3528.0	311.0	1120.0	0.5430	1.50
12/31/1996	1521.0	4326.0	335.0	1546.0	0.5230	2.00
12/31/1997	1511.0	5102.0	343.8	2033.0	0.5800	3.00
12/31/1998	1510.0	6205.0	345.0	2874.0	0.7000	4.50
12/31/1999	1473.0	7874.0	348.0	4430.0	0.6000	6.10
12/31/2000	1403.0	9369.0	336.0	6095.0	≈ 0.6000	8.85

2001, the data for the year 1999 is used as the basis. The wind power electricity production is given in Table 13.1. For the year 2000, wind power contributed about 1.8% to the German public electricity consumption. In 1999, this number was 1.3%. The contribution of all renewable energies, including hydro power, exceeded 6% of the total public electricity consumption in 2000. This number was 6% in 1999. Wind power electricity could reach the 2% mark in 2001.

Regionally, the wind power contribution to the electricity consumption shows considerable deviations from the mean values in Germany. The share of wind power was 18% for Schleswig-Holstein, 12% for Mecklenburg-Vorpommern, and 7% for Lower-Saxony. These are the three German coastal states that are not very densely populated. However, in North Rhine-Westphalia, with almost a third of Germany's electricity consumption, the wind power electricity share was 0.8%.

On a smaller scale, locally, the wind power electricity contribution may deviate even higher from the countrywide values. Here the connection to the grid may be a technical challenge, and in certain cases, grid connection is limited.

13.2.3 Numbers, Type, Make and Ownership of Turbines

Statistics of different WEC types built in Germany are shown in Figure 13.1. The figure also represents the WECs of the "250-MW Wind"-Program from the beginning of the program in 1990 until today. In 1990, many smaller WECs began operation that are no longer on the market. Due to the "250-MW Wind"-Program, the statistics of ownership is known (see Table 13.3). If private individuals, commercial operators, and operator groups are considered more or less as private operator forms, 83% of all WECs (80% of the rated power) are financed with private capital. Commercial operators lead with the average WEC size.

Table 13.2 Distribution of wind power for the 16 German states by December 31, 2000

FEDERAL STATE	NUMBER OF **WTGS**	INSTALLED CAPACITY MW
Lower Saxony	2572.0	1759.00
Schleswig-Holstein	2056.0	1178.00
North Rhine Westfalia	1197.0	644.00
Mecklenberg-Vorpommern	703.0	456.00
Brandenburg	617.0	442.00
Saxony-Anhalt	551.0	494.00
Saxony	413.0	300.00
Rheinland-Palatine	379.0	251.00
Hessia	356.0	212.00
Thuringia	222.0	182.00
Bavaria	113.0	67.00
Baden-Württemberg	98.0	61.00
Hamburg	44.0	24.00
Bremen	27.0	13.00
Saar District	21.0	13.00
Berlin	.0	0.00

Table 13.3 reflects the development of wind power in Germany since 1989/1990. At this time, farmers and private individuals bought the smaller WECs available at the early time of wind power utilization, whereas today commercial operators and operator groups invest in projects with WECs of the commercial MW-class of European manufacturers (see Table 13.4).

Table 13.3 Ownership of WECS of "250 MW Wind"-Program by January 2000

OWNERSHIP	WECS	RATED POWER (MW)	AVERAGE POWER (kW)
Private individuals, mostly farmers	722 (49%)	122 (35%)	169
Commercial operators of WECS and farms	339 (23%)	129 (37%)	381
Operator groups, private individuals	162 (11%)	35 (10%)	216
Regional and municipal utility companies	118 (8%)	24 (7%)	203
Commercial enterprises: (firms, factories, hotels ...)	132 (9%)	38 (11%)	288

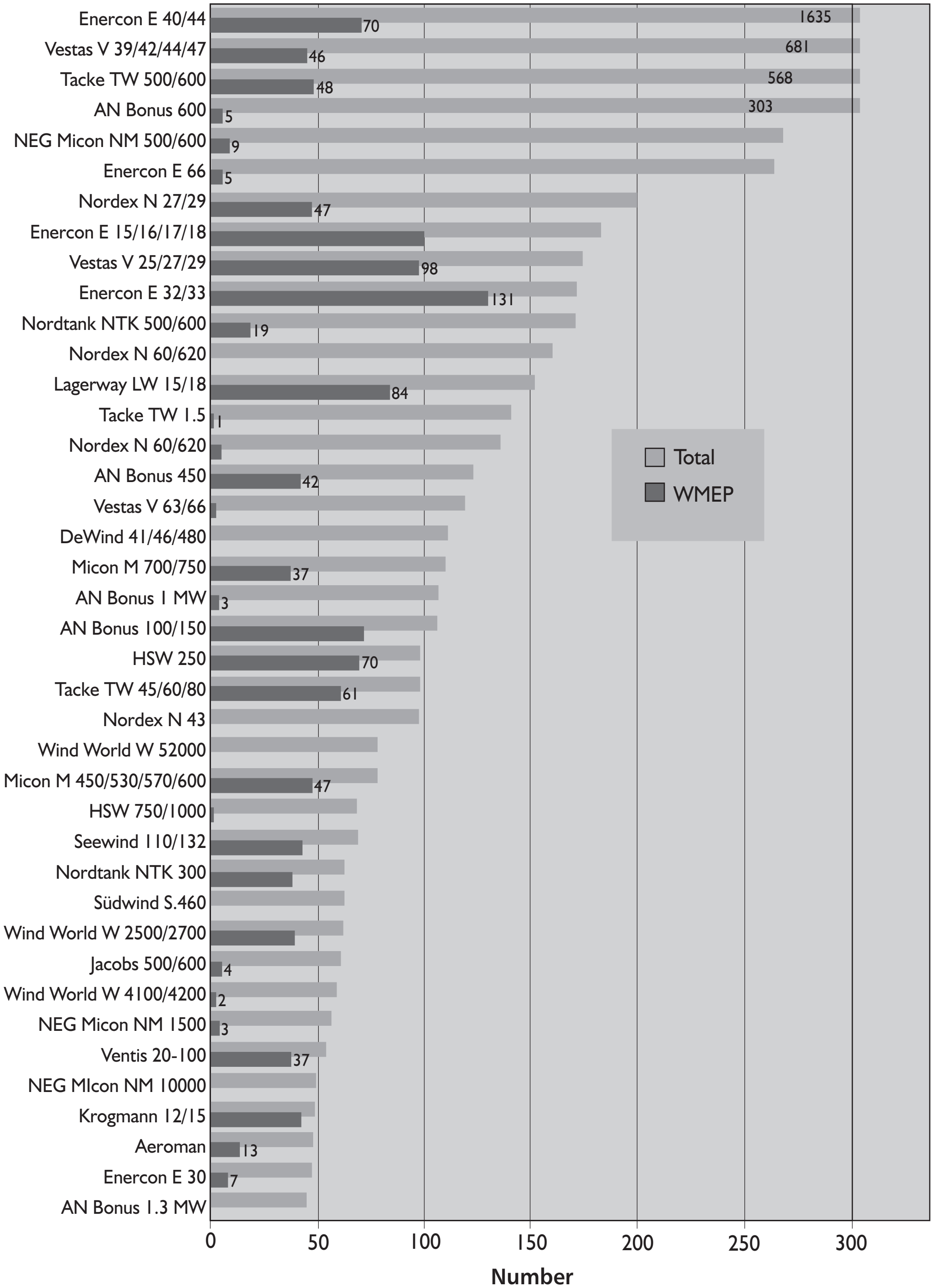


Figure 13.1 WECS types installed in Germany, December 31, 2000

The development of November 2000 provides an example: 196 turbines, corresponding to a total rate power of 224 MW, were erected as single units, farms, or farms under construction. Note that the 224 MW correspond to the total power reached during 1993 in Germany (see Table 13.1). From these 196 turbines, 67 had a rated power below 1 MW (600 kW, 660 kW, 750 kW, and 800 kW, from different manufacturers). It should be mentioned that in the considered month, 20 turbines of 1,800 kW (Enercon E66), one turbine of 2,000 kW (NEG Micon 2000), and one turbine of 2,500kW (Nordex N80/2500, in Mahlberg-Baden Würtemberg) were connected to the grid.

13.2.4 Performance and Operational Experience

Performance and operational experience for the turbines in the "250-MW Wind"-Program has been under investigation in the Scientific Measurement and Evaluation Program (WMEP) with the contractor ISET for more than ten years (see Section 13.6.3). The average technical availability for 2000 was approximately 98%. That means an average stand-still time of about 150 h per unit. The average time of operation of the WECs in the program is at present about eight years. So far, no considerable increase of failures with the total operation time of the WECs has been found.

Figure 13.2 shows examples of WMEP-failure statistics and statistics of repaired and exchanged parts. More than 50% of the causes of failure are identified with component failure and control system of the WECs. About 25% of the causes are identified with external influences (high wind, grid failure, lightning, icing).

Taking into account the actual situation of wind power in Germany, the contract of the running Phase IV of the WMEP (see Table 13.5) is extended to investigate the operation of modern turbines that do not participate in the "250-MW Wind"-Program.

13.3 MANUFACTURING INDUSTRY

13.3.1 Market shares

Table 13.4 shows the shares of the suppliers on the German market in 2000.

Table 13.4 Market shares in Germany (DEWI), December 31,2000

MANUFACTURER	TOTAL POWER %	WECS %
ENERCON	29.2	29.6
ENRON	13.3	11.0
VESTAS	14.0	12.6
AN WINDENERGIE	10.0	9.0
NEG MICON	12.5	13.2
AN WINDENERGIE	9.2	6.1
NORDEX	10.8	9.6
DEWIND	2.8	2.5
JACOBS ENERGIE	2.4	2.7
FUHRLAENDER	1.2	1.2
OTHERS	5.9	8.6
TOTAL	100.0	100.0

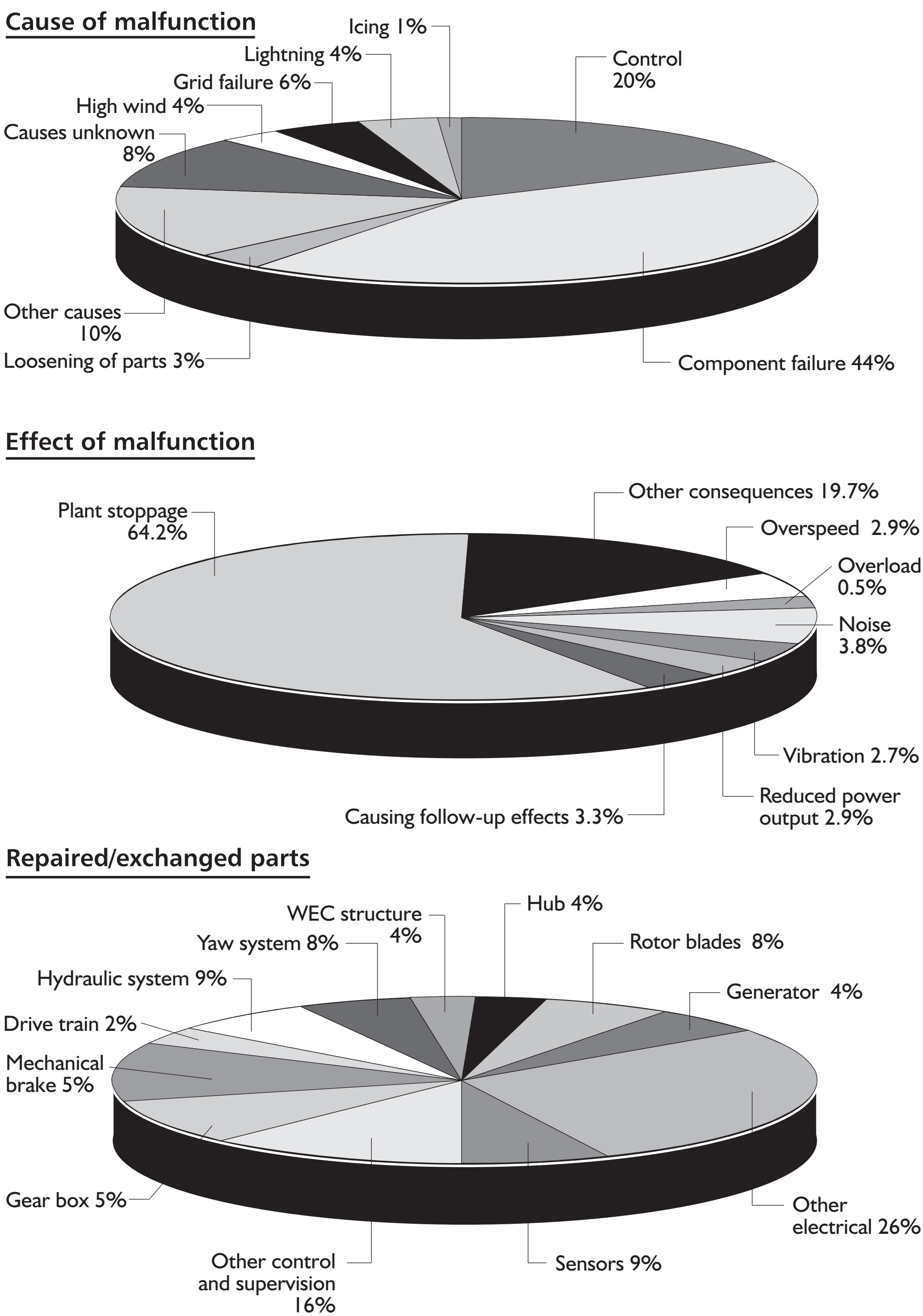


Figure 13.2 Failure and repair statistics for all WECs in the WMEP program

Table 13.5 Wind power R&D projects and the WMEP contract phase III and IV

SUBJECT	PERIOD	COSTS (MDEM)	BMWi (%)
Wind powered desalination plant, Rügen	06/93-05/97	3,891.50	70.00
Processing of wind measurement data up to 150 m for planned archive of wind data	04/92-01/98	607.00	100.00
Special wind data and programs for complex terrain	07/93-06/97	1,641.90	100.00
Phase III of 250 MW wind measurement and evaluation program WMEP	07/96-06/00	13,683.50	100.00
Early recognition of turbine failure	01/94-12/97	1,431.80	50.00
Fatigue loads WECS	07/95-06/97	443.60	50.00
MW WECS inland	06/95-09/99	4,893.60	20.43
Control LS WECS	07/95-06/99	1,192.60	40.00
Active stall rotor blade	08/96-07/98	2,505.98	50.00
Lightning protection WECS	10/96-09/99	600.00	50.00
Development of a 3-4MW WECS	08/98-2000	10,000.00	35.00
Decentralized electrical power plants for grids: voltage fluctuations	08/99-01/02	813.00	50.00
Integration of decentralized electrical power plants for grids	08/99-01/02	870.00	100.00
Phase IV, WMEP	07/00-06/04	11,450.00	100.00
Forecast wind medium and large utility regions	05/00-10/01	650.00	94.31
Aspects of construction and environment of offshore WECS	10/00-09/03	1,670.00	100.00
Addvanced drive train for LS-WECS	01/01-12/03	1,840.00	40.00

13.3.2 New Products and Technical Developments

The technical availability of the WEC installations in Germany is high at 98%. For the first time, the average size of yearly erected turbines exceeded the MW-threshold with 1.1 MW. In 1999, this number was 935 kW per unit. This indicates a rapid technical development of wind power that is not limited to German manufacturers, as shown in Table 13.4.

13.3.3 Business Developments

The number of direct and indirect employees in the German wind power industry is at present 20,000 (Appendix EEG).The total commerce connected with WECs in Germany in 2000 amounted to 3.66 billion DEM (DEWI, January 2000). Service teams had to be set up. On the average, one service person is required for each installed capacity of 20 MW. These jobs are needed for the lifetime of the turbines. Good service teams are considered most important to maintain the excellent availability, which averages 98%, of wind turbines and a long lifetime of the installations.

13.4 MARKET DEVELOPMENT

The rated power of the installed turbines has increased significantly over the years. In 1989 and 1990, the market offered WECs with a maximum power of 250 kW. Nevertheless, the majority of plants still had a rated nominal power of 100 kW or less. The typical operator was assumed to be a farmer who produced the electricity for the needs of his own farm and fed the surplus electricity into the grid. This situation has rapidly changed due to the technical and price development of WECs. In addition, the boundary conditions to finance wind power projects were improved drastically by different measures (see Section 13.5). This created confidence for investors in wind power technology and opened a rapidly growing market for European wind turbine manufactures in Germany. See Table 13.3.

Most of the WECs 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 WEC Type N80 by Borsig Energy GmbH with a rotor diameter of 80 m was erected, followed soon by commercial units of this type. R&D for a 3 to 4-MW turbine is on the way (see Section 13.6.2). The realization of wind power offshore projects was discussed during 2000 and is being considered as a wind power market in the near future. Most of the production by German companies is still sold inland, but export is considered as a further option. So far, the inland market is booming despite obvious constraints in a densely populated country like Germany.

Constraints, starting in the German coastal areas, include complaints that wind turbine installations are destroying the landscape and disturbing wildlife and birds. Neighbors of WECs 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. Owing to the necessity of noise emission reduction, a distance of about at least 500 m from the next resident is recommended for large-scale WECs. Although the corresponding land around a WEC 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 WECs.

13.5 ECONOMICS

13.5.1 Favorable Boundary Conditions, Especially the EEG

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

The Electricity Feed Law (EFL) became effective 1 January 1991. Since then, utilities have been obligated to pay the same 90% of the average tariffs per kWh that private consumers had to pay, with taxes of 15% excluded. In 1998, this amounted to 0.1679 DEM/kWh and 0.1652 DEM/kWh in 1999. EFL and 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 this 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 with the name "Gesetz für den Vorrang Erneuerbarer Energien" (Erneuerbare-Energien-Gesetz or EEG for short) came into force by 1 April 2000. The general contents of this law follow.

- Obligation on electricity grid operators to give priority access to all renewable electricity.

- Fixed tariff for each renewable.
- Rules on grid connection and grid reinforcement
- Mechanism 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 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 turbine” will drop to at least 0.121 DEM/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 output. An annual decrease in the two tariff rates of 1.5 % per year, starting from 1 January 2002 is foreseen. Offshore wind power is covered by the act in German territorial waters and the German zone outside of the 12 nautical miles zone. A premium support for first installations sited in water more than three nautical miles from a base line near the coast is given if they are installed before the end of 2006. In this case, the tariff of at least 0.178 DEM/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 are no longer qualified for the higher rate of 0.178 DEM/kWh, due to their age, 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 30 m height 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 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 WECs, while some other states, especially in the German inland, still conduct programs with direct funding (Nordrhein-Westfalia).

13.5.2 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 depends on the conditions for reimbursement regulated today by the EEG and the development of turn-key prices of WECs. It also depends on the interest rate for loans and mortgages with a pay-back time of ten years. The interest rate was about 10% by April 1991. This was followed by a fluctuating decrease of about 5% to 6%. Assuming a pay-back time of ten years, established methods project that a decrease of 3% in the interest rate corresponds to a price decrease of 25%.

The economics of WECs 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 the German meteorological and financial conditions, it is generally accepted that WECs erected in 2000 are an option for investors to receive a positive balance not far in the future. Of course, details depend on the special project. One more easy estimate of economics is the forecast of the balance of the yearly income and expenditure.

At good sites, close to the German or Baltic Sea—where the mean wind velocity at a height of 10 m is between 5.5 and 6 m/s—

the majority of WECs have lower production costs than income in only a few years.

At inland sites, it takes longer to reach a positive balance. The actual MW-size turbines with 80-m towers, or higher, use the higher wind speeds at the nacelle-level, compared to surface wind. It should be mentioned that already in the early 1990s, the governmental support of investment within the "250-MW Wind"-Program, as an option for special owner groups, depended upon the tower height. This stimulated techniques, especially for inland sites, relatively early.

In addition to high towers (additional costs are tolerable) for inland WECs, the meteorological site analysis made considerable progress. Financing of WECs 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 a 10-m height dominate—is significantly different from coastal sites. As seen in Table 13.2 and Figure 13.3, investors take into account a longer time before a positive balance is reached, building up a considerable share of Germany's wind power in inland states. It is obvious that the break-even point could exceed ten years.

Reducing the taxable income of certain investors is one of the further driving forces of the German wind power market. A depreciation time for WECs of ten years was possible until mid-1997. Since 1 July 1997, the depreciation time has been 13 years. With a linear depreciation, investors can reduce their taxable income by about 10% of the turn-key costs per year. This corresponds to approximately 100,000.00 DEM per annum. With an assumed tax rate of 30%, the taxes to be paid by the investor will be reduced by about 30,000.00 DEM per annum.

13.5.3 Results of the WMEP

Various measurements and operational reports provided an interesting generalized diagram, reflecting the distribution of electricity production for approximately 1,400 turbines installed in the 1990s in Germany. Figure 13.4 shows the distribution

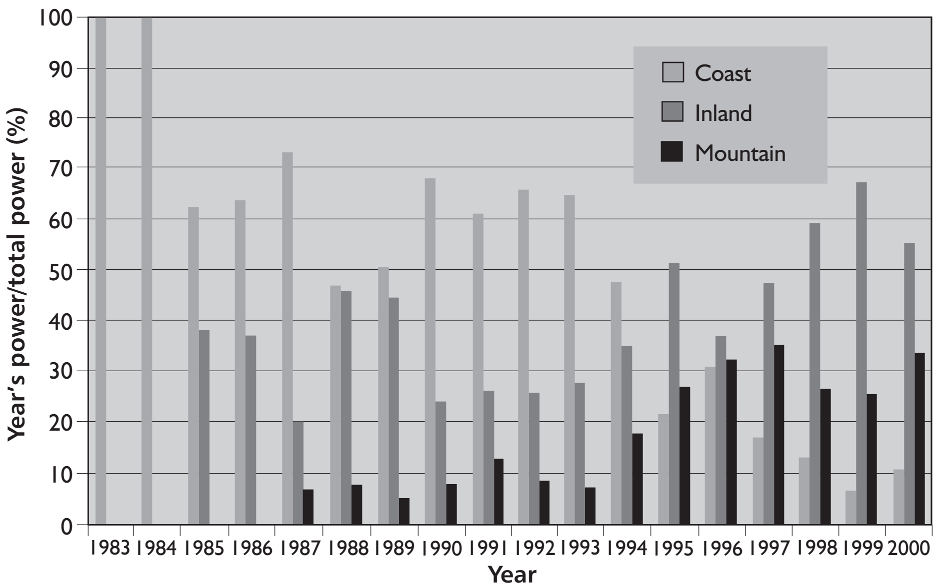


Figure 13.3 Regional development of wind power

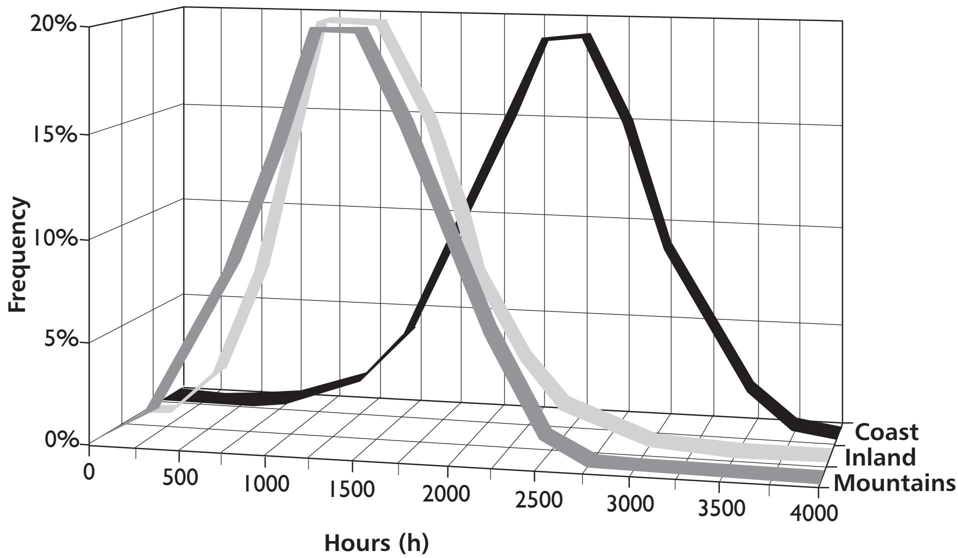


Figure 13.4 Full load hours "250 MW Wind"

of full-load hours for the coast, the northern German lowlands, and the low mountains. The broad curves again support the necessity for an investor to plan a project very carefully, but the diagram was used to investigate the spectrum of economics on a basis of more than 1,000 operating installations. ISET published results in its annual report.

13.6 GOVERNMENT-SPONSORED PROGRAMS

13.6.1 Funding

The BMWi 2000 funding levels of wind power were as follows in million DEM. (Levels for 1999 and 1998 are in brackets):

R &D:	DEM	6.09 (4.50, 5.50)
"250 MW Wind":	DEM	23.28 (37.20, 35.30)
ELDORADO:	DEM	0.09 (6.30, 6.30)
Total:	DEM	29.46 (47.00, 47.10)

The decrease of funding for the "250-MW Wind" Program results in the fact that more and more projects have reached the upper funding level.

13.6.2 R&D/WMEP

Recent R&D-Projects by BMWi are shown in Table 13.5. The projects include the engineering of a 3 to 4-MW, 110-m turbine, to be erected in near future. The WMEP, Phase III, involves a 13.683 million DEM contract for the period of July 1996 to June 2000. Phase IV is now in force. Actual wind power techniques and operational results are new tasks for the WMEP, in addition to the operational results of the turbines of the "250 MW"-Program.

In the autumn of 1998, experts reviewed the future of R&D for the wind energy technology on behalf of BMBF. They found that despite the fact that this technology has made a rapid technical development in the last ten years and that a market for wind power has opened worldwide, there is still much work left to be done to fulfill the potential of wind power as a key contributor to the renewable worldwide energy supply. Some recommendations are being realized by R&D projects, including one offshore research project. Additional R&D projects for the offshore utilization are discussed with the BMWi.

13.6.3 "250-MW Wind"–Program

The goal of the "250-MW Wind"-Program is to carry out a broad test of the application of wind energy on an industrial scale, which extends over several years. As an incentive for their participation in the "250-MW Wind"-Program, operators of the wind turbine/ wind farm receive grants for the successful operation of their installations.

The current subsidy for operators in the "250-MW Wind"-Program is either 0.06 or 0.08 DEM/kWh, depending on whether the energy is fed into the grid or is being used by the owner of the WECs. The latter applies to a farm, a factory, or a private household, in addition to a utility as a WECs owner. The grants are now limited to a maximum of 25% of the total investment costs. In certain cases (private individuals and farmers), a subsidy of the investment, limited to 90,000.00 DEM was possible.

The interest in support of the "250-MW Wind"-Program was high. Until the closing date for proposals (31 December 1995), more than 6,000 proposals were registered. This corresponded to a total rated power of more than 3,500 MW. During the development of the program, a total of 1,223 proposals were approved, corresponding to 1,573 WECs and 384.5 MW. The last approvals were for some projects with the new MW-size turbines, erected in 1998. The program will end around the year 2008 after ten years of WMEP-participation of the MW-size turbines.

It is expected that the total support will reach 300 million DEM. The costs of the measuring program are not included in this sum and could reach an additional 60 to 70 million DEM for the period 1990 to around 2007.

13.6.4 "ELDORADO Wind"–Program

BBMWi's interest also includes the application of wind energy in overseas countries. According to a study by the World Bank, almost 50% of the inhabitants in developing and threshold countries do not have access to central energy supplies (such as electricity, oil, and gas). They could be assisted by decentralized concepts, and renewable energies are considered to be an option for decentralized energy supplies. Therefore, BMWi launched the "ELDORADO Wind"-Program in 1991, which is now being jointly carried out with partner countries. The aim of BMWi is to encourage a large number of users in southern climatic zones to construct and operate WECs in co-operation with German partners. Nearly 30 projects were approved by BMWi. Most of the installations went successfully in operation. The total rated power is around 30 MW.

13.7 REFERENCES

Annual Report "Energieforschung und Energietechnologien"
BMWi, 2000). Available by
Fachinformationszentrum Karlsruhe
D76344 Eggenstein-Leopoldshafen
Telefax: 49/07247/808-135. E-mail: library@fiz-karlsruhe.de

Annual Report 2000 and other publications, ISET; Königstor 59,
D34119 Kassel,
Telefax: 49/561/7294/100. See also: http://www.iset.uni-kassel.de/reisi

3-DEWI-Magazin, February 2001.
Deutsches Windenergie-Institut GmbH, Ebertstraße 96, D26382 Wilhelmshaven
Telefax: 49/4421/48084. Internet: http://www.dewi.de

Further information and links by the home page of Project Management

Organization Biology, Energy, Environment of BMBF and BMWi, Forschungszentrum Jülich Gmbh.
Internet: http://www.fz-juelich.de/beo.htm

Authors: N. Stump, Forschungszentrum Jülich, BEO; R. Windheim, Jülich;

Figures, M.Durstewitz ISET, Kassel, Germany.

CHAPTER 14

14.1 NATIONAL POLICY

14.1.1 Strategy

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

According to the above Law, two bodies are 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.

Concerning wind energy, the main difference of the Law 2773/99 compared with the former Law 2244/94, in effect since 1995, is the tariff policy for wind energy produced. Wind energy is used primarily by the HTSO during the generation unit dispatching. The price payed to the producer is a percentage of the tariff paid by the medium voltage consumer, the same as defined by the Law 2244/94, in power until the Law 2773/99 came in effect. The difference is that the Minister of Development is allowed to ask the producers of renewable sources for a discount on this price.

In spite of the liberalization of the electricity market, there has been no revision of the National Program of Greece during 2000. 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.

14.1.2 Progress Toward National Targets

In 1995, the Ministry for Development set a target for 350 MW of installed wind energy capacity by the year 2005. As soon as the Law 2244/94 was issued in early 1995, a great interest was shown by the private sector in developing wind-power projects. According to that Law, interested parties could develop power plants up to 50 MW from renewable energy and sell electricity to PPC, ending the monopoly of PPC on power generation from wind energy. Other features affecting the development are the more simplified procedures (less bureaucracy) and attractive buy-back prices. As a result, a steep increase in wind energy capacity has occurred, bringing the installations up to 214 MW at the end of 2000 from the 29 MW installed by 1995.

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

14.2 COMMERCIAL IMPLEMENTATION

14.2.1 Installed Capacity

In total, 171 wind energy conversion systems (WECs) having an installed capacity of 105 MW in 13 separate projects have been connected to the electricity supply network within 2000, bringing the total installed wind energy capacity to 214 MW (481 machines).

14.2.2 Rates and Trends in Deployment

The development of wind energy within the last ten years is shown in Figure 14.1,

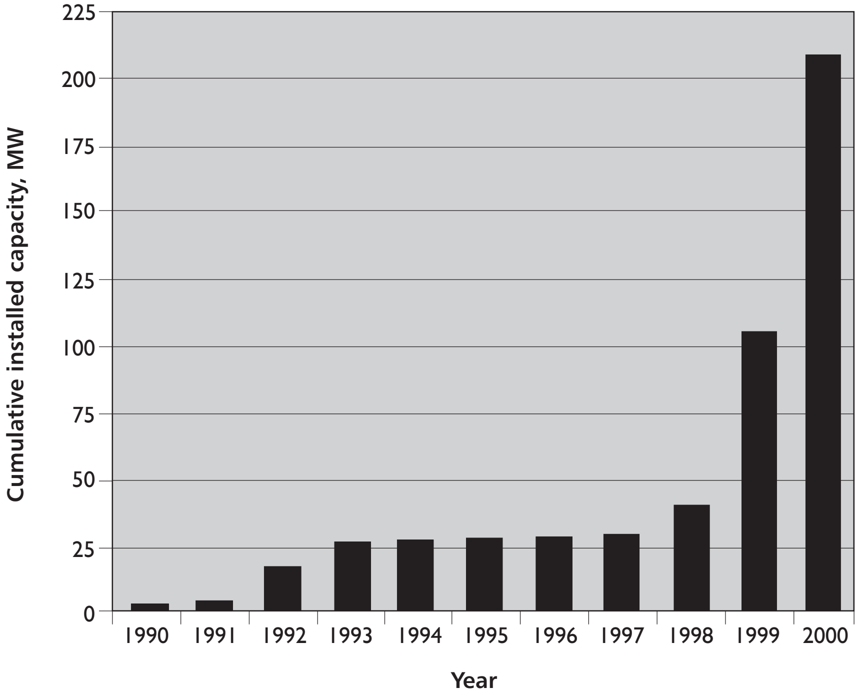


Figure 14.1 Cumulative installed wind capacity in Greece

where the total installed capacity per year is depicted.

14.2.3 Contribution to National Energy Demand

The energy produced from wind turbines during 2000 was approximately 460 GWh, while the energy produced in 1999, 1998, and 1997 was 160 GWh, 71 GWh, and 38 GWh, 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% of the energy demand. Figure 14.2 shows the electricity produced from wind turbines for the last ten years and the corresponding capacity factor.

14.3 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

14.3.1 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 is implemented within a continuous program, according to which wind projects may be subsidized up to 40% of the cost and receive reduced soft loans up to 40%.

14.3.2 Unit Cost Reduction

No data available.

14.4 DEPLOYMENT AND CONSTRAINTS

14.4.1 Wind Turbines Deployed

The average capacity of the wind turbines installed in 2000 was 615 kW, while the average capacity of all the wind turbines operating in the country is 450 kW. The market share per manufacturer is depicted in Figure 14.3.

14.4.2 Operational Experience

The majority of the wind energy projects are very recently developed. There have been no serious malfunctions reported

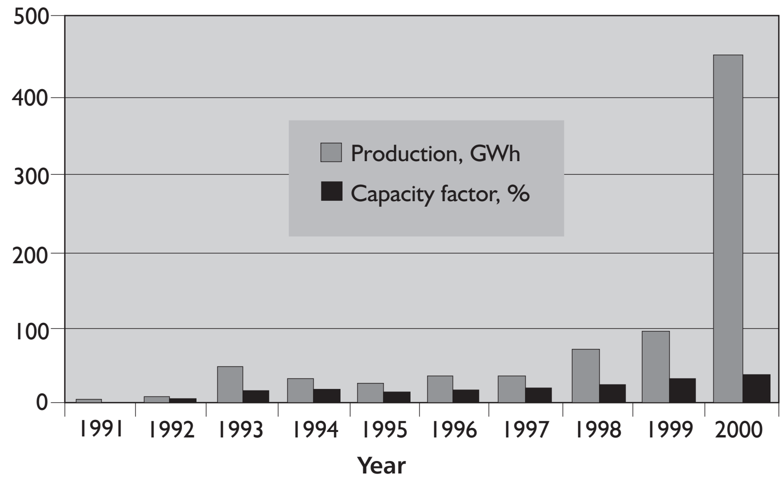


Figure 14.2 Electricity produced and capacity factor for wind turbines in Greece

during the relatively short period since their commissioning.

14.4.3 Main Constraints on Market Development

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

14.4.4 Trends in Investment

The total cost of wind power projects depends on the type of wind turbine and its size and accessibility. These costs vary from 330,000.00 to 400,000.00 DRS/kW. The generated wind power cost could be assumed between 9.00 and 16.00 DRS/kWh, depending on the site and project cost.

The typical interest rate for financing any project without subsidies is in the order of

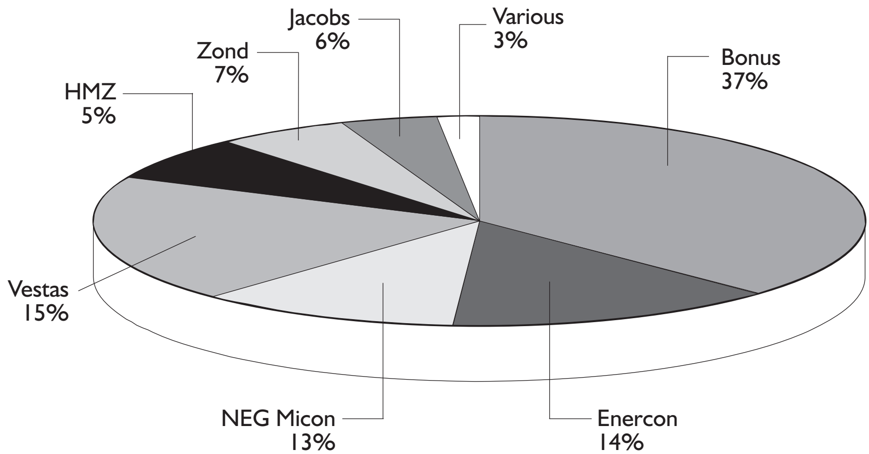


Figure 14.3 Market share in Greece of wind turbine manufacturers

8%. However, many investments, including wind projects, may be profited by reduced soft loans, according to the so-called “Law for the Economical Development” 2601/98.

14.4.5 Trends in Unit Costs of Generation

The system of power generation in Greece is divided into two categories: the so-called interconnected system of the mainland, and the autonomous power plants of the islands. In the liberalized electricity market, a single charging price exists in both systems, depending on the identity of the consumer and the voltage class. The following tariffs for the three voltages are valid since 15 July 1998.

—Low Voltage 26.60 Drs/kWh,

—Medium Voltage 21.51 Drs/kWh and 994 Drs/kW (peak power value),

The prices paid by HTSO for renewable energies are based on the actual selling price. For both autonomous and 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., 19.359 DRS/kWh), while the power component is set at 50% of the respective PPC’ power charge (i.e., 497.00 DRS/kW x P, where P is the maximum measured power production over the billing period). The aforementioned prices are effective since 15 July 1998. The Ministry of Development has the right to ask the producers for discounts on the above prices.

14.5 INDUSTRY

14.5.1 Manufacturing

Except for a couple of small wind turbine manufacturers (typical range 1.0 to 5.0 kW), there is no wind turbine manufacturing industry in Greece in a classic manner. However, the steel industry is quite developed in the country, being able to support wind turbine manufacturing. As a result, most of the tubular towers of the installed wind turbines have been constructed in Greece. Furthermore, a Greek company has been successfully involved in blade manufacturing. The company has produced blades up to 19 m.

14.5.2 Certification

To operate a wind turbine in Greece with rating of more than 20 kW, a certificate is required. The Center for Renewable Energy Sources (CRES) is, by law, the certifying authority for wind turbines in Greece. Until now, CRES has been accepting approval certificates issued by authorized institutions, while it is working on certification procedures and standards to be followed nationwide, taking into account the individual climate characteristics of Greece.

14.6 GOVERNMENT SPONSORED R, D&D PROGRAMS

14.6.1 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.

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 MW-size wind turbines or offshore deployments.

A project for the development of a 450-kW wind turbine was initiated within the framework of the EPET-II National Programme, in 1995. The project is aiming at both the development of a 450-kW, variable speed, stall-regulated wind turbine and the development of blade manufacturing technology. The assembly of the prototype has been concluded, while its installation at the test site is planned to take place in early 2001.

CRES is the national organization for the promotion of 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' Wind Energy Department is continuing the development of the National Certification System, as well as participates 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 2000, the active involvement in the activities of IEC TC-88, CLC/BTTF83-2 and their working groups was continued.

CRES' 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. The CRES Wind-Diesel Hybrid laboratory system—which simulates small autonomous grid operation, common in the islands of the Aegean sea—is effectively used in optimizing the integration of the renewable energies in such systems.

Basic R&D on wind energy is mainly performed at the country's technical universities.

14.6.2 New R, D&D Developments

A number of research projects were running or initiated at CRES during 2000, co-funded by DGXII and GSRT (the Greek Secretariat for Research and Technology) with the following goals.

- Characterizing the main features of complex or mountainous sites (since sites of such topography are the most favorable for wind energy develop ment), and identifying the crucial parameters affecting both the power performance and the loading of different types of wind turbines operating in such environments. In that direction, new techniques are under development for power-curve measurement of wind turbines operating in complex terrain.
- Developing wind turbines for installation in hostile environments of poor infra structure.
- 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, namely in rotor aerodynamics and wind energy integration in the electrical grid.

The Fluids Section of the Mechanical Engineering Department of the NTUA is active in the field of wind modeling, rotor aerodynamics, load calculation, fatigue analysis, noise, and wind farm design. The work conducted during 2000 concerned applied research on rotor aerodynamics for wind turbines. More specifics of this work follow.

- The tower effects on the aerodynamic behavior of rotor blades has been investigated based on CFD simulations. To this end, a two-block, 2-dimensional methodology has been developed for a generic configuration, consisting of an airfoil moving transversely upstream as well as downstream of a cylinder. One block contained the airfoil and one the cylinder. The communication between the two block was conducted through appropriate boundary conditions.

- The new viscous-inviscid interaction model for airfoils, concluded in1998, has been applied to investigate the aeroelastic stability problem for a generic 2-dimensional configuration in which flexibility is modeled by concentrated springs in the flap and edge direction.
- The Navier Stokes flow solver for rotating blades, developed in 1999, has been applied to produce parametric results with the aim to better under stand the characteristics of the flow established on stall-regulated machines.
- A family of new, low-drag airfoils has been used to design new blades for stall-regulated machines, aiming to optimize the energy capture. A 19-m blade has been designed, constructed, and tested in the laboratory. This blade is now ready for testing on a 450-kW, variable-speed machine.

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

In 2000, the Electric Power Division of NTUA focused its research activities on the issues that follow.

— 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.

— A proposal of electricity tariffs for embedded renewable generation.

— Power quality of wind turbines and wind parks.

— Design of electrical components for variable-speed machines.

— Lightning protection of wind turbines and wind parks.

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 due to very favorable wind conditions. Steady-state voltages, voltage variations, and power-quality issues have been investigated. Particular emphasis has been placed on the effect of storage, especially pumped hydro storage schemes, on the dynamic and operational performance of larger island systems, like Crete. CARE—an advanced control system comprising load and wind power forecasting, unit commitment and economic dispatch, and online dynamic security assessment modules integrated within a friendly Man-Machine Interface—has been developed. CARE is installed on Crete, providing dispatch and corrective advice for the secure operation of the system with increased wind power penetration.

Dispersed renewable generation can make a positive impact on power system costs by modifying system losses, as well as system capital costs through reducing demand for new network and generation facilities. Research has focused on the evaluation of these changes in costs and in recognizing them within the tariff structures and pricing mechanisms. NTUA's research has applied probabilistic techniques to deal with the stochastic nature of wind power production.

Various control systems of variable-speed wind turbines have been studied. A specialized code for the simulation of wind turbines capable of providing constant, active power and voltage support have been developed.

Research on lightning protection of wind turbines and Wind Parks has been continued with particular emphasis on the efficient design of their grounding systems. Actual wind park grounding systems in new sites have been studied.

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

The University of Patras has successfully completed structural designs for 4.5, 5.5, 8, 10, 14, and 19-m GRP blades, verification of which was performed by full-scale static, fatigue, and modal tests at the CRES blade testing laboratory. During 2000, in the framework of EPET-II National Program and JOULE-III, a 19-m GRP rotor blade was adapted by UP to meet certification requirements of different loading conditions. A rotor was constructed by a Greek industrial partner, Geobiologiki S.A., and is currently under installation in a prototype wind turbine at the CRES test site.

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

During 2000, two new research projects, in which UP is participating, were funded by EC and are about to start: "DAMP-BLADE-Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites" and "MEGAWIND-Development of a MW Scale Wind Turbine for High Wind Complex Terrain Sites."

Other research activities of the Applied Mechanics Section are: (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; and (e) structural damping, passive and active vibration control

Figure 14.4 Windfarm with capacity of 11.2 MW on Evia Island, comprising 17 Vestas V42, 600-kW wind turbines (provided by G. Gilinou, CRES)

14.7 DEMONSTRATION

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

The following four demonstration projects were ongoing in 2000:

1) A large, advanced, autonomous wind/diesel/battery power supply system in Kythnos (THERMIE programme).

   The aim of the project in Kythnos is the demonstration of the technical feasibility of the integration of a very high penetration of wind energy in large supply systems. This large modular system for the island of Kythnos is designed for the combination of diesel generator sets, battery storage, rotating phase shifter, five small wind energy converters, and one additional large-wind energy converter. This large-wind energy converter, with a power output of 500 kW, will supply a great portion of the power demand. It will be the first time that such a high portion, more than 50%, of the energy demand is realized by wind turbines, and due to this, the diesel generators can be totally stopped when the power output of the wind turbines is sufficient. Furthermore, the already existing PV system, with a nominal power of 100 kW, as well as the existing 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 PPC and SMA. The wind turbine was erected in mid 1998, and the commis sioning was completed during 2000. High-wind penetration, reaching up to 100%, has been achieved while the system is still in trial operation.

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

   CRES' demonstration wind farm is located just near the wind turbine Test Station in Lavrio. The purpose of the project is to study the effects of the complex topography on the performance of the wind turbines as well as on the overall wind farm. It 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. The electrical infrastructure has been constructed, and the commissioning is expected within January of 2001.

3) A 300-kW induction wind turbine connected to the desalination plant of Mykonos Island (THERMIE programme).

   The aim of this project is to couple a medium-size wind turbine with a desalination plant with the opportunity of operation as a standard, grid connected machine, if necessary. During the year 2000, the NTK 300-kW wind turbine was erected, and the commissioning started in August. By the end of the year, approximately 400 MWh had been produced. Additionally, an extended monitoring campaign has been initiated by CRES, in order to evaluate the project's results.

4) A 500-kW wind turbine direct-coupled to a desalination plant on Syros Island (JOULE-THERMIE programme).

   An Enercon E40 500-kW wind turbine was installed on the Island of Syros, the capital of Cyclades Islands, late in 1998. The aim of the project, which is managed by the NTUA, is to demonstrate the successful operation of a wind-desalination system. The wind turbine is directly coupled to a desalination plant of 900 m^3/d capacity, while a grid-connection alternative has also been foreseen. The system is in commissioning.

14.8 OFFSHORE SITING

No offshore wind farms were installed in 2000.

Authors: P. Vionis, M. Koulouvari, and P. Zorlos, Greece

CHAPTER 15

15.1 INTRODUCTION

Since the end of 1996, the Interministerial Committee for Prices (CIP) Provision No. 6/92 has shown itself to be the most successful instrument for the commercial implementation of wind energy in Italy. In fact, with the sole exception of 1997, the years following 1992 have been characterized by a continuous increase in the wind capacity installed in accordance with this provision. Now, a new legislative decree (the Legislative Decree No. 79/99), which provides for the liberalization of the electricity market on the basis of the European Union Directive No. 96/92/EU, will dramatically change the system of stimulation and exploitation of renewable energy sources.

At the end of 2001, most wind plants previously authorized through the afore-mentioned CIP 6/92 will probably be brought to completion. After that, the new system based on the quota allocated to renewable sources and on green certificates will determine wind energy deployment for the next decade.

15.2 NATIONAL POLICY

The Italian Government attributes strategic importance to renewable energy sources because of the contribution these sources can give 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. For this reason, within the scope of a coherent and comprehensive policy of support by the European Union, the Government intends to sustain the progressive integration of these sources into the energy market and develop co-operation with other countries.

In the last two or three years, several initiatives have been taken with the aim of promoting and increasing the penetration of renewables in the Italian energy market.

In particular, the resolution of the Interministerial Committee for Economic Planning (CIPE) No. 137/98, issued on 19 November 1998, began to deal with the reduction of greenhouse gas emissions with guidelines for national policies and measures in which some objectives, in accordance with the Kyoto protocol, were fixed. The actions through which it is possible to obtain a reduction of greenhouse gas emissions for values equivalent to 95 to 112 Mt CO_2 by 2008 to 2012 were specified. In this context, an important role is attributed to renewable energy sources with a contribution forecast in a reduction of 18 to 20 Mt CO_2 by 2008 to 2012, while more specifically 3.4 Mt CO_2 is the part assigned to wind power.

In addition to this resolution, the same CIPE approved the Italian White Paper for the exploitation of renewable energy sources in August 1999. In this document, which was prepared on the basis of the Green Paper drawn up in view of the National Energy and Environment Conference, the role of renewables previously determined in order to reduce CO_2 was fully confirmed, and the goal of a reduction of 18-20 Mt CO_2 by 2008 to 2012 was raised to 24 Mt CO_2. Lastly, the Legislative Decree No. 79/99, issued on 16 March 1999 on the liberalization of the electricity market in Italy and the Decree issued on 11 November 1999 are now the new instruments put in force by the Government, of which one aim is to achieve the goal of doubling the contribution of renewables by 2010.

On 20 July 2000, the Ministry of the Environment issued Decree No. 337 in which it was established that a share of the carbon tax revenues for the year 1999 was to be devoted to renewable sources. In particular, regarding wind energy, it was decided to provide investment subsidies of up to 40% for the construction of wind plants in the smaller islands.

15.2.1 Strategy

Achieving the objective of doubling the contribution of renewable sources in the decade 2000 to 2010 is quite ambitious and requires the intervention of the state and other public institutions. The various steps of an action plan follow.

- — Adopt coherent policies.
- — Decentralize functions and structures for regions and local authorities.
- — Disseminate awareness of energy-related environmental issues.
- — Acknowledge the strategic role demonstrated by research.
- — Encourage integration with energy markets.
- — Meet organizational requirements.
- — Start off framework projects and support initiatives.

15.2.2 Progress Towards National Targets

As specified in the national white paper for renewables, targets have been fixed for wind power capacity for three periods: 2002 = 700 MW; 2006 = 1,500 MW; and 2008 to 2012 = 2,500 MW.

The investment cost necessary for carrying out all projects—totaling 2,400 MW in the years 1997 to 2012—was estimated to be between 1.5 and 1.8 billion/MW ITL in 1997, corresponding to a total of about 3,800 billion ITL.

Given the growing rate of new wind installations registered in the last two years and the decision of most developers to bring to completion the major part of the wind farms entitled to the premium energy buy-back prices under the CIP Provision No. 6/92 by 2001, it is very likely that the first goal, 700 MW by 2002, will be achieved. Regarding the likelihood of reaching the other targets after 2002, this will depend on the effect of the new legislative framework, and in particular, the results achieved by the introduction of the green certificate mechanism.

15.3 COMMERCIAL IMPLEMENTATION

The satisfactory trend in the growth of wind power capacity in 1999, with around 100 MW installed, continued in 2000 when wind plants totaling 147 MW were added. During 2000, several wind installations were built in the Campania region, which together with the Apulia region represents the most developed area in the wind sector in Italy, both in terms of capacity installed and projects supported by public funds.

15.3.1 Installed Capacity

In the course of 2000, IVPC 4 and Edison Energie Speciali installed capacities of 97 MW and 50 MW, respectively. Also in 2000, 151 Vestas V-42 and V-47 wind turbines of 600 kW and 660 kW, respectively, were constructed and transported on site in the Campania and Apulia regions by the IWT manufacturer based in Taranto. In addition, 85 Enercon 40 of 600 kW each were installed in the Abruzzo, Campania, and Apulia regions. The average size of these turbines is 626 kW. With these new installations, totaling 147 MW, total wind power capacity in Italy at the end of 2000 rose to 427 MW, with an average turbine size of 521 kW. The total number of wind turbines was 819. In Fig. 15.1, the annual and cumulative power capacity data are represented.

15.3.2 Rates and Trends in Deployment

During the first half of the year, only 16 MW were installed in Italy. But in the last six

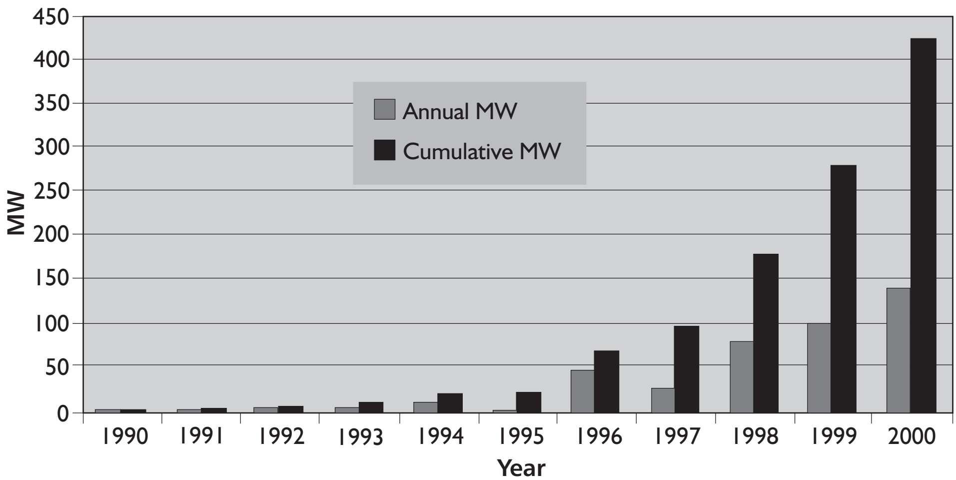


Figure 15.1 Trend of Italy's installed wind capacity

months, the situation changed as a result of the installation at the Apennines sites of another 131 MW—so now the trend is quite good, with the expected rate of 200 MW/year to be reached next year. In the year 2000, the increase in wind power capacity was about 50% more than at the end of 1999.

15.3.3 Contribution to National Energy Demand

In 1999, Italy's overall electricity demand was nearly 286 TWh (including transmission and distribution losses) for the whole electricity sector. Of this, about 42 TWh was imported from neighboring countries. The net electric energy produced in Italy was 253 TWh (the Enel Group produced nearly 71% of this). The energy supplied to end users totaled 267 TWh.

Italy's net production from renewable sources in 1999—including large and small hydro, geothermal, wind, and photovoltaic plants—was as much as 22% of total net production. Installed net capacity totaled about 73.8 GW (of which 20.4 GW were hydro and 52.5 GW were thermal plants) as of the end of 1999. Of this, 57.5 GW (of which 16.8 GW were hydro and 40 GW were thermal plants) belonged to the Enel Group. Despite the growing rate in the dissemination of wind energy plants, the contribution to national energy demand remains very small, both in terms of energy production and power capacity.

15.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

With the completion of the initiatives already authorized under CIP Provision No. 6/92, foreseen by 2002, the new instrument constituting the main measure in support of renewables is the Legislative Decree No. 79/99.

15.4.1 Main Support Initiatives and Market Stimulation Incentives

According to Article 11 of Decree 79/99, the transmission system operator (GRTN) must assure priority in dispatching to plants fed by renewable energy sources. In addition, starting from 1 January 2002, there is an obligation to introduce into the public electricity network, or to acquire fully or partially, a given percentage of electric energy from renewable sources, for all the subjects producing or importing electric energy from conventional sources.

The above percentage is initially fixed at 2% of the conventional energy that exceeds 100 GWh per year and must be exclusively assured through new or repowered plants entered in operation after 1 April 1999 (for repowered plants, only the energy produced by the added capacity can be taken into account). Cogeneration (CHP), auxiliary service consumption, and exports of energy are excluded from this computation.

A specific decree devoted to putting into effect the rules set by Article 11 of Decree No. 79/99, regarding renewable energy sources, was issued on 11 November 1999. This decree states precisely the meaning of "plants that have entered into operation after 1 April 1999." In this category, the following plant types are included.

— New plants.

— Plants existing for at least five years, in which measures to increase energy production have been taken. In this case, only the additional production is considered.

— Plants running for at least ten years which have been rebuilt, in the sense that the main components have been substituted. For instance, a wind plant is considered rebuilt when the wind turbine rotor, generator, and gearbox have been replaced.

— Plants brought into use again, after a stop period lasting at least five years.

— Plants where renewable and non-renewable fuels are used, for production using renewable fuels.

Renewable energy plants can also be located in foreign countries, but these countries must have in force similar tools to support renewables and respect the reciprocity principle.

Electricity produced by renewable energy sources having a value equal to or multiple of 100 MWh is labeled with green certificates issued by the transmission system operator (GRTN). Green certificates are tradable.

Beginning in 2003, producers or importers who have to fulfil the 2% quota are obligated to hand over to GRTN the green certificates they got in the previous year, which are annulled. Another important aspect of green certificates concerns their compatibility with other incentives. In other words, for a green energy producer it will be possible to combine green certificates with any kind of subsidy, except the premium energy buy-back prices of CIP 6/92.

GRTN itself will own the certificates for the electricity produced by renewable plants constructed after 1 April 1999 and authorized under the old regime (CIP 6/92, fixed buy-back prices). However, when selling its own certificates, GRTN must apply a fixed price, calculated as the difference between the average cost of purchasing that energy (under the old promoting scheme) and the electricity market price.

A small part of 1999 carbon tax revenues, introduced in Italy that year, were devoted to the production of energy from renewable sources. According to Law No. 112/98—which assigns new duties to Regions, Provinces, and Communes, particularly in the new energy sector—the majority of this new instrument of financial support has been attributed to these local bodies.

Another financial tool, covering the Southern Italian Regions, is constituted by their regional plans, called PORs (Piani Operativi Regionali). Through this important financial instrument, several wind projects will obtain subsidies, in variable percentages of eligible cost. PORs are funded both with national (state, regional) and European resources, the latter through the FESR Structural Funds.

15.4.2 Unit Cost Reduction

Detailed figures from main developers are not available for unit cost reduction, but it is possible to estimate a cost reduction for wind turbines based on some information from manufacturers and developers.

In 1995, the turbine cost was around 1.68 million/kW ITL. In 2000, this cost decreased to nearly 1.43 million/kW ITL. The balance-of-system cost fell, in the same period, from 0.52 million/kW ITL to 0.46 million/kW ITL, taking the total cost per kW installed from 2.2 million ITL down to 1.9 million ITL.

54.5 DEPLOYMENT AND CONSTRAINTS

15.5.1 Wind Turbines Deployed

As said previously, only two types of wind turbines were installed in 2000 in Italy: 85 Enercon 40 and 151 Vestas V-42 and V-47, with a unit power ranging between 600 and 660 kW. Turbine size has been increasing rather slowly due to the complex topography of sites, which brings about transport problems and has a considerable visual impact on the top of the mountain ranges, where turbines are generally located.

Regarding the sites that have been chosen for further wind installations planned in 2000 and 2001, several of them are still in the Campania and Apulia regions quite close to existing installations, while the others are scattered along the Apennines range in a northwest and southeast direction. In 2001, according to the plans of IVPC 4 and ERGA, the bigger islands of Sardinia and Sicily will also be affected, with wind installations for a total capacity of approximately 80 MW.

IVPC 4, presently 50% owned by IVPC Energy 4 B.V. and 50% by Edison Mission Wind Power Italy B.V., was incorporated in 1995 with the aim of locating and developing suitable sites for the construction of wind farms. In 1999, a corporate merger was planned between IVPC 4 and IVPC Puglia, which was 50% owned by IVPC Energy 4 B.V. and 50% by IVPC Energy 5 B.V. After that, IVPC 4 placed orders to Italian Wind Technology (IWT)—which is now to become completely owned by Vestas—for a total of 437 turbines and a related power of 283 MW. In March 2000, the company completed its project financing, approved by Mediocredito Centrale, lead arranger of the financing operation, with the English National Westminster Bank Plc and the Dutch Fortis Bank as arrangers.

Edison Energie Speciali has completed some wind farms by putting into service a first set of turbines supplied by Enercon, and taking advantage of the good climatic conditions in Southern Italy in the last month of the year. In addition, Edison Energie Speciali plans to build the remaining wind farms (around 80 MW), authorized under the CIP 6/92, during 2001.

Developers Lucky Wind and Filippo Sanseverino plan to produce more electricity by wind. Lucky Wind, through the enlargement of its wind farm at Accadia, is adding six IWT V-47 turbines, which equates to 3.96 MW and brings the plant total to 14.76 MW. Filippo Sanseverino will install two IWT machines of the same size at Frigento and, by the end of 2001, anticipates installing another 20 MW of IWT V-47 machines very close to its previous wind farm at Castelfranco in Miscano.

Within the Enel Group (the utility Enel has been turned into a holding company that controls several companies), ERGA operates geothermal, small hydro, wind, and photovoltaic power plants totaling 1,600 MW of capacity. In the wind sector, where its online capacity was formerly 25 MW, ERGA launched a construction program in 2000 aimed at reaching 350 MW by 2003 and involving an investment of 600 billion ITL. When online, this capacity is expected to yield 780 Gwh/year.

At the end of 2000, 3 ERGA wind farms totaling 22 MW were under construction in

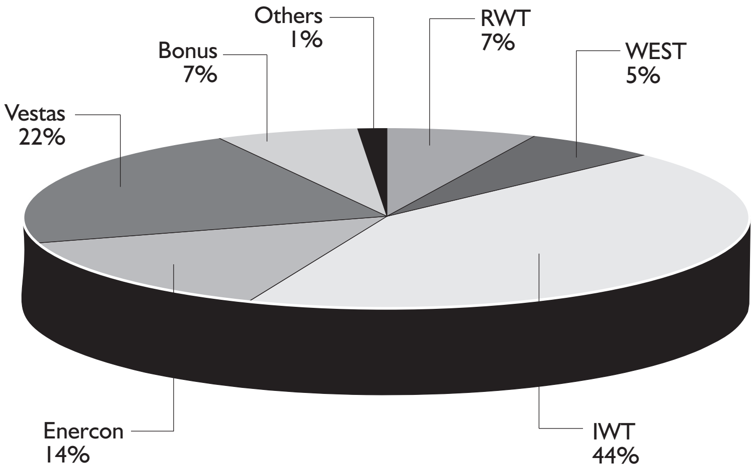


Figure 15.2 Market shares of wind turbine manufacturers at the end of 2000 (as a percentage of total on-line capacity)

Sicily, at the sites of Caltabellotta (ten 750-kW NEG Micon machines), Carlentini (11 660-kW Vestas machines) and Sclafani Bagni (11 660-kW Vestas machines). These machines should go into operation in 2001. An overall additional capacity of 30 MW is also planned at these sites shortly after, possibly with larger machines. Work was also started at Campolieto in Molise, Central Italy, on a 3-MW wind farm (four 750-kW NEG Micon units). Work on other plants totaling 61 MW should start in 2001. The sites are being chosen in Sardinia and Southern Italy.

Meanwhile, ERGA has also been striving to enlarge its site portfolio by conducting new wind surveys and has also been seeking agreements with other operators to speed up wind farm development.

Figures 15.2 and 15.3, respectively, show how manufacturers and wind producers are represented in the Italian market. Figures 15.4, 15.5, and 15.6 show three wind farms recently installed in the Campania region by Edison Energie Speciali, IVPC 4, and Filippo Sanseverino.

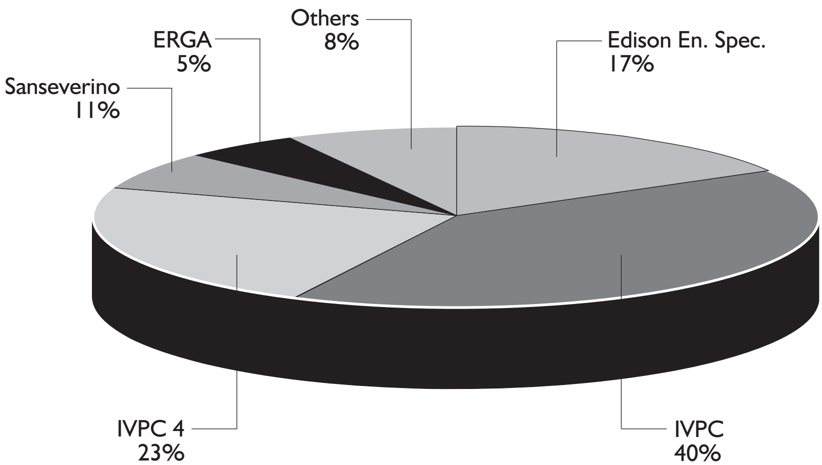


Figure 15.3 Contribution by electricity producers from wind at the end of 2000 (as a percentage of total on-line capacity)

Figure 15.4 Edison Energie Speciali 10 MW windfarm at S. Giorgio la Molara (20 wind turbines Enercon 500 kW)

15.5.2 Operational Experience

Italy's electric energy production from wind plants totaled more than 500 GWh in 2000. In the Apulia and Campania area, where more than 80% of Italian wind farms are located, machine availability was around 99%, and the average load factor was around 0.25 (up to 0.30 at some plants).

15.5.3 Main Constraints on Market Development

Bureaucracy, visual impact, and weakness of the electricity grid are the most common causes of difficulties that wind developers have to deal with, particularly at the local level, where sometimes a minority can create problems generally requiring significant time to be solved. ENEA is searching to overcome the shortage of proper information on the matter by giving at any time accurate advice about wind technology and the advantages and disadvantages connected to a wider dissemination of wind energy

Figure 15.5 IVPC 4 27 MW windfarm at Bisaccia (12 wind turbines Vestas IWT 600 kW and 30 IWT 66 kW)

Figure 15.6 Filippo Sanseverino windfarm at Castelfanco in Miscano (2 wind turbines Vestas 600 kW and 48 Bonus 600 kW)

in the country. Moreover, the general rules to be observed at the planning stage of wind installations, in order to achieve agreement from the local populations, are discussed in meetings held by central and local authorities.

So far, no problem has arisen with birds hitting wind turbines.

15.6 ECONOMICS

15.6.1 Trends in Investment

In 2000, the wind plant cost was around 1.9 million ITL/kW; therefore, in the same year, the total invested capital on wind energy plants in Italy was about 280 billion ITL.

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

In regard to energy cost, the selling price of electricity (net price without taxes) varies from 100.00 ITL/kWh to 300.00 ITL/kWh for typical domestic customers. For industrial consumers, this cost varies from 100.00 ITL/kWh to 230 ITL/kWh. For wind energy, 2000 buy-back prices fixed by CIP 6/92 were 198.30 ITL/kWh for the first eight years of the plant operation and 95.20 ITL/kWh for the remaining lifetime.

As mentioned, so far the support initiatives on renewables, and in particular on wind energy, have been based on CIP 6/92 buy-back prices. In the future, because of the new legislative framework, the support system will change through the introduction of the green certificate mechanism.

15.7 INDUSTRY

15.7.1 Manufacturing

In spite of the internal market development, the Italian wind industry has suffered a profound crisis and now only the company IWT, which will shortly become a 100%-owned subsidiary of Vestas, is manufacturing medium-sized wind turbines.

IWT was set up in 1998 as a joint venture between the Danish Vestas and the Italian WEST. In the first two years of activity, the company made 150 medium-sized, 600-kW turbines. At the end of 2000, a total of 170 660-kW machines had been delivered. Most of these machines were manufactured and installed in the second part of the year 2000 after a big contract was signed between IVPC and IWT.

Regarding the fully national industry, RWT and WEST, which had previously been engaged in the construction of medium-sized turbines (with around 100 single-bladed, 350-kW machines and 70 two-bladed, 320-kW units, respectively), are now only involved in the maintenance of existing machines and no further activities in the manufacturing field are anticipated.

15.7.2 Industry Development and Structure

IWT is actively working on the production of medium-sized wind turbines in Italy in its factory in Taranto, where blades and nacelle covers are made, and 660-kW Vestas V-47 wind turbines are currently assembled. IWT is building six machines per week, most of which are to be set up at IVPC's wind sites.

15.8 GOVERNMENT SPONSORED R, D&D

15.8.1 Priorities

The total R, D&D expenditure borne by the Italian Government during 2000 was around 2 billion ITL. Activities in the wind R, D&D sector in Italy are carried out by three entities: ENEA, CESI of the Enel Group, and a few universities.

ENEA

In the framework of an Italian-French joint project, research has been undertaken with the aim of developing wind power exploitation in the inner Antarctica environment and installing a new, small wind turbine in order to supply clean energy to the Dome-C Concordia station.

Interest in zero-emission power sources for the supply of electricity to remote installations and stations in Antarctica is increasing among researchers and bodies involved in activities in this type of environment.

For this purpose, a special 5-kW wind turbine has been developed. The main characteristic of this turbine is a directly driven, permanent magnet generator. Moreover, some components have been tested and modified to face the extremely low temperatures expected.

The wind turbine was tested for one year at ENEA's Casaccia test field and was finally installed at Dome-C during the 1999-2000 Antarctic expedition.

CESI

On 1 January 2000, Enel's R&D Department merged into CESI S.p.A. (55% owned by Enel), which has long been a market leader in the testing and certification of electro-mechanical equipment and electrical power system studies. CESI has thus enlarged its field of activity into research formerly carried out by Enel in the field of generation, transmission, distribution, end uses, environment, and renewable energy sources.

The wind energy expertise acquired now enables CESI to provide third parties with services and consultancy, and to perform some further research on specific topics in the interest of Italy's electricity sector, under contract to the Ministry of Industry. The topics currently include the following.

- Completion of the assessment of Italy's wind energy potential, based on results already gained in past Enel surveys. The work consists of general analysis through mathematical models of areas not yet studied beforehand (such as Northern Italy), gathering and analysis of existing wind data, and additional in-field measurements by means of some new wind stations suitably scattered in several parts of Italy. The latter are aimed at validating the results of model analysis as well as at establishing correlations with other stations for which historical data are available; some evaluation of off-shore wind potential is also planned.

- Evaluation of the cost-effectiveness and feasibility of exploiting wind sites in mountain areas above the altitudes so far involved in Italy (namely above 1000 m a.s.l.), and assessment of wind turbine technology with special attention to machines to be operated in harsh environments, such as high-altitude mountain sites and offshore areas.
- Further investigation of some aspects of compatibility of wind plants with the environment (noise, visual impact, etc.).

Universities

Regarding the involvement of Italian universities, some research activities are being carried out by Rome University in the field of axial flux permanent magnet generators, while Genoa and Bologna Universities are still engaged in the definition of local wind maps and in the assessment of wind resources including offshore applications, respectively.

15.8.2 Offshore Siting

ENEA is involved in the Offshore Wind Energy in Europe (OWEE) contract of the European Commission for developing state-of-the-art R&D activities in the field. ENEA is also engaged in a research activity within a European project (WEMSAR), jointly with Denmark and Norway (coordinated by the Nansen Institute), for evaluating and exploiting wind resources for offshore applications. A particular methodology, taking into account the potential offered by satellites, is under development. The Italian anemometer stations that will be utilized in this activity are located very close to the small islands of Pianosa and La Maddalena (three years of offshore wind data is available).

N.B. Costs and prices have been expressed in Italian Lire (ITL): 1 Euro = 1936.27 ITL

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

CHAPTER 16

16.1 INTRODUCTION

During 2000, wind power capacity in Japan increased 172%. After the installation of a 20-MW wind farm in December 1999, three 20 to 30-MW-class wind farms were also installed. The cumulative wind power capacity in Japan reached 121 MW at the end of 2000. The Government conducts research programs in order to develop applied wind energy technology and wind turbines that are suitable for Japanese environmental conditions.

16.2 NATIONAL POLICY

16.2.1 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% by 2008 to 2012 compared to the 1990 level. In September 1998, the Government adopted a new energy supply plan to stabilize CO_2 emissions by 2010. In the stimulated case, the percentage of petroleum among primary energy resources will be reduced from 55.2% (1996 level) to 47.2% in 2010, while the percentage of new energy resources will be increased from 1.1% to 3.1%. The Ministry of International Trade and Industry (MITI) projected that the cumulative capacity will reach 300 MW by 2010; 1,060 MW by 2020; and 2,120 MW by 2030. This national target of 300 MW of capacity from wind is expected to contribute 5.3% of total new energy resources.

16.2.2 Progress Toward National Targets

In order to attain the national target of 300 MW from wind energy set in the latest Primary Energy Supply Plan, the New Energy and Industrial Technology Development Organization (NEDO) has been conducting a subsidy program since 1995, as a part of MITI's introduction and dissemination program. 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. These activities are encouraging local governments and private companies to install wind turbine generators, and are motivating development of large-scale wind farms. As a result, the trend of wind energy development has been accelerated rapidly and the national target of 300 MW by 2010 is likely to be attained in a couple of years.

16.3 COMMERCIAL IMPLEMENTATION

16.3.1 Installed Capacity

The cumulative wind power capacity has been increasing dramatically due to the national subsidy programs and the surplus electricity purchase system. Total wind power capacity in Japan reached 121.1 MW in 2000. During 2000, new wind generating capacity of 50.5 MW was added with 132 units newly installed. Figure 16.1 shows the history of wind turbine development in Japan. Figure 16.2 shows a view of the Tomnamae Wind Farm developed by Electric Power Development Company.

16.3.2 Rates and Trends in Deployment

Cumulative wind power capacity in Japan has increased from 70.6 MW at the end of 1999 to 121.1 MW at the end of 2000. This is an increase of 172%. The average capacity of a new generating unit has also increased from 386 kW in 1999 to 518 kW in 2000. This trend is supported by the Governmental subsidy programs, such as the Field Test Program begun in 1995 and the New Energy Business Support Program begun in 1997. The private Long-Term Electricity Purchase Contract Menu for new energies offered

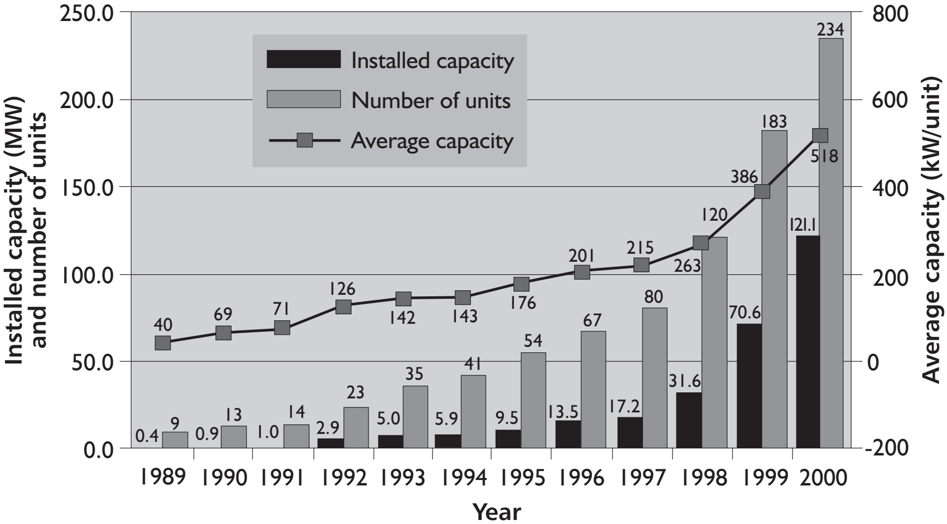


Figure 16.1 Time history of installed capacity of wind turbines in Japan

by utilities in 1998 has also stimulated wind power business.

16.3.3 Contribution to National Energy Demand

The contribution of wind power to national energy demand was 76 GWh in 1999. According to a national projection, 300 MW of wind power capacity is equivalent to120 ML of oil, the contribution of which to the national primary energy resources is 0.02%. (Wind Energy/New Energy = 120 ML/19100 ML and New Energy/Total Primary Energy = 3.1%.)

Figure 16.2 Tomamae Wind Farm developed by Electric Power Development Company

16.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

16.4.1 Main Support Initiatives and Market Stimulation Incentives

NEDO has been conducting the following three subsidy projects as a part of MITI's introduction and dissemination program. In June 1997, the Law on Special Measures for Promotion of Utilization of New Energy (New Energy Law) was enacted, which provided the initiative for wind energy businesses in Japan. These projects are playing an important role for local governments' and private companies' construction of wind turbine generators, and motivating development of large-scale wind farms.

1. Field Test Program for developing wind turbines

   This program was started in 1995 to stimulate the introduction of wind energy plants into Japan. NEDO subsidizes the cost to 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

   Since 1998, this program has supported new energy projects developed by pioneering developers or public organizations. NEDO subsidizes costs up to 50% for the design and construction of wind power plants above 1,200 kW.

3. New Energy Business Support Program

   This program is for private wind farm developers and NEDO subsidizes costs up to 33% for each facility design and construction.

The results of these initiatives can be seen in Figure 16.1. The wind farm market has recently been very stimulated.

16.4.2 Unit Cost Reduction

More than 85% of installed wind turbines in Japan are imported from Europe. Therefore the unit cost itself is almost the same as in Europe. However, most wind power plants in Japan consist of one or only a few turbines which increases the unit cost. The more large-scale wind farms are developed, the less the plant cost will become. Although costs will come down for wind farms, the average unit cost is still high and subsidies are quite necessary to operate a commercial wind power plant.

16.4.3 Green Power Fund and Green Electricity Certification

Tokyo Electric Power Company (TEPCO) established a new "Green Power Fund" program in October 2000. The program is designed to foster wind power and solar photovoltaic generation facilities. People who wish to make a social contribution make donations to accelerate the promotion of natural energy. The Green Power Fund program is operated by a non-profit organization Greater-Kanto Industrial Advancement Centre (GIAC). A single donation is 500 Yen per month. A newly established company, Japan Natural Energy Company Lt. (JNE), started an entrustment business on natural energy generation in November 2000. The aim was to balance the extra cost needed for natural electricity generation by publishing Green Electricity Certificates.

16.5 DEPLOYMENT AND CONSTRAINTS

16.5.1 Wind Turbines Deployed

As shown in Figure 16.1, installed capacity increased 39 MW in 1999 and 50.5 MW in 2000. The average capacity per unit also increased to 518 kW in 2000, which is two times larger than in 1998, and three times larger than in 1995. Most wind turbines employed in Japan are Danish turbines, and more than 85% of all turbines are made in Europe. The only Japanese wind turbine manufacturer is Mitsubishi Heavy Industries (MHI). Ltd. The percentage of wind turbines sold in Japan by each manufacturer is illustrated in Figure 16.3. MHI is the fifth largest.

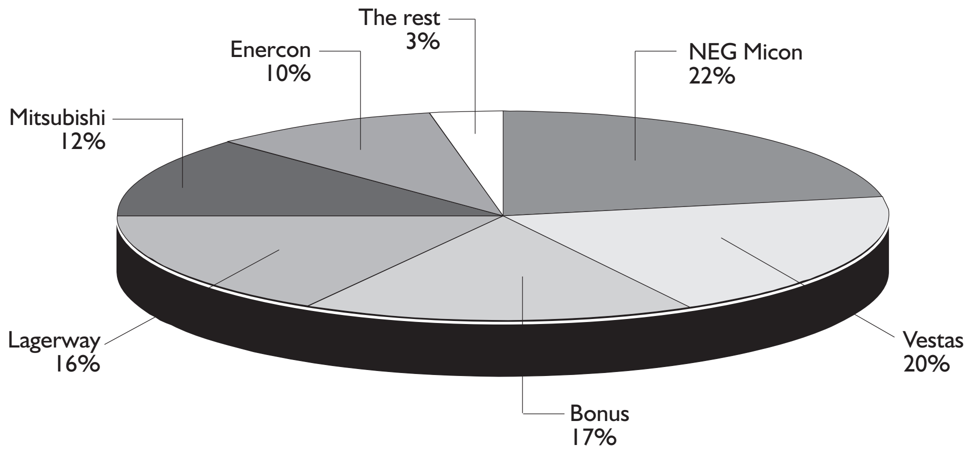


Figure 16.3 Share of wind turbine sales in Japan among manufacturers (December 2000)

16.5.2 Operational Experience

At good wind sites, the annual mean capacity factor is around 20% such as for Tappi Wind Park owned by Tohoku Electric Power Co. In the same wind farm, the factor varies with each unit from 15% to 33% because of the complex terrain. Operational and technical data are usually not published, especially for large commercial plants. However, the most common technical problems in Japan are lightning strikes, typhoon attacks, and power quality.

16.5.3 Main Constraints on Market Development

Generally, there are no severe objections from citizens about wind turbines harming birds, causing noise, or having visual impact. Power quality is one of the key issues, because most promising wind sites are located in weak grid regions of Japan. In Hokkaido, where largest wind farms have been erected very rapidly, the electric power company limited development to 150 MW within his grid region. To help ease this problem, NEDO has started investigating power stabilization techniques and battery-back-up systems.

The problem of complex terrain affects both the mechanical strength and electrical quality due to the gusty and turbulent wind. The complex terrain also increases the cost of transportation, erection, and grid-connection. These issues must be solved, or they will present a huge barrier to the market.

16.6 ECONOMICS

As large scale wind power plants of 20 to 30 MW are developed, the economics are getting more and more competitive.

16.6.1 Trends in Investment

After installation of a 20-MW wind plant in October 2000, a 30-MW wind plant was just recently installed. Another eight large wind plants over 10 MW are planned within the next few years.

16.6.2 Trends in Unit Cost of Generation and Buy-Back Prices

Installation cost is decreasing as the number of large-scale wind power plants increases. The cost differs depending on wind conditions and plant size. At a site with 6 m/s of annual mean wind speed, the installation cost is 300,000 Yen/kW for small wind turbines (up to 100 kW), 130,000 to 200,000 Yen/kW for medium size wind turbines (100 to 500 kW), and 130,000—200,000 Yen/kW for large wind turbines (above 1,000 kW). Because more than 85% of the wind turbines installed in Japan are made in Europe, the unit cost is the same as in Europe. However, due to other external conditions, cost of energy

(COE) is more expensive than in Europe. One study compared the costs between Europe and Japan. For a 20-MW wind farm of 600-kW turbines, the installation cost is 130,000 Yen/kW in Europe and 180,000 Yen/kW in Japan, while the COE is 6 Yen/kWh in Europe and 8 to 9 Yen/kWh in Japan.

Electric power companies set their own purchase price menus. They purchase wind electricity at the price of 11.5 yen/kWh on average with a 17-year contract period. Although the average purchase price is high, the balance is hard to attain without NEDO's subsidies.

16.7 INDUSTRY

16.7.1 Manufacturing

There are many types of wind turbines supplied by many manufacturers around the world. Mitsubishi Heavy Industries Ltd. (MHI) is the only Japanese manufacture that supplies middle to large wind turbines. Most conventional wind turbines are two-speed induction generators of 300 kW, 600 kW, and 1,000 kW. MHI is also developing variable speed synchronous wind turbines of 300 kW, 600 kW, and 2,000 kW. In all, MHI had sold 1,121 units with generating capacity of 397 MW by November 2000.

Fuji Heavy Industries Ltd. (FHI) is a new wind turbine manufacturer. FHI is developing 20-kW-class rotors in cooperation with the Mechanical Engineering Laboratory (MEL) of AIST, MITI, a 100-KW wind turbine as a national project, and a 40-kW wind turbine.

16.7.2 Industry Development and Structure

The market shares of manufacturers were shown in Figure 16.3. The major types of large wind turbines installed are Neg-Micon 400 to 750 kW, Vestas 225 to 1650 kW, Bonus 1,000 kW, Lagerway 600 to 750 kW, MHI 300 to 1,000 kW, Enercon 230 to 1,500 kW, NORDEX 600 to 1,300 kW, Jacobs 500 kW and DeWind 490 kW.

16.7.3 Export Potential

Mitsubishi Heavy Industries, Ltd is marketing wind turbines all over the world, such as in the United States (California, Hawaii, Wyoming), the United Kingdom (Wales), Portugal, India, Mexico, and Germany.

16.8 GOVERNMENT SPONSORED R, D&D

16.8.1 Priorities

Since 1978, after the oil crises, the Government has operated its wind energy R&D program to improve energy security. This is part of a general R&D Program for renewable energy called the "New Sunshine Project" and is directed by the New Sunshine Program Promotion Headquarters (NSS-HQ), the Agency of Industrial Science and Technology (AIST), and MITI. After concern about global warming was raised, the objective of the New Sunshine Project became to develop innovative technology to create sustainable growth while solving both energy and environmental issues. The national wind energy activities in Japan are shown in Table 16.1.

1. New Sunshine Project: Research & Development, Demonstration

   In 1999, Japan started a new R&D, D program as described in next section.

2. Power Stabilization from Wind Turbines

   Two new research projects were under taken to develop techniques to stabilize the output power from wind turbines in 2000 by NEDO.

3. Promotion of Introduction with Subsidies

   NEDO's Field Test Program, the New Energy Local Introduction Supporting Program and New Energy Business Supporting Program have played an

Table 16.1 National activities on wind energy in Japan

NATIONAL ACTIVITIES	PERIOD	ORGANIZATION/INSTITUTE
New Sunshine Project (R,D&D)	1978–	NSS-HQ
1. Wind resources measurement	1990-1993	NEDO
2. R&D of LS-WTGS (500 kw) on Tappe Cape	1991-1998	NEDO/MHI/Tohoku EPC
3. Demonstration of a MW-class wind farm on Miyako Island	1990-1997	NEDO/Okinawa EPC
4. Generic, innovative R&D	1978–	MEL
5. Advanced WTGSs for remote islands	1999-2003	NEDO
6. Local area wind energy prediction model	1999-2002	NEDO
New Research		
1. Research on stabilization of output power from WTGSs	2000	NEDO
2. Research on stabilization of output power from a WTGSs with storage batteries	2000	NEDO
Promotion of Introduction	1992-	MITI/NEDO
1. Field test program		
2. New energy business support		
Standard: IEC, ISO, JIS	1988-	MITI/JEMA/MEL/Industries/etc.
IEA wind R&D	2000-	MEL/MU

important role in promoting the introduction of wind turbines among the private sector as well as with local governments.

4. Integration of Japanese Industrial Standards (JIS) and IEC Standards

   The national programs include cooper ation in IEC Standard activities for wind energy. MITI is also promoting the policy to keep international consistency in the standard. Therefore, JIS for wind turbine generator systems are being developed. In 1999, two JIS on wind energy conversion systems were published, and in 2000 three more JIS were prepared.

5. International Energy Agency (IEA) R&D Wind

   NEDO, MEL, Mie University (MU), and the Japan Electrical Manufacturers' Association (JEMA) participate in international activities by contributing technical data to IEA R&D Wind's tasks XI, XV, XVII and XVIII.

6. Funding Levels

Table 16.2 shows the history of the budget of MITI for various wind energy activities.

16.8.2 New R, D&D Developments

Since 1999, MITI has conducted new R&D programs in order to meet the national target of 300 MW of wind power by 2010. Since the installed wind energy capacity is estimated to exceed 2,000 MW by 2030, other research is now underway on power quality, battery-supported systems, and offshore plants. These projects began in 2000 to explore these inevitable issues for Japan's environmental conditions.

1. Advanced wind turbines for remote islands

   This project is developing a prototype 100-kW-class wind turbine to withstand conditions such as high wind speed exceeding 80m/s (typhoon conditions). This turbine must be erected with no construction machines like large cranes or trailers. The turbine will be installed at sites like remote islands and hilly areas where the wind is turbulent, accessibility is poor, and there are no wide roads or

Table 16.2 Budget for national wind energy projects in MJPY

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NSS project (R,D&D)	540	981	978	744	634	606	554	477	414	516
NEDO subsidies (field test)	–	–	–	–	80	320	460	1529	1739	1620
NEDO subsidies (business support)	–	–	–	–	–	–	430	1670	3320	5490
NEDO R&D on power stabilization	–	–	–	–	–	–	–	–	–	1730
Total	540	981	978	744	714	926	1444	3676	5473	9356
(R&D)	540	981	978	744	634	606	554	477	414	2246
(Subsidy)					80	320	890	3199	5059	7110

large harbors. Figure 16.4 shows a conceptual design of such a turbine that can be installed by gin pole and winch.

2. Local area wind energy prediction model

   This project is developing a computa tional fluid dynamics (CFD) model that predicts wind and wind power generation quickly and accurately and is applicable to Japan's complex terrain and turbulent wind conditions. Figure 16.5 shows an illustration of this CFD model. The data base will be provided for the public so that the wind condition of any site can be found by way of a computer.

3. Research on stabilization of output from wind turbines

   This program studies the state-of-the-art technology for the leveling effect of multiple wind turbines and collects practical data on power quality in relation to fluctuating wind conditions at specific sites.

4. Research on stabilization of output from wind turbines with storage batteries

   This program examines the effect of a battery-supported system with, for example, NAS or Redox flow on the stabilization of the output from wind turbines.

5. Investigation on offshore technology

   Japan is surrounded by ocean and there is a huge wind energy potential offshore. However, the sea-bed is very steep and

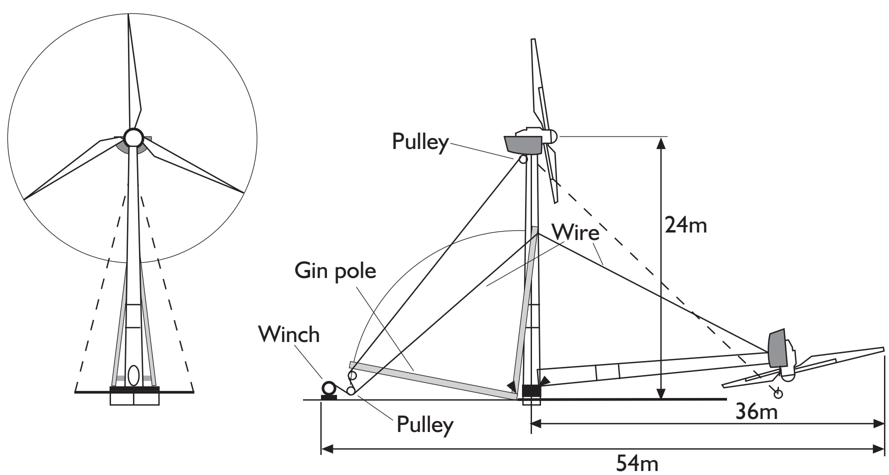


Figure 16.4 A conceptual turbine for remote islands

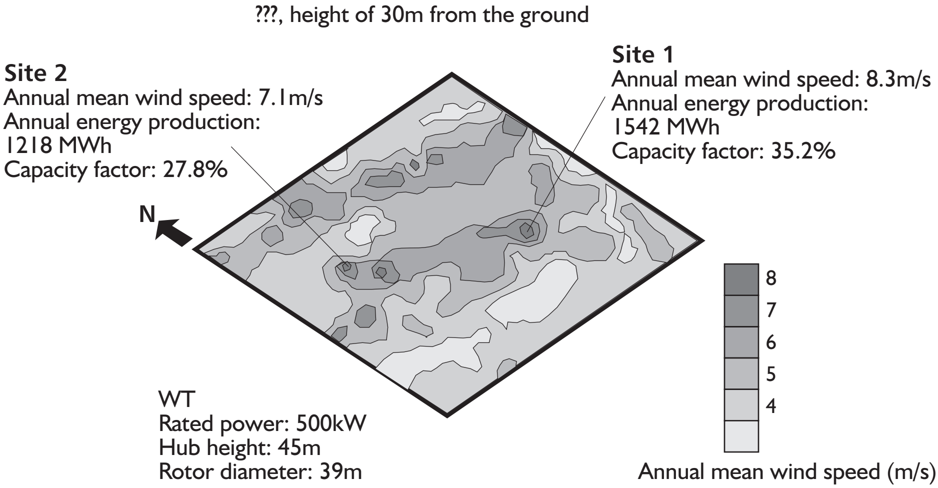


Figure 16.5 Local area wind energy prediction model

there may be technical, legal, and environmental issues to resolve. NEDO started technical investigations to assess the technical potential of offshore technology. Figure 16.6 shows an image of offshore technology under discussion.

6. Wind-Solar hybrid system

   Besides the above programs, NEDO has been conducting an international R&D project with Myanmar since 1999 which aims to develop a wind-solar hybrid system with demand control.

*List of abbreviations

NSS H.Q.=New Sunshine Program Promotion Headquarters in AIST, MITI-
AIST=Agency of Industrial Science and Technology
MEL=Mechanical Engineering Laboratory of AIST, MITI
MU=Mie University
JEMA=The Japan Electrical Manufacturers' Association
MHI=Mitsubishi Heavy Industries Ltd.
FHI=Fuji Heavy Industries Ltd.
EPC=electric power Company
JIS=Japanese Industrial Standards
CFD= computational fluid dynamics

Author: Hikaru Matsumiya, Chief Researcher, Mechanical Engineering Lab., MITI, Japan

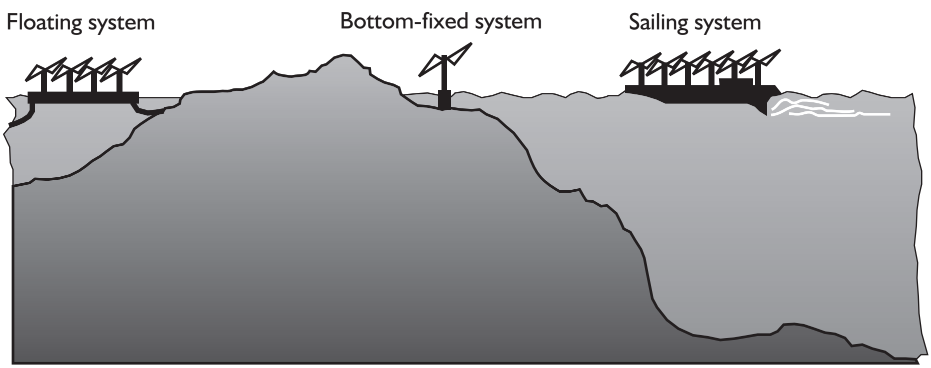


Figure 16.6 An image of offshore technology

CHAPTER 17

17.1 INTRODUCTION

Promoters of wind energy have pointed out that exploiting the main wind resource in Mexico could lead to the installation of 3,000 to 5,000 MW of wind power capacity. The major development of wind power in Mexico could take place at the south of the Tehuantepec Isthmus, in a 3,000 km^2 region known as La Ventosa (see Figure 17.1). Average annual wind speeds from 7 to 10 m/s, at 30 m above ground, have been measured in this region. It is estimated that up to 2,000 MW of wind power capacity could be installed there with technical and economic advantages.

17.2 NATIONAL POLICY

The Mexican energy policy on electricity is aimed at securing enough supply to allow expected economic development. According to official projections, from 2000 to 2009 the country is required to install around 26 GW of new generation capacity. Around 12 GW of the new capacity are already under construction or committed. The rest (around 14 GW) has been pointed out as an opportunity for private investment. It has been stated that from 2000 to 2009, most of the new capacity will be based on natural gas combined-cycle power stations, due to the low investment cost of this technology. However, projects may also be proposed based on different fuels or technologies (including renewable energy). Therefore, on the basis of sustainable development, it is expected that a fraction of the "non-committed" capacity be based on suitable wind power projects.

Up to now, the Mexican Government has not issued particular plans to incorporate a meaningful capacity of wind power into the national electric system. However, promoters of renewable energy have proposed to the New Mexican Government to consider wind power in the national energy mix and to establish adequate conditions to promote and support a prosperous wind power market. Some proposals have outlined that Mexico would be capable of installing at least 2,000 MW of wind power over one

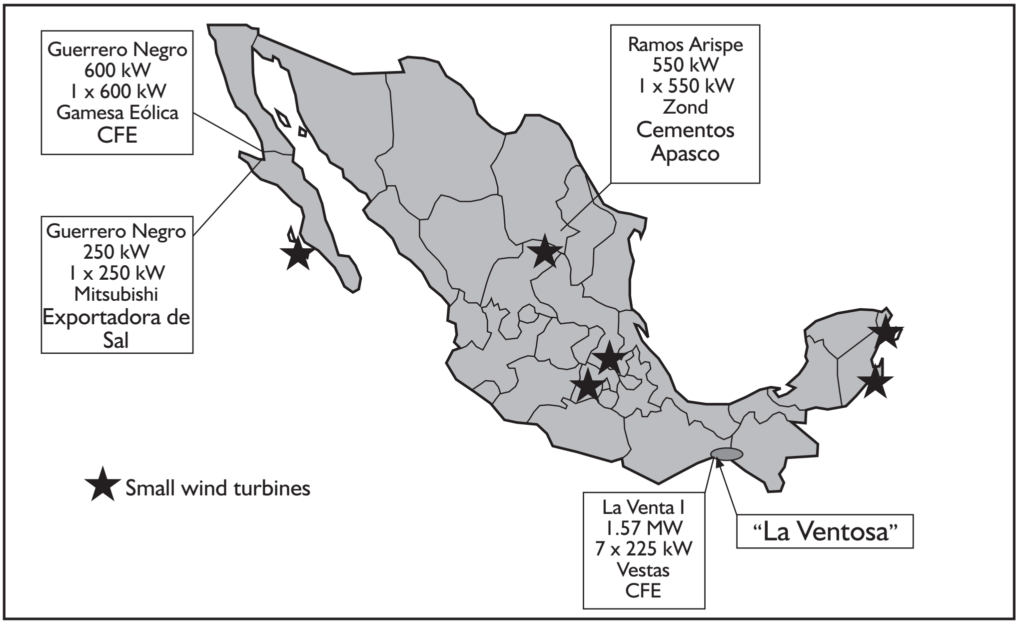


Figure 17.1 Distribution of wind turbine installations in Mexico

decade, after appropriate wind power market conditions are established.

17.2.1 Strategy

The Government of the State of Oaxaca is very interested in promoting the development of wind power in La Ventosa, on the basis of economic and social development. In October 2000, a Colloquium on Opportunities for the Development of Wind Power in La Ventosa, Oaxaca, was held in Oaxaca city. About 100 people attended the colloquium, including officials from the Ministry of Energy, the local Government, the National Commission for Energy Conservation, the Federal Electricity Commission, the Energy Regulatory Commission, the Advisory Council for the Promotion of Renewable Energy, the Electrical Research Institute, the National Solar Energy Association, universities, and national and foreign private companies.

The most important topics on opportunities and constraints for the implementation of wind power in Mexico were addressed. A number of private developers of wind power projects expounded several conditions required to get confidence for investing in wind power projects in Mexico. On the other hand, officials from the public sector outlined realistic possibilities in that direction.

Today, as a result of this colloquium, it is very clear that in Mexico the public and private sector are willing to undertake a meaningful development of wind power. Nevertheless, it was also evident that plausible actions have to be carried out in order to remove existing barriers and establish suitable wind power market conditions. To this end, it will be expected that during 2001, the Advisory Council for the Promotion of Renewable Energy, which integrates members from a number of both public and private entities, will come out with a realistic and acceptable proposal to the New Mexican Government.

17.2.2 Progress Towards National Targets

As mentioned above, a national target for the installation of wind power capacity has not been established yet. However, in order to develop specialized local capacity for supporting the different topics involved in the implementation of wind power (e.g., resource evaluation, pre-investment studies, regional planning, standardization, demonstration, and evaluation), the Electrical Research Institute (IIE)—which has the mission to promote and support technological innovation within the electrical sector—has been preparing a "full-scale" project proposal for the Global Environment Facility/United Nations Development Program (GEF-UNDP).

This project has been envisaged and planned as a national effort aimed at removing barriers for the implementation of wind energy in Mexico. Therefore, participation of a number of public institutions and private companies is anticipated. And evidently, the project will include a plan of action to assist the Advisory Council for the Promotion of Renewable Energy in the task of achieving the creation of a suitable wind energy market in Mexico.

Local officials from GEF-UNDP have examined the concept paper for the project, and after some recommendations, a final draft has been issued. Formal procedure to submit the project to GEF-UNDP could be underway by April 2001 (as long as required endorsement by the Mexican Government is granted). According to officials from GEF-UNDP, if the project is approved it would commence by mid 2002. In the meantime, efforts by wind energy promoters will continue, but these will be limited by the moderate budget available because of priorities in the public sector.

Table 17.1 Wind turbine installations in Mexico by the end of 2000

LOCATION	MANUFACTURER	WIND TURBINES (kW)	CAPACITY (MW)	COMMISSIONING DATE	OWNER*
Guerrero Negro, B.C.S	Mitsubishi	1 x 250	0.250	1985	(1)
La Venta, Oax.	Vestas	7 x 225	1.570	1994	CFE
Ramos Arispe, Coah.	Zond	1 x 550	0.550	1997	(2)
Guerrero Negro, B.C.S.	Gamesa Eolica	1 x 600	0.600	1998	CFE
Total		10	2.970		

* (1) Compañía Exportadora de Sal (salt producer); (2) Cementos Apasco (cement factory)

17.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

17.3.1 Installed Capacity

During 2000, additional wind power capacity was not connected to the national electrical system. The total installed capacity of wind turbines in Mexico remains around 3 MW. See Table 17.1 and Figure 17.1.

17.3.2 Rates and Trends in Development

Rate in wind power development is negligible. Construction of a 54-MW wind power station proposed by the Federal Electricity Commission in 1996 was postponed again. Another five projects, led by private companies, continue in the negotiation phase (see Table 17.2). The Energy Regulatory Commission has already issued permits to build four of these projects; nevertheless, construction of all these have been postponed again.

17.3.3 Contribution to National Energy Demand

Contribution from wind power generation to national energy demand is negligible. During 2000, total electricity sales accumulated 155 TWh. Wind power production was less than 10 GWh.

17.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

At present, wind power market stimulation instruments do not exist in Mexico. However, in late 2000, the Energy Regulatory Commission announced an initiative to improve regulations for renewable energy. Details of this initiative and the effect on economic feasibility of wind power projects have not been released yet. This information could be available by early 2001.

Table 17.2 Wind power plants under negotiation

	PROMOTER	LOCATION	CAPACITY (MW)
1	Federal Electricity Commission (CFE)	La Venta, Oax.	54.0
2	Cozumel 2000	Cozumel, Q. Roo.	30.0
3	Baja California 200	La Rumorosa, B.C.	60.5
4	Fuerza Eólica del Istmo	La Ventosa, Oax.	30.0
5	Electricidad del Sureste	La Mata, Oax.	27.0
		Total	201.5

17.5 DEPLOYMENT AND CONSTRAINTS

17.5.1 Wind Turbines Deployed

Additional wind turbines were not installed during 2000. The number of wind turbines installed in Mexico remains at 10 (see Table 17.1).

17.5.2 Operational Experience

During 2000, energy production from the La Venta wind power station was 6.77 GWh. The facility operated with an annual capacity factor of 49%. The overall availability was 94.5%, according to the general manager of "La Venta" Wind Power Station. Annual average wind speed, measured by the anemometers located on the nacelle of the wind turbines, was 9.6 m/s.

After 18 months of operation, the 600-kW wind turbine installed at Guerrero Negro performed with a capacity factor of 25%. Preliminary data reveal that energy production during 2000 was around 1.3 GWh. Annual average wind speed at this site is around 8 m/s at 50 m above ground.

Performance data from the 550-kW wind turbine installed at Ramos Arizpe, and from the 250-kW installed at Guerrero Negro, was not released.

17.5.3 Main Constraints on Market Development

The main constraints on wind-power market development in Mexico are the low cost of conventional electricity for the industrial sector, the large availability of fossil fuels, and the lack of a national program on wind power for sustainable development.

Preliminary accounts indicate that by the end of 2000, total installed capacity in Mexico for electricity generation was 39 GW. It was mixed as follows: thermoelectric (60.1%), hydro (26.5%), coal (7.1%), nuclear (3.8%), geothermal (2.3%), and wind (negligible).

17.6 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 during the day. Table 17.3 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 appropriate strategy for creating a convenient wind power market. At present, a special buy-back price for wind energy has not been set in Mexico.

17.7 INDUSTRY

Except for a small (5-kW) wind turbine manufacturer, there is no wind turbine manufacturing industry in Mexico. However, it is known that there is an increasing interest from private investors to establish wind turbine manufacturing joint ventures. According to a recent study by the IIE, several wind turbine components

Table 16.3 Average electricity prices in Mexico during 2000

SECTOR	AVERAGE PRICE (MEXICAN PESOS)
Industrial	0.5022
Agriculture	0.2859
Domestic	0.5556
Commercial	1.2960
Public service	1.0539

NOTES: a. Preliminary data
b. 1 Peso = 0.103627 USD (January 2001)

(e.g., towers, nacelle, electrical devices, cables, transformers, and others) could be manufactured in Mexico using existing infrastructure. It is expected that a meaningful level of activity in local integration of wind turbines could impel the deployment of wind energy in Mexico. During 1999, a Mexican company manufactured a number of 750-kW electric generators for a wind turbine manufacturer.

17.8 GOVERNMENT SPONSORED R, D&D

The La Venta wind power plant was the first demonstration project sponsored by the Mexican Government in 1994. Next was the 600-kW wind turbine installed at Guerrero Negro in 1998. The Federal Electric Commission operates both of these projects. During 2000, additional demonstration or research facilities were not installed.

References:

Documento de Prospectiva del Sector Eléctrico 2000-2009. Ministry of Energy

Hiriart Le Bert, Gerardo. México: Experiencia de la Comisión Federal de Electricidad en la Generación Eoloeléctrica. Presented during the "Colloquium on Opportunities for Wind Power Development at La Ventosa, Oaxaca". Oaxaca, Oax., October 2000.

Author: Marco A. Borja, Engineer, Mexico

CHAPTER 18

18.1 INTRODUCTION

In 2000, almost 40 MW of wind capacity was installed in the Netherlands. This is a continuation of the steady installation rate of 40 to 50 MW in the last 4 years. However, the maximum possible capacity on land is thought to be 1,500 MW. To reach the national target of 2,750 MW in 2020 it will be necessary to go offshore. In 2000, preparations for the necessary step to offshore were taken at the technical and administrative level.

18.2 NATIONAL POLICY

In the Third Energy Memorandum of 1995, the Dutch government sets down its CO_2-emission targets for the year 2020, aiming at an overall stabilization of CO_2 emission and fossil fuel use at the level of 1990. For wind energy, the target is in annual saving of fossil fuels of 12 petajoules in 2000 and 45 petajoules in 2020. To reach the target in 2000, a total installed capacity of about 750 MW, and in 2020, a total of 2,750 MW should be reached of which about 1,250 MW will be installed offshore.

18.2.1 Strategy

The strategy to reach the targets of the *Third Energy Memorandum* are set down in the action plan *Renewable Energy on the March* of March 1997 and in 1999 in the evaluative *Renewable Energy in Execution*. The recommended actions concern improvement of the price-performance ratio, removal of administrative bottlenecks, and stimulation of market introduction. The measures for wind energy were partly executed through the 1996-2000 TWIN-program, that supported R, D&D activities and the deployment campaign Room for Wind Energy. To stimulate the industry to develop innovative renewable energy options, the program Economy, Ecology, and Technology (EET) is carried out. To stimulate the market introduction, several tax incentives were introduced a.o. a steadily increasing eco tax. Special arrangements for renewable energy were provided in the Electricity Law. Also the Ministry of Economic Affairs promised to liberalize the green electricity market in 2001.

18.2.2 Progress Toward National Targets

The target of 750 MW has not been met as the installed capacity was 447 MW at the end of 2000. The main reasons for this delay are: the time consuming procedures to get building permits, including necessary policy changes in the municipalities, and the not in my backyard attitude. Due to these reasons, about 2/3 of all initiatives fail in an early stage. In hindsight this is not surprising for a country like the Netherlands with a population density of more than 380 people per square kilometer. However it is envisaged now that the target of 2,750 MW in 2020 can be met with proper provincial and municipal planning procedures in place and the possibilities of offshore installation.

18.3 COMMERCIAL IMPLEMENTATION OF WIND POWER IN 2000

18.3.1 Installed Wind Capacity

In 2000, a total of 48 turbines were installed with a capacity of 39.4 MW and nine turbines with a capacity of 1.5 MW were removed. This brings the total installed capacity at the end of 2000 to 447 MW with 1,297 turbines. The final numbers for 1999 show a total increase in operational capacity of 46 MW. This brought the total operational capacity by the end of 1999 to 409 MW with 1,258 wind turbines.

18.3.2 Rates and Trends in Deployment

Apart from the large installed capacity in 1995, due to the end of the 86-95 investment

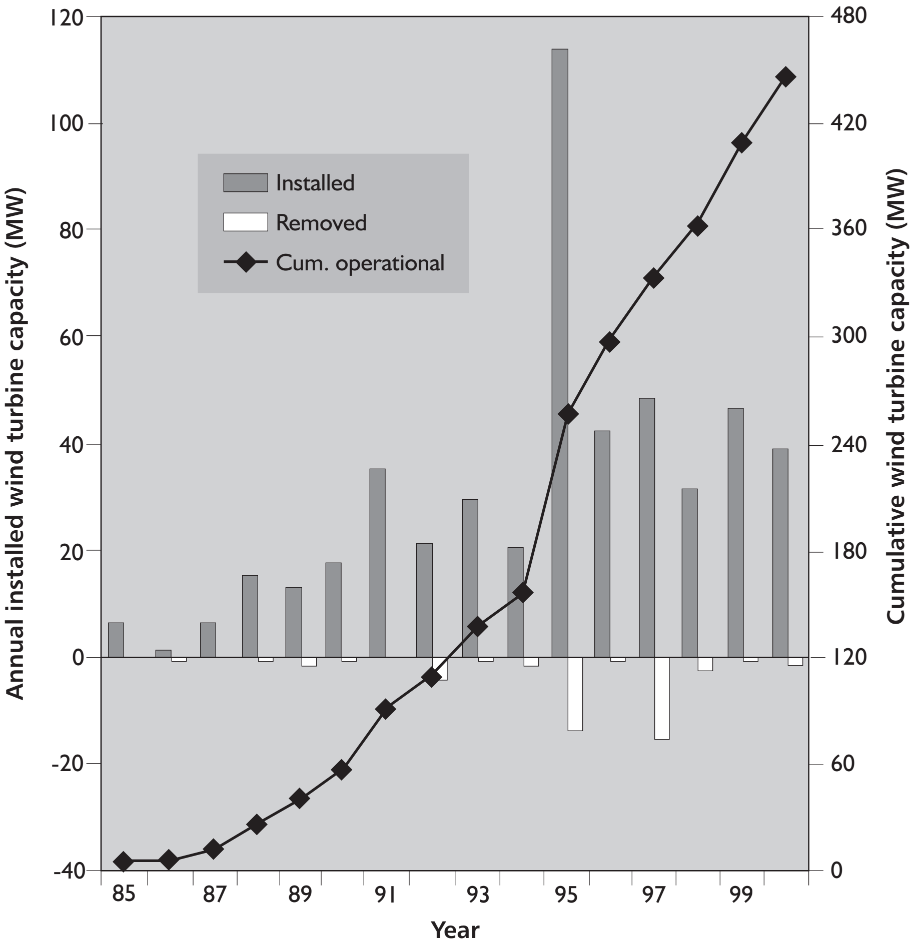


Figure 18.1 **Installed, removed, and operational wind capacity**

subsidy regime in that year, the installation rate has been about 40 to 50 MW per year in the last 4 years. The average installed capacity per turbine has been steadily rising from 150 kW in the mid-eighties to more than 800 kW in 2000. The average hub height rose from 28 to 55 m, and the installed swept area per unit of power form 1.7 to 2.5 m^2/kW

18.3.3 Contribution to National Energy Demand

Final numbers for 2000 are not available yet. The electricity generated by wind turbines in 2000 is estimated at 750 GWh. The Windex, which compares the annual wind speed in a certain year with the 30-years average wind speed set at 100%, is estimated at 92%. Total national electricity consumption in 1999 was 93,505 GWh. Production form renewables was 2,146 GWh or 2.3% of the total. Wind provided 0.7 % of total consumption. In 2000, we expect the national consumption to be 95,000 GWh and wind production to be 0.8% of that.

18.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

18.4.1 Main Support Initiatives and Market Stimulation Incentives

In order to stimulate market penetration of renewable energy, the Dutch government

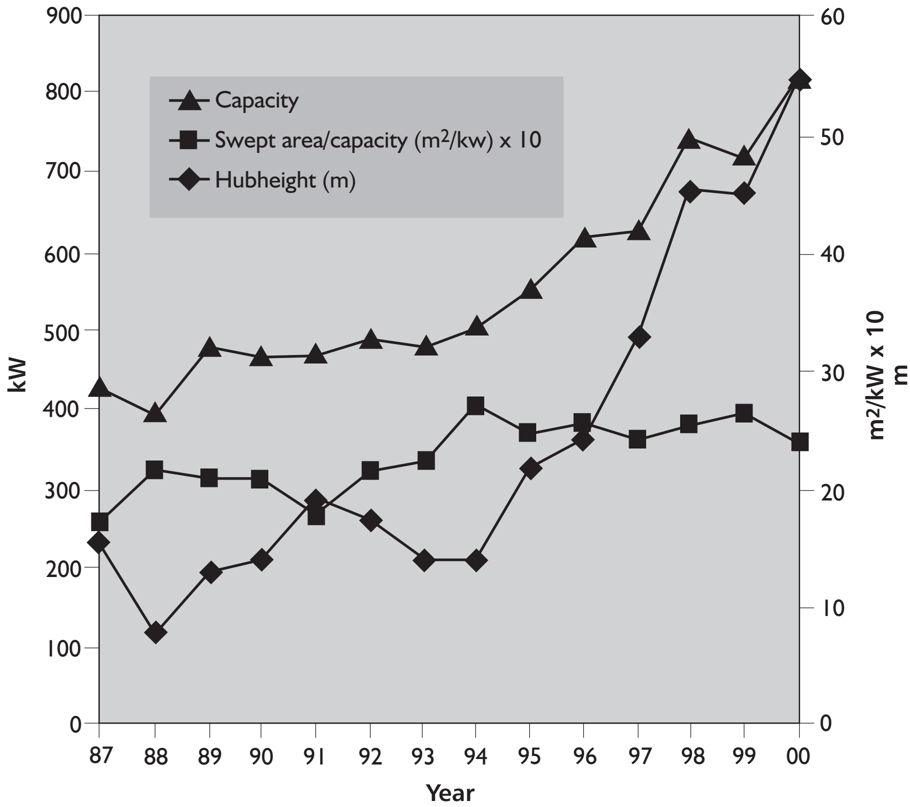


Figure 18.2 Average characteristics of installed turbines

has introduced different market stimulation instruments. A detailed account of these initiatives and incentives was given in the 1999 IEA Annual Report. Following is a summary and the main changes.

1. Tax on energy to stimulate energy efficiency.

   The Regulating Energy Tax, a kind of Eco tax, is a tax on energy carriers like natural gas and electricity (see Table 18.2). The consumer pays this tax via the energy bill to the energy company that pays it to the Ministry of Finance. Most of this tax is fed back to the taxpayer though a lower income tax. On the average it is budgetary neutral for the taxpayer, but on a national level it shifts the burden from labor to energy. The Eco tax can also be seen as the attribution of a value to the external costs of energy.

2. Tax incentives in order to reduce the capital costs of renewable energy installations.

   - Green Funds invest in green projects like wind turbine installations. Revenues like dividend or interest are exempted from income tax.
   - Energy Investment Deduction Scheme allows profit-making companies to deduct 40% of the investment in renewable energy installations from company profits in the year of invest ment.
   - Accelerated Depreciation on Environmental Investment Scheme allows free depreciation of renewable energy installations.

The effect of these tax incentives is that they lower the production costs of a kWh of electricity for the owner of a wind

Table 18.1 Electricity production, avoided fuel and emissions

Year	ESTIMATED ELECTRICITY GENERATED GWh	WINDEX %	PRIMARY ENERGY SAVINGS 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*	750	92	6.50

*2000 numbers are estimates

plant. The cumulative effect for a typical wind farm can be between 0.02 and 0.04 NLG/kWh.

3. Measures to create a reasonable pay back rate for renewable generators.

   The Ministry of Economic Affairs and the association of Dutch energy distribution companies EnergieNed agreed that energy companies pay for the avoided costs. They also took on the obligation that the remaining costs, to reach a reasonable pay back rate, is split equally between the utilities and the government.

   - The basic reimbursement for avoided fuel costs, which was around 0.07 NLG/kWh (0.032 Euro/kWh) in 2000.
   - The Feed back of Eco Tax. For each renewable kWh the generators get the Feed back Eco tax. (Table 18.2).
   - Greenlabels. Each utility committed itself to supply a 3.2% share of renew able electricity in its total output in the year 2000. In 2000, Greenlabels were traded at about 0.05 NLG/kWh (0.023 Euro/kWh). The volume reached about 1,500 GWh.

4. Stimulating market demand.

   In 2000, energy distribution companies offered their customers green electricity at a about the same price as grey electricity. In 2000, about 600 GWh of green electricity was sold to about 600,000 customers. Consumers that buy

Table 18.2 Eco tax

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

green electricity do not have to pay the Eco tax. The energy companies pay the Feed back Eco tax to the generator. The energy companies use the difference to buy green labels and invest in new capacity. Grey electricity for domestic purposes with an annual use of approx imately 3,000 kWh, was priced at between 0.25 and 0.30 NLG/kWh (0.11 to 0.13 Euro/kWh), including VAT and Eco tax. For industrial purposes prices vary between 0.11 and 0.13 NLG/kWh (0.05 to 0.06 Euro/kWh).

18.4.2 Unit Cost Reduction

There are no reliable statistical data for 2000. There are indications that the cost per installed kW is rising. This is due to increasing size of wind turbines to 1.5 MW and wind farms to 5 to 10 MW. Also project development costs are rising and the costs of electrical infrastructure are increasing, due to greater distances to the medium voltage grids. Indications are for turbines 1,900 NLG/kW, electrical infrastructure 200 NLG/kW, and project development 200 NLG/kW. We estimate the average for large and small projects at 2,100 NLG/kW installed and 1,800 NLG/kW for turbines.

18.5 DEPLOYMENT AND CHALLENGES

18.5.1 Wind Turbines Deployed

The majority of the installed wind turbines in 2000 are from Vestas followed by NEG-

Figure 18.3 Enercon 40 of 600 KW and 4 meter diameter near Gouda

Table 18.3 Distribution of new wind turbines by manufacturer

MANUFACTURER	TURBINES (Number)	INSTALLED MW	INSTALLED %	ROTOR AREA m^2
Vestas	35	31.5	78	73,291
NEG-Micon	5	3.8	10	9,048
Bonus	6	2.1	6	5,900
Enron	1	1.5	4	3,902
Enercon	1	0.6	2	1,519
TOTAL	48	39.4	100	94,000

Micon. Two new turbine types were the Enron-Tacke of 1.5 MW which was installed in Zoetermeer along highway A12 and the new Enercon 40 of 600 kW and 44 meter diameter near Gouda (see Figure 18.3). The Enron Tacke is owned by Siemens Renewable Energy and has a view platform just under the nacelle.

In 2000, one large wind farm was installed consisting of 10 Vestas wind turbines of 1.65 MW. One wind farm consist of 10 Vestas wind turbines of 660 kW. The remainder consist of two groups of 2 wind turbines and the 1.5 MW machine. The rest of 23 wind turbines are solitary (Table 18.4).

18.5.2 Operational Experience

There were no major incidents or accidents in 2000.

18.5.3 Main Challenges in Market Development

The main challenge still is securing enough locations to put up wind turbines. The Minister of Economics Affairs in 2000 has repeatedly asked municipal authorities to work on a favorable policy for wind energy. Provinces are working on provincial spatial plans. A positive sign came in April 2000 from the Foundation for Nature and Environment in collaboration with the 12 provincial Environmental Federations. They issued a brochure called “Frisse Wind door Nederland5.” In this brochure they indicate locations per province that are suited for wind energy from their point of view. In total, they indicate new locations with a possible capacity of 1,695 to 1,840 MW on top of the already installed 420 MW in 1999.

18.6 ECONOMICS

18.6.1 Trends in Investments

Based on an average price of 2,100 NLG/kW, the investment in wind turbines totaled 82.7 million NLG in 2000.

18.6.2 Trends in Unit Costs of Generation and Buy-Back Price

For the more windy part of the Netherlands, wind energy can be exploited economically. There are no publicly available numbers for the cost price of wind energy. Estimates are that the cost price is varying form 0.10 to 0.20 NLG/kWh (0.046 to 0.091 Euro/kWh) depending on average wind speed and the cost for capital and maintenance an operation. The total pay-back rate offered by energy companies for 5 to 10-year contracts in 2000 was between 0.15 to 0.175 NLG/kWh (0.068 to 0.080 Euro/kWh).

Table 18.4 Size of wind plants installed in 2000

NAME OF WIND FARM	MANU-FACTURER	NO. OF TURBINES	HEIGHT (m)	SWEPT-DIA. (m)	CAP-ACITY (MW)	AREA (m^2)
Almere	Vestas	10	67.0	66.0	16.500	34,212
Amsterdam-West	Vestas	10	65.0	47.0	6.600	17,349
Zoetermeer	Enron Wind	1	85.0	70.0	1.500	3,870
Borssele	Vestas	2	65.0	47.0	1.300	3,470
Bath	Vestas	2	60.0	47.0	1.300	3,470
Various	Danish/Dutch/German	23	—	—	12.100	31,645
TOTAL		48			39.400	94,000

18.7 MANUFACTURING INDUSTRY

18.7.1 Manufacturing

Lagerwey has been selling turbines of the type 55 m/750 kW. They sold about 150 to Japan, 50 to Spain, and some 30 to Germany. The blade manufacturer Polymarin was bought by ZWT (Zeeuws Vlamse Windtechnologie). They have a 50% participation in Canadian Polymarin Huron Composites of which the other half was taken over by the Australian company Bollwell, now renamed Polymarin Bolwell Composites. They are starting up production of a 37 meter blade for the Enron 1.5 MW turbine with 77 meter diameter.

18.7.2 Industry Development and Structure

NEG Micon Holland is the leader of the co-operation between NEG-Micon Holland, LM Glasfiber Holland, Van Oord ACZ, TU-Delft and ECN. NEG hired an office in Bunnik near Utrecht. Here the DOWEC team is working on the 5-MW offshore turbine.

The head office of Siemens Renewable Energy is situated in Den Haag, the Netherlands. The company is active in project development. Major projects are in Groningen with a total capacity of 80 MW. The 1.5 MW Enron-Tacke turbine in Zoetermeer is their flagship (Figure 18.4).

For the 100-MW Near Shore Wind farm, two consortia have publicly announced their interest to realize it. One of the consortia, called North Sea Wind Power, consists of Siemens NL, energy companies Essent and Eneco, bank RaboBank International, contractor Heijmans Bouwbedrijven, offshore company Van Oord ACZ, and insurer-broker Profin BV. The other consortium is called Noordzeewind and consists of Shell Renewables, energy company NUON International, bank ING Bank, engineering firm Jacobs Compimo, and NUON owned project developer WEOM.

18.8 GOVERNMENT SPONSORED R, D&D PROGRAMS

18.8.1 Funding Levels and Priorities

Novem's wind energy program for 1999-2000 with the Ministry of Economic Affairs had a budget of about 31.8 million NLG (14.5 M Euro). The R&D budgets of ECN from the Ministry of Economics Affairs have slightly increased over the years. Through the Ecology, Economy and Technology (E.E.T.) program of the Ministry

Figure 18.4 Enron-Tacke 1.5 MW with rotor 70.5 m with view platform just under the nacelle

of Economic Affairs and the Ministry of Science, two wind energy projects are funded. One researches the possibilities of producing large blades form ecologically friendly materials. The other is the DOWEC project.

Table 18.5 Levels of R,D&D funding in The Netherlands 1991–2000 in NLG million

	1991	1992	1993	1994
TWIN (subtotals)				
Short term implementation	1.5	1.7	1.1	1.1
Long term implementation	0.1	0.2	0.4	0.3
Industrial development	4.0	3.6	3.5	3.5
Technical development	3.0	3.4	3.0	3.0
Dissemination of know-how	0.4	0.5	0.3	0.3
TWIN R,D&d total	9.0	9.4	8.3	8.1
Applied R&D (ECN)	2.5	2.5	3.0	3.0
R&D Universities (est.)	2.0	2.0	2.0	2.0
R&D Utilities	0.6	0.6	0.6	0.4
E.E.T. program				
TOTAL	14.1	14.5	13.9	13.5

18.8.2 New R, D&D Developments

Related to near shore wind farms, the KEMA and Van Hattum en Blankenvoort are developing a truss tower for offshore wind turbines with an ingenious system to neutralize the interaction between the wave effects and the wind fluctuations. As a result, it will be possible to construct less heavy towers. On top of that, KEMA and the Royal Volker Wessel Stevin developed a tracked vehicle that will make it possible to drive the assembled wind turbines to their foundations in the sea (see Figure 18.5 for an artist impression). Also for maintenance, a tracked vehicle will be developed. KEMA claims that these three patented innovations will result in a cost reduction of at least 15 % compared to the monopile solution.

The DOWEC project includes NEG-Micon Holland, LM glasfiber Holland, Van Oord ACZ, TU-Delft and ECN conducting a design study for offshore wind turbines. The concept study resulted in five feasible concepts for far offshore wind turbines of 5 to 6 MW. From these concepts, one was selected by industry for further development. The next step in the project will be the design of a 3-MW R&D turbine. According to the time schedule, this R&D turbine must be ready for installation on a test location on land by the end of 2001. After one year of testing, this turbine will be moved to an offshore test location. At the same time, the development of the 5 to 6-MW turbine will start. It is foreseen

Figure 18.5 Artist impression of a tracked wheel vehicle with turbine

1995	1996	1997	1998	1999	2000
0.7	0.9	2.5	2.5	6.4	6.6
0.2	1.8	2.2	2.2		
3.3	3.3	6.1	6.1	4.0	0.0
2.4	2.4	3.3	3.3	5.3	7.1
0.5	0.7	0.7	0.7	1.2	1.2
7.0	9.0	14.8	14.8	16.9	14.9
3.0	3.0	3.5	3.5	3.5	3.5
2.0	2.0	2.0	2.0	2.0	2.0
0.0	0.0	0.0	0.0	0.0	0.0
		5.0		10.0	
12.0	14.0	25.2	20.2	32.4	20.4

that the prototype of this turbine will be ready in 2004.

One of the major issues in the development of offshore wind turbines will be the improvement of the reliability of the turbines. Especially for the North Sea region, it will be necessary to improve the reliability dramatically in order to get an acceptable availability.

18.8.3 Offshore Siting

In February, the government decided on the final location for the demonstration project 100-MW Near Shore Wind farm. The selected location is situated about 10 km off the coast near the village of Egmond aan Zee. In April, the provincial government of North Holland approved the intentions of the government. On December 15, the government confirmed the decision to build the wind farm at Egmond aan Zee. After parliament has taken a positive decision in spring 2001, the tender procedure will start. Then the interested consortia can apply for the concession to build and exploit the wind farm. In connection to this 100 MW wind park, two test locations will become available for testing large offshore wind turbines under realistic conditions.

According to the requirements in the environmental effect report for the Near Shore Wind farm, a monitoring and evaluation program has to be carried out. Novem has formulated the outlines of this program, which cover environmental, economical and technical aspects, in the beginning of 2000. According to these outlines, this program has to start with an evaluation of the undisturbed situation. This whole program is aiming at learning as much as possible from this near shore wind farm for the larger offshore wind farms that have to be realized in the future.

At the same time, Novem has been working on a schedule for all the preparatory activities that are necessary in order to be able to install a wind farm outside of the territorial waters. These activities include all kinds of institutional items, technical aspects, environmental, market and economical issues, etc. For many of these issues, the Near Shore demonstration wind farm is an ideal small-scale test and demonstration facility.

The final report, *Werken aan Offshore Windenergie,* (Working on Offshore Wind Energy) has been issued last June.

References:

Derde Energienota, 1995, ISSN 0921-7371, SDU Uitgeverij, Plantijnstraat, The Hague, Internet http://info.minez.nl/nota/enota

Duurzame energie in opmars. Actieprogramma 1997-2000, March 1997. Ministry of Economic Affairs, P.O. Box 20101, NL-2500 EC, The Hague. Summary in English: Renewable Energy Advancing Power Action programme for 1997-2000, Internet http://info.minez.nl

Duurzame energie in Nederland, Bijdrage aan de energievoorziening 1990-1999. [Renewable energy in the netherlands. Contribution to the energy supply 1990-1999. Preliminary version], January 2001, Novem, P.O. Box 8242, NL-3503 RE Utrecht, The Netherlands

Frisse Wind door Nederland, Stichting Natuur en Milieu, April 2000 to be ordered form Stichting Natuur en Mileiu, Donkerstraat 17, 3511 KB Utrecht, fax +31 30 233 13 11, e-mail: snm@antenna.nl.

Werken aan Offshore Windenergie, Activiteitenplan, Novem B.V., June 2000 to be ordered from Publicatiecentrum Novem Apeldoorn P.O Box 1305, 7301 APELDOORN, The Netherlands.

Author: Jaap L. 't Hooft, NOVEM, the Netherlands

CHAPTER 19

19.1 INTRODUCTION

There were not any wind farms built in Norway in 2000. The two wind farms granted building permission and public financial support at the end of 1999 are still in the planning stage, mainly due to low electricity market prices. In addition, several project developers did apply for building permission during 2000. In December 2000, permission according to the energy act was given to three wind farms, with an estimated total energy production of about 770 GWh/year. The interest is still high for wind power as a commercial source for energy production, although financing remains a substantial hurdle.

19.2 NATIONAL POLICY

19.2.1 Strategy

Most of the electricity production in Norway is based on hydro power. Remaining new hydro-power projects are limited both in size and quantity, which has created a greater focus on wind energy. The ambition of the Norwegian government is to have an annual electricity production based on wind energy of 3 TWh/year by 2010. This represents about 1,000 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 in the range of 2 billion NOK (220 million USD). In 2000, the electricity production based on wind energy was about 32.5 GWh, with an estimated full-year production of about 37 GWh.

19.2.2 Progress Towards National Targets

Two wind farms, of 39 MW and 4 MW, were given permission and financial support at the end of 1999. By the end of 2000, the final decision to build the wind farms still had not been made—but according to the developers, these wind farms will most likely be erected during 2001 and 2002. An additional three projects, with a total estimated energy production capacity of 770 Gwh/year and 276 MW of total installed capacity, received building permission at the end of 2000. Depending on the annual grants in the national budget in the coming years, this could imply a total installed capacity of 330 MW by the year 2004, or approximately one third of the national target.

19.3 COMMERCIAL IMPLEMENTATION

19.3.1 Installed Capacity

No new wind power installations were commissioned during 2000, and the total national installed capacity remains at 13 MW. An overview of the Norwegian wind turbines and their energy production, both in 2000 and an accumulated total, is shown in Table 19.1. However, the production is somewhat less than estimated, mainly due to wind conditions and some cases of mechanical failures and repairs.

19.3.2 Rates and Trends in Deployment

Figure 19.1 below illustrates the increasing trend of wind energy in recent years.

19.3.3 Contribution to National Energy Demand

The total Norwegian electricity generating capacity is about 27,833 MW, 98.9% of which is hydro-power. The mean energy production from hydro-power is 113.4 TWh/year. Thus, the contribution from wind power is merely 0.03% of the total electricity production capacity. If the national target of 3 TWh/year by 2010 is met, the wind energy share of the total electricity production will be approximately 2.6%, assuming no significant capacity increase from other sources.

Table 19.1 Wind turbine projects and their energy production

WIND TURBINE PROJECTS	YEAR	NO. UNITS	TOTAL POWER (kW)	PRODUCTION 2000 (GWH)	ACCUMULATED PRODUCTION (GWH)
Frøya	1986	1	55	0,157	1,949
Frøya	1989	1	400	0,739	8,699
Vallersund	1987	1	75	0,181	2,441
Kleppe	1988	1	55	0,047	0,554
Smøla	1989	1	300	0,632	7,078
Andøya	1991	1	400	0,876	8,998
Vesterålen	1991	1	400	1,034	10,038
Vikna I & II	1991/93	5	2200	6,165	54,862
Hundhammarfjellet	1998	1	1650	3,535	9,296
Lindesnes	1998	5	3750	10,174	24,531
Sandøy	1999	5	3750	8,984	9,984
TOTAL		23	13,035	32,524	138,424

19.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

19.4.1 Main Support Initiatives and Market Stimulation Incentives

In order to enhance the introduction of wind energy in Norway, several measures were introduced in 1998, effective from 1 January 1999. One measure is the exemption for wind turbines and related equipment from a 7% investment tax. Another measure is an energy production support, equaling half of the general electricity levy (0.0428 NOK/kWh in 2000). There is still a need for additional financial support, which will be 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. In 2000, no new projects were given financial support.

19.4.2 Unit Cost Reduction

Some work has been done to reduce costs related to foundations, due to the fact that most wind turbines in Norway are located on solid rock. So far, the new concepts have not been tested in full scale.

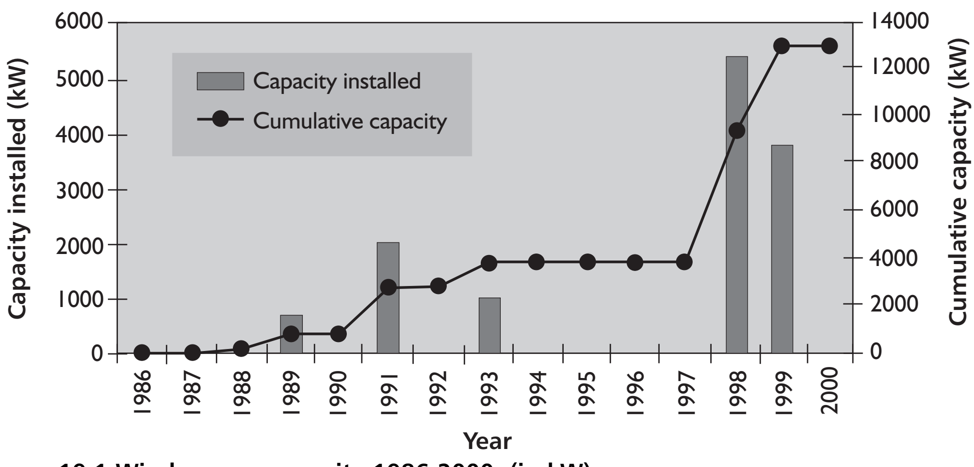


Figure 19.1 Wind energy capacity 1986-2000, (in kW)

19.5 DEPLOYMENT AND CONSTRAINTS

19.5.1 Wind Turbines Deployed

As discussed in Section 19.3.1, no new wind power installations were commissioned during 2000, and the total national installed capacity remains at 13 MW.

19.5.2 Operational Experience

No serious incidents have occurred, though several turbine owners refer reports of various mechanical problems. Two wind turbine owners report significant operational problems, contributing to an annual energy production of less than 75 % of the expected amount. These figures do not account for variations in wind resources 2000 compared to the estimated value.

19.5.3 Main Constraints on Market Development

In recent years, interest in wind energy has increased, and several projects have been planned. The main constraint for these projects is the low price of electricity, but visual and environmental concerns are also major factors that limit the possible deployment of wind energy in Norway. Another limiting factor is that several of the possible wind farm sites along the coast play an important role as recreational areas to tourists and the local population. The coastal areas are quite densely populated by Norwegian standards, which makes it difficult to find favorable wind sites that do not interfere with already-existing buildings. Choosing areas farther away from the population, however, reduces the number of locations with sufficient grid capacity and other infrastructure.

19.6 ECONOMICS

19.6.1 Trends in Investment

The estimated unit cost of the most recently planned Norwegian wind turbines is about 7,500.00 NOK/kW (833 USD/kW). However, since no installations have been built since 1999, these figures are somewhat uncertain. Generally, the unit cost so far for wind power has come down to about 7,500.00 to 8,500.00 NOK/kW for turn-key installations.

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

The Norwegian spot market price of electricity at the main grid level is shown in Figure 19.2.

The yearly average spot market price has steadily decreased since 1997 as follows:

- 135.0 NOK/MWh in 1997,
- 116.3 NOK/MWh in 1998,
- 111.9 NOK/MWh in 1999
- 103.33 NOK/MWh in 2000.

In addition to the electricity price, the customer must include costs covering transmission and taxes in order 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 to 300.00 NOK/MWh, including capital costs, operation, and maintenance. Thus, compared with the shown spot market electricity price, wind energy cannot compete on commercial terms. However, compared with the price of new hydro-power projects, some of the wind energy projects are 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 is too small. However, the Norwegian/Swedish company, Scanwind AS, is working on the development of 3-MW wind turbines. The first installation will probably be made during 2002 on the Swedish island, Gotland.

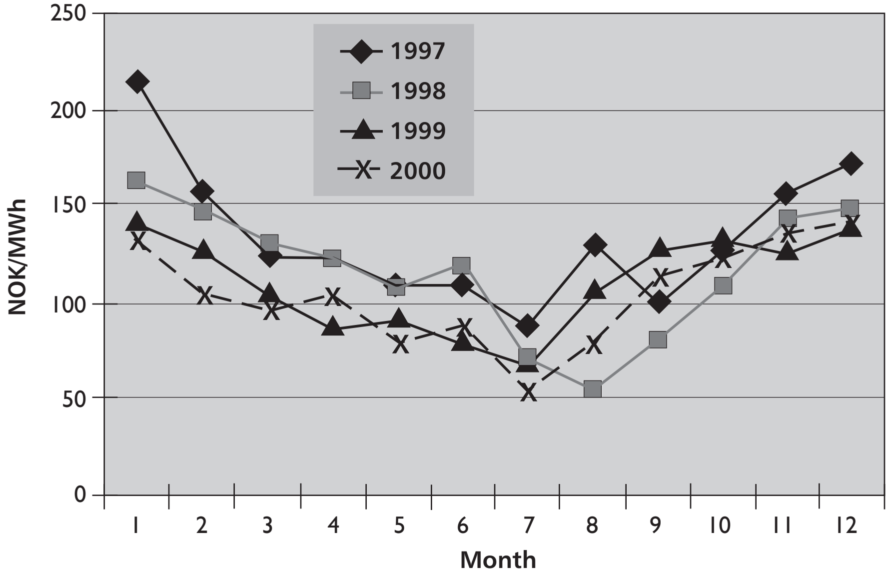


Figure 19.2 Spot market price of electricity 1997-2000 (Source: Nordpool ASA)

19.8 GOVERNMENT SPONSORED R, D&D

19.8.1 Priorities

The Norwegian Water Resources and Energy Directorate coordinates public support for projects in close collaboration with the Norwegian Research Council. Current priorities are for projects close to market introduction, and projects proposed by researchers in collaboration with industrial partners are preferred.

19.8.2 New R, D&D Developments

In 2000, the following R, D&D projects related to wind energy were financed by the Norwegian Research Council and/or by the Norwegian Water Resources and Energy Directorate, NVE.

1. Large Scale Integration of Wind Energy Into the Norwegian Electricity Grid.

   An estimation of the Norwegian wind energy potential indicates 13TWh/year and 5,000 MW installed capacity. Current installations still only include 23 wind turbines, producing approximately 32.5 GWh/year, or merely 0.03% of the total electricity production. A study is currently being undertaken by the utility Statkraft SF, to consider the effects of large scale wind power on the overall reliability, operation and maintenance and electricity quality in the national power system.

2. Short Term Estimations of Wind Energy.

   To better achieve optimized electricity production, a project utilizing an improved prognosis to estimate near future wind resources has been under taken by Kjeller Vindteknikk AS, the Norwegian Meteorological Institute (DNMI), and Institute for Energy Technology (IFE). The outcome of the project is intended to increase the value of wind energy because wind energy production could be forecast with better accuracy, which could enable wind energy to be sold at a somewhat higher price.

Norsk Hydro AS, together with Haugaland kraft utility company and the Municipality of Utsira, are doing a pre-feasibility study of a combined wind/hydrogen/fuel cell installation on the Island Utsira off the south-western coast of Norway. A similar study has also been undertaken by the utility Lofotkraft, together with the

Municipality of Rost. The site considered in the latter study is Rost Island in Lofoten, off the coast of Nordland County. The concept considered in both studies consists of wind turbines covering a base electricity load and also feeding excess electricity into an electrolyser to produce hydrogen. Stored hydrogen is subsequently converted on-demand to electricity and heat through the use of fuel cells.

The company Vector is completing a project using numerical flow simulations, based on existing wind measurements, to form a rough wind atlas, which will be used as a basis for deciding where to locate wind farms. The resulting wind atlas will be presented on the Internet at http://windsim.com. The area considered is the coastline from the southernmost tip of Norway, along the west coast and north-east to the Russian border.

The IFE has, in collaboration with utility companies Nord-Trondelag Elektrisitetsverk and Kjeller Vindteknikk A/S, computed a wind map covering the county of Nord-Trondelag. The project is based on 40 years of re-analyzed data and the meso-scale MM5-model; it takes into consideration both atmospheric flow and micro-scale parameters. The final resource estimations will be compared with in-situ measurements and other calculations.

The IFE has also developed a numerical micro-scale model called 3DWind, which is a non-neutral, non-hydrostatic Navier-Stokes Solver developed specifically to estimate terrain effects not resolved by meso-scale models and available measurements. The model is both a practical tool for evaluation of potential wind turbine sites, as well as a research and educational tool with optional effects not normally accounted for in micro-scale models. The options include a simplified energy equation; buoyancy and the Coriolis force; and zero, one, and two-equation turbulence models.

The Norwegian University of Science and Technology (NTNU) and other research institutions and industrial partners are planning a full-scale test station for wind turbines at the coast of Sor-Trondelag County.

As part of the Norwegian participation in IEA Wind Annex XVII, a new system to record wind speed time series at 20 Hz has been developed and will be installed at NTNU's wind measurement station on the coast of Sor-Trondelag. The measurements will be used to investigate the wind gust structure. Correlations in the wind speed field for distances typical of a wind turbine diameter are also being investigated.

1 NOK = 0.11 USD

Author: Harald Birkeland, Norwegian Water Resources and Energy Directorate, Norway.

CHAPTER 20

20.1 INTRODUCTION

Spain continues the successful implementation of wind energy into its energy structure. The dramatic increase in wind energy is welcomed by the citizens who appreciate wind energy's contribution to conserving the environment and promoting industrial development and job creation.

New manufacturers, investors, producers, and researchers have joined the wind energy business in the last year. The future looks promising, and targets are being reached.

20.2 NATIONAL POLICY

Spain is a country with a strong dependence on external sources of energy. There are no oilfields, or gas reserves in Spanish territory and only a few coal mines of low quality coal. Table 20.1 shows the distribution of primary energy used for 1999 and 1998. The total primary energy consumed in 1999 was 119,410 ktep.

In 1998, renewable energy sources contributed 6.3% to the total national energy balance. In 1999, the contribution was reduced to 5.6% because of low production from hydroelectric plants (68% of the average year production). Renewable energy sources contributed 15.6% of the electricity produced in 1999 (11.1% from hydro plants). Wind energy contribution grew from 2,945 GWh in 1999 to 4,162 GWh in 2000 (41% increase).

Spain is a country with excellent wind resources and well-developed wind energy technology making wind energy a clear alternative for the integration of renewable energy into the Spanish energy structure. The wind energy target for 2010 is to reach 8,974 MW installed, with an average production of 21.5 TWh/year.

20.2.1 Strategy

The strategy of the Spanish government is summarized in the new "Program for Promotion of Renewable Energies" approved by the Parliament. It maintains the situation of the Royal Law 2818/1998 of 23 December 1998, about the Electrical Special Regime for Renewable Energy Plants connected to the grid. That law fixed the price and the bonus for electricity produced by renewable energy plants. The price will be up-dated every year by the Spanish Ministry of Energy and Industry according to the annual variation of the market price.

This program was prepared by IDAE (the National Diversification and Energy

Table 20.1 Primary energy balance for 1999 and 1998

	1999		1998	
SOURCE	Ktep	%	Ktep	%
Oil	63,041	53.0	62,123	54.5
Coal	20,337	17.1	17,463	15.3
Nuclear	15,337	12.9	15,366	13.5
Gas	13,535	11.4	11,826	10.4
Renewable Energies	**6,667**	**5.6**	**7,173**	**6.3**
TOTAL	119,410	100.0	113,951	100.0

Saving Agency) and is the response to enactment of Law 54/19976 on the Electricity Sector. That law defined the target of achieving at least a 12% contribution to electricity demand in Spain from renewable energies by the 2010. The program also is the Spanish incorporation of the European recommendations made in the White Paper on Renewable Energies.

The target of the Program for Promotion of Renewable Energies (PPRE) for the period 1999 to 2010, is to install 5,540 MW in the seven-year period from 1999 until 2006 and another 2,600 MW between 2007 and 2010 (650 MW per year).

In total, 8,140 MW must be added to the 834 MW existing on 31 December 1999 to reach the figure of 8,974 MW for 2010. Table 20.2 shows the share by autonomous communities.

Other actions included in the PPRE are:

- New R, D&D National Program (large and small wind turbines)
- Financing the improvement of the transmission grids

Table 20.2 Power target by autonomous communities

AUTONOMOUS COMMUNITY	P.P. R.E. TARGET FOR 2000 (MW)
Andalucia	1,100
Aragon	1,000
Asturias	300
Islas Baleares	49
Islas Canarias	250
Cantabria	300
Castilla-Leon	850
Castilla-La Mancha	400
Cataluña	425
Extremadura	225
Galacia	2,500
Madrid	50
Murcia	300
Navarra	635
La Rioja	100
Comunidad Valenciana	290
Pais Vasco	200
TOTAL	8,974

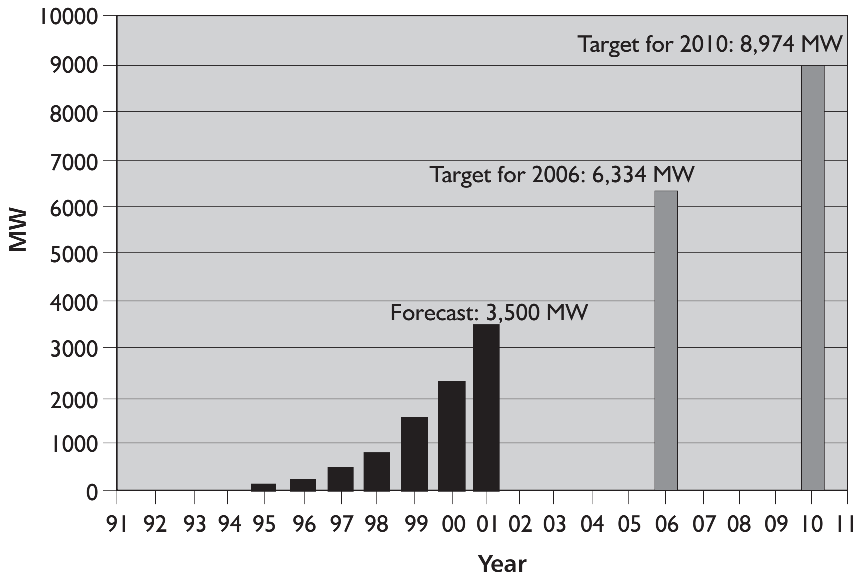


Figure 20.1 Wind installations in Spain: PPRE targets

- Regulation of the administrative procedures for renewable energy power plants.
- Support to the Spanish participation on the working groups for standards elaboration
- Information Programs
- Educational Programs

The program is complemented by the new "National Plan for Scientific Research, Development and Technological Innovation (2000 to 2003)".

20.2.2 Progress Towards National Targets

In Spain, 705 MW were installed in 1999, and another 795 MW in 2000. For 2001, there are more than 1,200 MW under construction. That will make a total of 2,700 MW installed in the three-year period (1999 to 2001). This corresponds to 48.7% of the target for the seven-year period.

The target looks to be realistic, and, according with the present data, targets will be reached sooner than planned.

The majority of the autonomies have regional wind energy programs that give a total figure of more than 10,000 MW to be installed in the next decade (exceeding the PPRE target).

20.3 COMMERCIAL IMPLEMENTATION

20.3.1 Installed Capacity

In 2000, another 795 MW were installed, and the total power on 31 December 2000 was 2,333.79 MW.

20.3.2 Rates and Trends in Deployment

Annual power installed continues to grow. Figure 20.2 shows the annual power installed in Spain in each of the last ten years.

For 2001, the figure is estimated to be more than 1,200 MW in 53 new wind farms. The new wind farms are large and medium size, located on the mainland. They are mainly owned by consortiums formed by utilities, regional institutions involved in local development, private investors (national and foreign), and in some cases the manufacturers. Private individuals are not taking an important role in the development of wind energy in Spain.

Offshore wind farms are not yet being developed in Spain. High water depth and steep seabed slope seem to be the main drawbacks to off-shore development in Spain. However there are plans for a wind farm in the Estrecho de Gibraltar (Cadiz, in front of Trafalgar Cape), ten kilometers from the shore. The project developer is waiting for permission to

Table 20.3 Accumulated wind power and annual growth rate

YEAR	POWER INSTALLED (MW)	ACCUMULATED POWER (MW)	ANNUAL GROWTH RATE
1994	23	73	46%
1995	46	119	63%
1996	95	214	80%
1997	213	427	100%
1998	407	834	95%
1999	705	1,539	85%
2000	795	2,334	52%

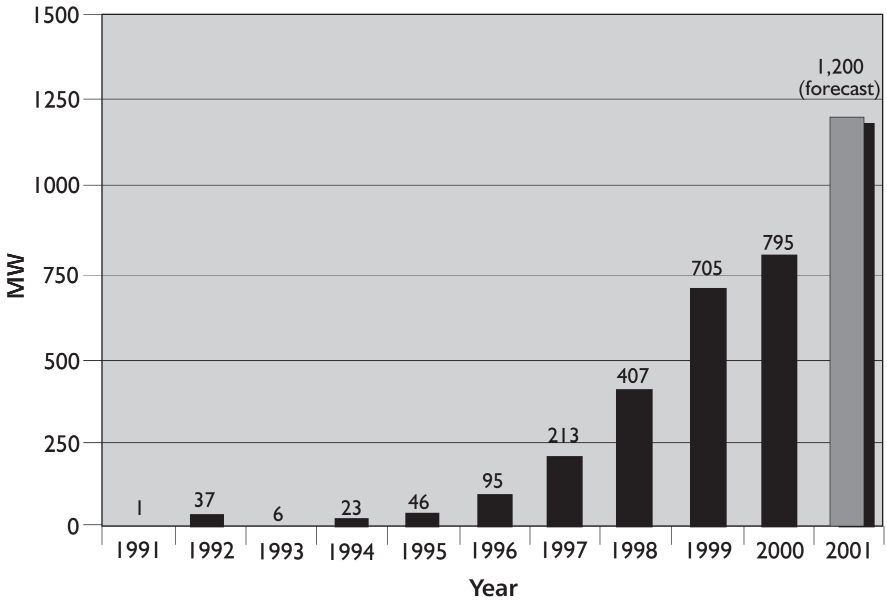


Figure 20.2 Annual power installed

install a meteorological mast and begin taking wind speed measurements. Also at Huelva's harbor dock, measurements are being taken. There are plans for installing 40 to 50 MW in a 13 km dock, but the resource has not been evaluated yet.

Galicia, Castilla-La Mancha, and Castilla Leon y Navarra are the autonomous communities with the most activity during 2000. It is important to point out that during 2000 another three regions have started to have wind farms installed in their territory: La Comunidad Valenciana in the east of the country and La Rioja and País Vasco in the north. Other autonomies like Madrid, Asturias, and Extremadura will be incorporated during 2001. A very positive trend has been confirmed in 2000 for the regions which were already active in wind energy exploitation. In addition, an important change of attitude has taken place in other regions such as La Rioja, País Vasco, Valencia, Asturias, and Madrid. At the present time, almost all the Spanish autonomies are involved in incorporating wind energy into their energy structure.

20.3.3 Contribution to National Energy Demand

The total production of wind power plants for 2000 was 4,162 GWh. The total electricity demand in Spain for 2000 was 195,800 GWh (6.25% higher than in 1999). Wind-generated electricity contributed 2.13% of the total electricity demand in the country.

20.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

20.4.1 Main Support Initiatives and Market Stimulation Instruments

The main method of market stimulation is the price paid for electricity generated by renewable energy systems (RES). This price is regulated through two Royal Decrees (the latest approved in December 1998) obliging utilities to pay a guaranteed price to RES generators for a five-year period. The price and the related bonus are revised and fixed every year according to variations in the market price of electricity.

Figure 20.3 Regional distribution of wind installations (31 December 2000)

20.5 DEPLOYMENT AND CONSTRAINTS

In general, Spanish society welcomes the growing development of wind energy and appreciates its contribution to environmental conservation, industrial development, and associated job creation. Job creation is the most important feature of wind energy for

Table 20.4 Wind power installed distributed by autonomies

AUTONOMOUS COMMUNITY	TOTAL POWER 12/31/99 (MW)	POWER INSTALLED IN 2000 (MW)	TOTAL POWER 12/31/00 (MW)
Andalucía	126	22	148
Aragón	188	46	234
Canarias	102	7	109
Castilla y León	108	107	215
Castilla-La Mancha	111	212	323
Cataluña	59	12	71
Galicia	441	242	683
Murcia	6	5	11
Navarra	398	88	486
C. Valenciana	0	3	3
País Vasco	0	26	26
La Rioja	0	24	24
TOTAL	1,539	795	2,334

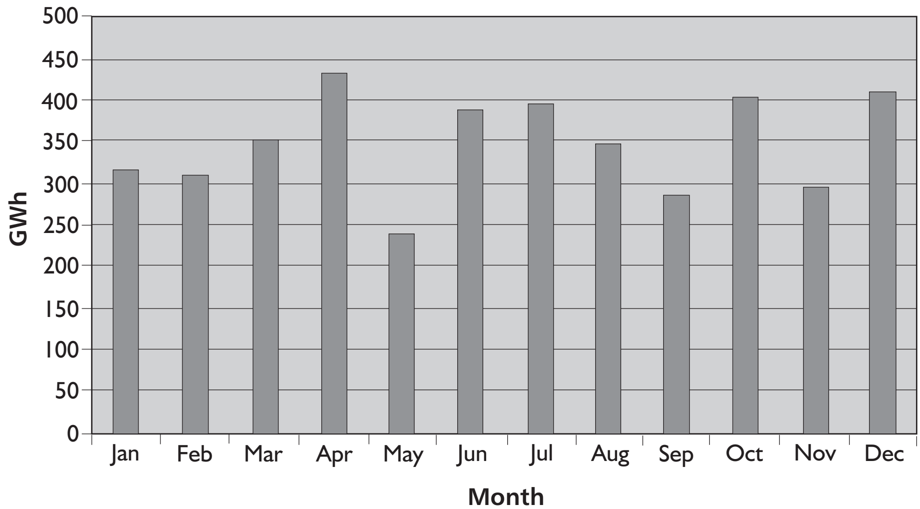


Figure 20.4 Monthly distribution of electricity produced by wind farms in 2000

the Spanish population. Also the benefits obtained at the local level (landowners and municipalities) promote a favorable attitude toward 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, national public company) and the utilities must allow the connection of wind turbines to the grid. Developers have to fulfil the technical requirements defined in the electrical law. The cost associated with the connection is the responsibility of the developer of the plant. There have not been 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 2000 in Spanish wind farms range in size from 600 kW to 1,650 kW. The largest wind turbine is the 1,650-kW Gamesa-Vestas, followed by the 1,320-kW MADE. Wind turbines of 600, 630, 640, 660, 700, 750, and 800 kW have been used. The average generating capacity of a wind turbine in Spain for 2000 is 661 kW.

The Table 20.5 shows how the market is divided among manufacturers.

20.5.2 Main Constraints on Market Development

Some opposition has emerged recently against the installation of new wind farms in the Galicia area and in the Castilla-León community. Local ecology groups complain about the landscape impact and the possible impact on bird life. However, that opposition is not an important constraint for the development of new wind plants in Spain.

The main constraint in market development is the limitation of the capacity of the grid for energy transmission. Generally, the wind farms are located in areas with low-density population, and the grids there are weak and require reinforcement and improvement. Concerted actions between utilities and developers are ongoing to solve the problem.

20.6 ECONOMICS

20.6.1 Trends in Unit cost of Generation and Buy-Back Electricity Prices

The Royal Law 2818/1998 of 23 December 1998 about the Electrical Special Regime

Table 20.5 Market share by manufacturer of installations in 2000

MANUFACTURER	WIND FARMS	NUMBER OF WIND TURBINES	TOTAL POWER (MW)	RATE OF POWER (%)
Gambesa	33	887	587.59	63.4
Ecotechia	6	276	183.09	19.7
Made	11	125	82.78	8.9
Bazan-Bonus	3	77	46.20	5.0
NEG Micon	3	37	27.75	3.0
TOTAL	56	1,402	927.41	100.0

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 energy, with the specific target that "the contribution of the renewable energy to the Spanish energetic demand, will be at least 12% for the year 2010." All the installations using renewable energy as their primary source, with installed power equal to or lower than 50 MW, could be included in that regime. The regime gives two choices to producers. One is a fixed price for the kWh generated. The second option is a variable price, calculated from the average price of the market-pool, plus a bonus per kWh produced. The fixed price and the bonus will be up-dated every year by the Spanish Ministry of Energy and Industry according to the annual variation of the market price. The up-dated prices for 2000 are presented in Table 20.6.

For 2001, the prices will be maintained, even taking into account that the average electricity price in 2000 decreased nearly 2%.

20.7 INDUSTRY

Activity to install wind generators has stimulated development of the Spanish wind industry, covering not only the manufacture of complete wind turbines but also the manufacture of components such as blades, generators, gear boxes, towers, wind sensors, etc. Also the service sector (installation, maintenance, engineering) has grown in the last year.

20.7.1 Manufacturing

The companies that are leading the Spanish wind industry are Gamesa Eólica, Ecotecnia, Made, Bazan-Bonus, Desa, and Taim-Neg Micon. Other manufacturers are initiating their activities in Spain, such as Enron Wind Iberica S.L:, Nordex or DeWind.

GAMESA EOLICA is manufacturing wind turbines using Vestas Technology. The majority of the components are manufactured in Spain (including blades). During 2000, Gamesa installed 887 units with a total of 587 MW.

ECOTECNIA started wind technology development in 1981, having more than nineteen years of experience in that field. The company has a technical staff of 60 people. It also has 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 into the MCC group, one of the biggest world-wide co-operatives, with activities in the industrial, distribution, and financial sectors.

The wind turbine models under production include the ECO/640 kW and ECO/750 kW. They are three-bladed, stall-control wind

Table 20.6 Buy-back electricity prices for renewable enrgy systems in 2000 and 2001

RENEWABLE SOURCE	BONUS ADDED TO THE BASE PRICE (Euro/kWh)	FIXED PRICE (Euro/kWh)
Small Hydro	0.0288	0.0626
Wind Plants	**0.0288**	**0.0626**
Geothermal	0.0299	0.0636
Wave	0.0299	0.0636
Primary Biomass*	0.0277	0.0615
Secondary Biomass*	0.0256	0.0594

1 Euro = 166.4 Pts
* Solar plants for electricity production: PV plants and solar thermal power plants
** Primary biomass: agricultural crops; secondary biomass: agricultural and forest residues

turbines, incorporating a very advanced design in the drive train. The company is now developing a variable-speed, stall-regulated system, to be incorporated into the present designs. They also have a new prototype of 60-m diameter, that will begin testing next year.

At the end of 2000, Ecotecnia had in operation more than 280 MW, with wind turbines from 150 kW to 750 kW. For the next year, they foresee a production of 200 MW. At the present time, Ecotecnia has wind turbines also in India and Cuba. The company has signed a technology transfer and representation agreement with the Japanese multinational Hitachi Zosen.

MADE is another of the pioneer companies in Spain. Since 1982, they have developed ten different models of wind turbines. The first design was a 24 kW and the latest AE-61 is 1,320 kW. During 2000, MADE installed 125 wind turbines making a total of 83 MW. The new designs, the MADE AE/52 (800 kW) and MADE AE/61 (1320 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 synchronous generator and variable speed operation. The AE/61 is a stall-controlled turbine with asynchronous generator (4 and 6 poles).

BAXAN-BONUS is manufacturing models of 600 kW, 1 MW, and 1.3 MW of Bonus in its factory located in El Ferrol (La Coruña). At the end of 2000, Bazan-Bonus had 189 wind turbines in operation in Spain. During 2000, 77 units of the MK IV-600 kW model were installed. The first unit of the 1.3 MW, 62-m diameter wind turbine was installed in the Sotavento wind farm.

NEG Micon Iberica S.A., installed 37 wind turbines in 2000. The total number of wind turbines in operation in Spain, is 174. The company has 104 workers in Spain.

ENRON inaugurated a new factory in Spain in 2000. Enron Wind Iberica has the target of producing more than 700 MW/year.

In the sector of small wind turbines, BORNAY is the company leader, with more than 170 units installed during 2000, in Spain, Germany, Portugal, Japan, Tanzania, and others. Bornay is manufacturing eight models from 60 W to 12 kW. The company has signed a contract with Atlantic Orient Corporation (US) to distribute the 50-kW AOC wind turbine in Spain.

The company SOLENER is also 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. Some use foreign technology, like Enron Wind Iberica, Nordex, or DeWind. Others are developing their own technology like M. Torres company, that will increase the capacity of the Spanish industry to fulfil not only the internal market but also other markets.

Spanish manufacturers are planning projects in North Africa (including Tunisia, Morocco, and Egypt) and also increasing the marketing activities in other countries (such as India, China, and South-American countries).

The wind industry is spread across Spain. Almost all the autonomous communities are involved in the development of wind energy, and in many areas 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 to 2003)" has been launched. The target areas defined in the plan for wind energy projects are as follows.

- Environmental Impact Reduction of Wind Systems
- Technology Cost Reduction
- Technology Development for Large Wind Turbines (1-2.5 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 research centers and universities involved in R&D projects increased their activities during 2000 (see list included in the 1999 IEA R&D Wind Annual Report).

The most important event was the creation of a new national center for development of Renewable Energies that will be located in Pamplona (Navarra). The new center, Centro Nacional de Energías Renovables (CENER) is sponsored by the national center CIEMAT, and will cover new activities in the field of renewable energy supplies. The activities in wind energy will be focused on large wind turbine testing, blade development, control systems, etc. The new center will start activities in 2001.

Remarkable among the new installations is Sotavento wind farm (Galicia), that started operation in November 2000. The installation with a total power of 17.5 MW, consists of 24 wind turbines, using nine different models from five manufacturers. Rated power varies from 600 kW to 1,320 kW. The wind farm will be a "window" of the technologies used in the Galicia wind farms, and a center for promotion of the use of wind energy.

Author: Felix Avia, Departamento de Energias Renovables, C.I.E.M.A.T, Ministerio de Ciencia y Tecnologia, Spain

Table 20.7 Wind turbines installed at the SOTAVENTO wind farm

WIND TURBINE MODEL	RATED POWER (kW)	UNITS
Bazan-Bonus MK-IV	600	4
Ecotecnia 44/640	640	4
Made AE 46/1	660	4
Gamesa G47	660	4
NEG-Micon 48	750	4
Made AE 52	800	1
NEG-Micon 52	900	1
Bazan-Bonus 62	1,300	1
Made AE 61	1,320	1

CHAPTER 21

21.1 INTRODUCTION

Sweden has a good wind energy resource but so far the deployment has been slow. However, in the last few years, deployment and development of wind power technology have speeded 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 effects on health, the environment, and climate, while at the same time assisting the move towards an ecologically sustainable society.

Considerable challenges face Sweden in the future. The decision to phase out nuclear power, the commitment to reduce greenhouse gas emissions in line with the Kyoto Protocol, and the limitations on further expansion of hydro-power resources make the development and market introduction of alternative energy sources, as well as successful energy efficiency measures, of crucial importance. Wind energy is one of the key elements in the transformation of the power system.

In a final Government Committee report on Wind Energy in June 1999, the Committee found that there is a need for general wind surveys and for mapping of the feasibility of siting wind power stations at sea and in mountain areas. A large potential for a major expansion of wind power exists in the large sea and mountain areas of Sweden. Investigations at the central level should focus on the feasibility of siting wind farms in the sea and mountain areas. These investigations should result in a national classification of the suitability of different areas for the establishment of wind power plants. The aim must be to furnish guidance for municipal comprehensive planning, but also to provide a solid foundation of knowledge for concrete wind power projects. In July 2000, the parliament decided to appoint a governmental working group to perform the investigations.

At the same time, the parliament appointed the Swedish National Energy Administration (SNEA, sw: Statens Energimyndighet) to, until 30 April 2001, suggest a planning target for the implementation of wind power in Sweden. Furthermore, the administration was appointed to identify local areas especially suited for wind power.

In the new Budget Bill, recently laid forth by the government, several measures are proposed in order to reinforce the energy policy actions that were established in 1997. The government is considering a system of green certificates to improve the conditions for electricity from renewable energy on the liberalized electricity market. This is to be done by designing a market-based system for production and trade of electricity from renewables such as biomass, wind, and small-scale hydro-power. This system should be in place by 2003. The system of certificate trade will be independent of state funding. It will stimulate cost effectiveness and promote the expansion of renewable energy technologies. The Budget Bill for 2001 also contains guidelines for a review of the energy taxation system. The aim is to improve the energy tax system to obtain an effective environmental policy instrument.

20.2.1 Strategy

An extensive energy policy program has been started to facilitate the restructuring and development of the energy system. The main thrust is a substantial long-term concentration on research, development, and demonstration of new energy technology.

Over one billion Euros have been allocated to the program that consists of two parts. The first part is a seven-year research, development, and demonstration program aimed at promoting renewable energy sources and new conversion and end use energy technologies. These long-term efforts will focus on new technology development of biofuel fired CHP; biofuel supply and ash recycling; new processes for ethanol from forestry raw materials; alternative motor fuels; solar and energy efficiency in the buildings, industry and transport sectors; and wind power.

The second part of the energy program is to replace the electricity production loss of about 4 TWh from Barseback nuclear power plant. A five-year short-term subsidy program is in progress to promote electricity production from renewable energy sources such as biofuels, wind, and small hydro-power plants and to promote energy efficiency. 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 rests with SNEA, which was formed on January 1, 1998.

As for wind energy, the government is supporting the development and installation of wind turbines in three programs managed by SNEA:

1. A fully financed research program with a three-year budget of 46.8 MSEK for 1998 to 2001. The program is presented in Section 21.8.
2. A development and demonstration program for wind systems, with a maximum of 50% support.
3. An investment subsidy program has been running since 1997 with a possibility to receive 15% of the total investment cost. The program for 2001 and 2002 is now expanded and limited to 100 SEK for the year 2001 and to 100 MSEK for 2002.

The utilities are also engaged in studies, demonstration, and evaluation projects. From 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 of wind electricity production. 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 shortly will be determined.

21.3 COMMERCIAL IMPLEMENTATION

21.3.1 Installed Capacity

The expansion of the annual power generation from wind turbines and the installed capacity in Sweden by 31 December each year shown in Figures 21.1 and 21.2.

The total installed wind power capacity in Sweden is 241 MW (31 December 2000),

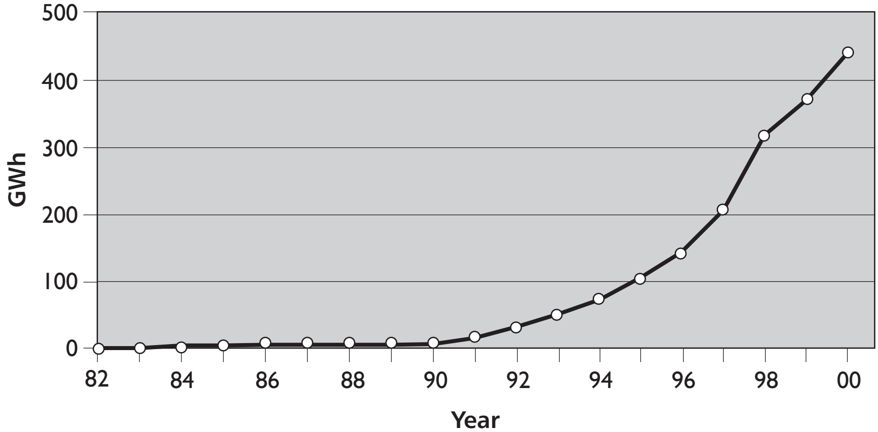


Figure 21.1 Wind power generation in Sweden (GWh)

an increase of 21 MW since 31 December 1999 (+10%). The number of wind turbines has increased by 31 to 517 turbines (up 6%) during 2000. Wind power generation during 2000 was 440 GWh, an increase of 19% since 1999 (371 GWh).

21.3.2 Rates and Trends in Deployment

No wind turbines in Sweden are erected today without the investment subsidy. Deployment has been evenly distributed over the years, because the budget for the investment subsidy budget is evenly distributed, with 60 MSEK per year. During 2000, the budget was increased for 2001 by 40 MSEK and for 2002 by 40 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 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

20.4.1 Main Support Initiatives and Market Stimulation Incentives

During the 1990s, the Swedish electricity market was reformed in several steps. Since 1 January 1996, Sweden has a

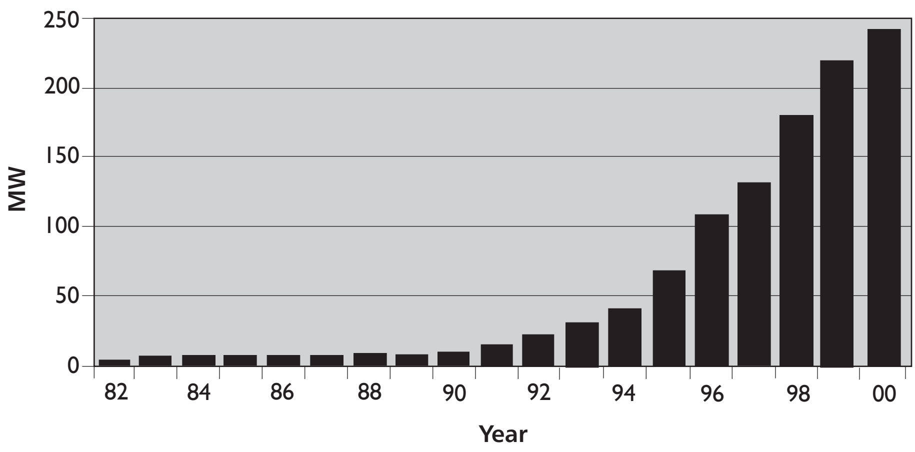


Figure 20.2 Wind power capacity (MW)

Table 21.1 Total installed electricity capacity and generation in Sweden 31 Decembr 2000

GENERATOR TYPE	2000 MW	2000 TWh
HYDRO POWER	16,192	76.90
NUCLEAR POWER	9,452	54.20
THERMAL POWER PRODUCTION (CHP, cold condensing)	3,541	8.90
WIND POWER	241	0.44
NET IMPORT		4.70
TOTAL	29,400	145.10

liberalized electricity market. All consumers are free to choose their electricity supplier. The objectives of the reform have been to increase the 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. There is an obvious risk that renewables might lose market share due to the low electricity prices. The liberalization of the electricity and gas markets forces the industry to constantly strive for improving their efficiency and competitiveness.

Since 1 November 1999, the wind energy producers compete in the same market as conventional electricity producers. The average North Pool price in Sweden during 2000 was 0.120 SEK/kWh. The very low market price this year was caused by extremely large quantities of rain and new records in hydro-power generation in the connected electricity system (Sweden, Norway, and Finland). Hydro-power generation rose to about 40 TWh above a normal year in the combined system. See North Pool's homepage: www.nordpool.no under Elspot and then Monthly prices.

On top of the market price, the wind turbine owner receives by law an "environmental bonus," which has been 0.162 SEK/kWh during 2000 (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 (max. generator size 1500 kW). For 2001, the government has presented a proposition with an increased "environmental bonus" to 0.181 SEK/kWh and a continued "small-scale" generation support of 0.090 SEK/kWh. The wind turbine owner also gets an income from the transmission net owner, related to the value of the decreased electricity net losses, which on average results in about 0.010 to 0.015 SEK/kWh. The deregulated market also allows the turbine owner to sell electricity to any customer. This gives the opportunity for a "wind electricity market."

A second market stimulation program started on 1 July 1997. The 15% investment subsidy subsidy has a five-year budget of 380 MSEK. By the end of 2000, SNEA had received applications for investment subsidies for projects with a total investment value of 2,012 MSEK, and the total granted subsidies amounted to 228 MSEK. The granted subsidies for 2000 were 83.8 MSEK. These projects had a generating capacity of 62 MW.

20.4.2 Unit Cost Reduction

The mean cost of producing electricity at commercial wind power plants is 0.40 SEK/kWh (calculated with an interest rate of 6% over a period of 20 years without state subsidy). In Sweden, support is generally required for wind power to be viable. The unit costs in SEK per kW for different turbine sizes are shown in Figure 21.3. The larger turbines (1000 to 1500 kW) are getting cheaper, but are still slightly more expensive than the 600-kW turbines.

The statistics are based upon the applications for investment subsidy, including almost all the wind turbines erected since 1997.

21.5 DEPLOYMENT AND CONSTRAINTS

21.5.1 Wind Turbines Deployed

The wind turbines that have been erected during 1997 to 2000 in Sweden have a capacity between 225 and 1,750 kW with a majority of 600-kW turbines, which can be seen in Figure 21.4. They are mainly manufactured in Denmark or in Germany.

21.5.2 Operational Experience

According to the Swedish wind turbine monthly and annual statistics, the average availability during 1999 was 98.3%. During 1997, the figure was 98.4%, and during 1998 it was 98.5%.

21.5.3 Main Constraints on Market Development

Public attitudes toward wind power, especially its impact on the landscape, is a most important factor that influences practically every wind project. Noise emission is also important, but maybe rather as 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 planned.

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.

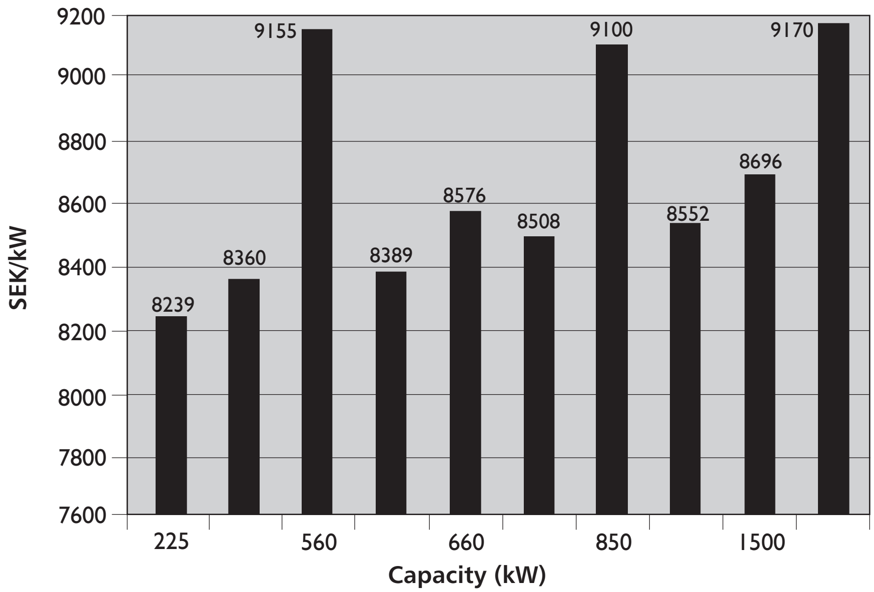


Figure 21.3 Unit costs in SEK/kW with wind power projects grouped per turbine size

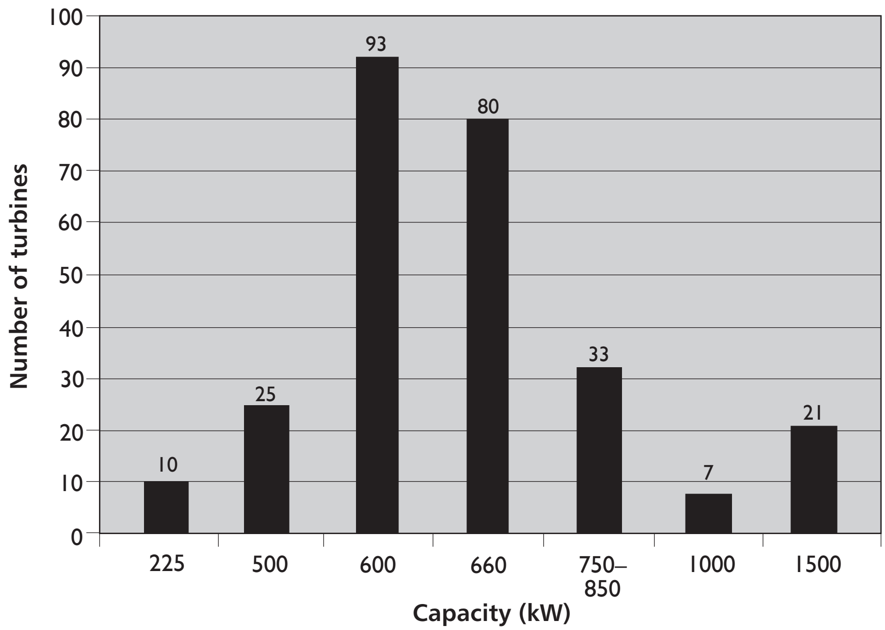


Figure 21.4 Number of wind turbines of specific capacity in projects in the investment subsidy program (1997 to 2000)

1. Public attitudes

A series of investigations on the public attitude towards wind power plants has been carried out. The investigations have included both inhabitants and summer residents around the plants, and politicians and civil servants from the municipalities. A majority of those interviewed had a positive attitude towards wind power. In the summer house areas, there were more doubts about wind power plants. The public attitudes are also investigated in a research project, examining how attitudes can be improved, e.g. by public consultation in the permission process for wind power.

2. Noise

Noise is a subject frequently discussed in wind turbine projects. The studies on assessment of wind turbine noise have shown that not only the sound level and its temporal pattern, but also several other factors are important for the subjective responses. Work is continuing on how to describe the noise disturbances in physical terms.

3. Disturbances on military structures

A research project is underway to create a reliable model of the disturbance wind turbines can cause on military microwave links, radar, and intelligence activities. Thus far, the results show that the disturbance due to wind turbines on radar has been quite overestimated.

21.6 ECONOMICS

21.6.1 Trends in Investment

During the years 1998 to 2000, approximately 400 MSEK per year has been invested in erecting wind turbines. Correspondingly, the investment subsidy of 15% has had a budget of 60 MSEK per year. The extra 40 MSEK per year for 2001 and 2002 should increase the investments for 2001 and 2002 to 660 MSEK per year.

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

The mean unit cost for generation is 0.40 SEK/kWh. (See section 21.4.2)

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. The price of bulk power as a proportion of the price paid by the end customer is consequently relatively low at just under one-third of the price, excluding taxes, payable by a household without electric heating (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 2000, wind turbine owners received a market tender price and other support as follows.

- a market tender price of around 0.130 SEK/kWh,
- an environmental bonus of 0.162 SEK/kWh,
- a temporary subsidy of 0.090 SEK/kWh for small generators max 1,500 kW, and
- the "local grid value" of in average 0.010 SEK/kWh,

These supports total 0.392 SEK/kWh.

This price model was in force until the end of 2000. In autumn 2000, the Swedish government decided to prolong the price model another two years, until end of 2002. Thereafter, a new system with Green Certificates will be implemented from 2003 on.

21.7 INDUSTRY

21.7.1 Industry Development and Manufacturing. MW-Rated Turbines

Two manufacturers have developed large wind turbines in Sweden: Kvaerner Turbin AB and Nordic Windpower AB.

Kvaerner Turbin AB has 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 partner in the OPTI OWEC project for offshore wind turbines

Table 21.2 Price of network service and electricity, excluding taxes, on January 1, 2000 in sales of electricity to various typical customers

CUSTOMER TYPE	NETWORK SERVICES öre/kWh			ELECTRICAL ENERGY öre/kWh		
	1999	2000	% Change	1999	2000	% Change
Apartment	42.3	42.3	0.0	27.1	21.8	-20
Single-family house without electric heating	37.2	37.2	0.0	26.3	21.7	-17
Single-family house with electric heating	20.6	20.8	1.0	24.4	21.4	-12
Agriculture or forestry	21.8	21.9	0.4	23.1	21.1	-9
Small industrial plant	15.0	15.2	1.3	22.8	20.3	-11
Medium-sized industrial plant				21.6	19.6	-9
Electric-intensive industrial plant				22.5	19.7	-12

Source: "Prices of electrical energy and transmission of electricity in 2000," EN17 SM 0001, Statistics Sweden in Europe within the THERMIE programme. During 1999, the company name for these wind power activities has changed to SW Vindkraft AB.

In 2000, Nordic Windpower AB manufactured and erected the second generation of their two-bladed, light-weight Nordic 1,000-kW wind turbine for Vattenfall at Näsudden on Gotland. The Nordic 1000:2 project is sponsored by SNEA.

A new manufacturer of large, 3,500-kW wind turbines has sold its first turbine in 2000. Vattenfall is the purchaser, and the supplier is a consortium formed by ABB and SW Vindkraft AB. The new technology "Windformer" is a development of ABB's hydro-power technology "Powerformer," combined with the new High Voltage DC transmission system HVDC-light. Both were tested in Sweden during the last few years, in Lapland and on Gotland.

The first Windformer system will be erected in autumn 2001 at Vattenfall's test-site for large wind turbine technology on Näsudden on Gotland. It will be designed for offshore conditions and applications. It is three-bladed, direct-drive without gear-box and has a cable wired high voltage generator, and permanent magnet rotor. It runs at variable speed around 18 rpm and has a hub height of 70 m and a rotor diameter of 90 m. The project is called Näsudden III and is sponsored by SNEA.

Danish and German wind turbine manufacturers produce parts for their wind turbines, such as cast goods or shafts, with Swedish subcontractors at different workshops in Sweden.

21.8 GOVERNMENT SPONSORED R, D&D

The overall goal for the Swedish wind energy research program is to develop knowledge within the wind energy area, so it will be possible to manufacture and develop wind turbines and utilize the wind energy efficiently in the Swedish energy system.

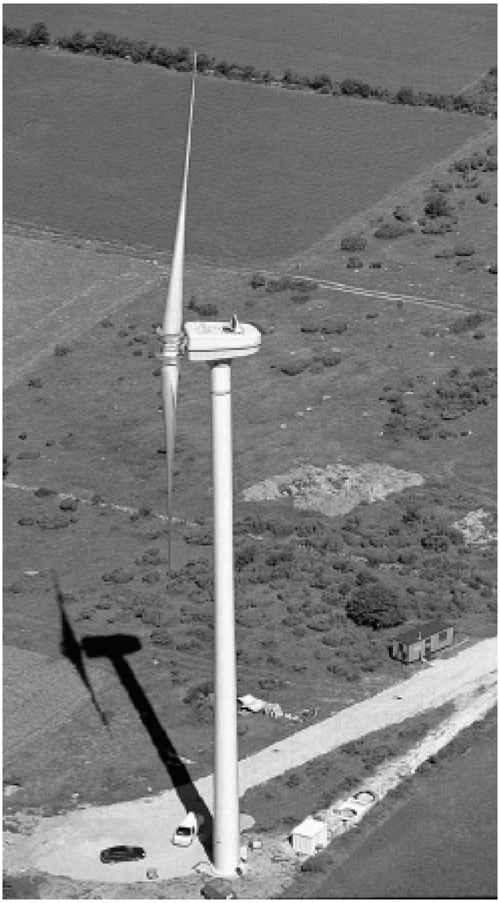


Figure 21.5 Nordic 1000:2

On 1 July 1998, a fully financed research program started with a three-year budget of 46.8 MSEK for 1998 to 2001. The subjects of research are as follows.

- 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 (VKK stands for wind energy—knowledge—competence). VKK was formed in 1994 and is led by the Aeronautical Research Institute of Sweden (FFA). For more information see the Web page: http://www.ffa.se/windenergy/windenergy.html.

21.8.1 Priorities

The research has been very technology oriented, but now when more wind turbines are fitting into the landscape, "softer" issues (planning, environmental, acceptance) have to be given higher priority. At the same time, it is important to continue research in the conventional technology areas in order to increase turbine availability and reduce costs.

21.8.2 New R, D&D Developments

In the following, some of the current research and demonstration projects are presented.

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 with this project, a study of environmental effects on reindeer has been initiated.

Suorva in Lapland

In October 1998, at one of its large hydropower dams in the Lule River valley, the utility Vattenfall erected a 600-kW wind turbine with a Finnish-Danish non-icing system in the blades. Suorva is situated 100 km north of the Arctic Circle. A 35-m mast with four anemometers has recorded data since 1995 and shown a good local wind resource equivalent with the island of Gotland. An evaluation program will be operated for three years. The project is sponsored by SNEA.

2 The Power Quality of Wind Turbines (Author: Åke Larsson)

At the department of Electric Power Engineering at Chalmers University, a dissertation was published during the year, dealing with the power quality of wind turbines. The first part of the thesis describes the electrical systems used in wind turbines. The second part presents the results of measurements of different types of wind turbines connected to different types of grids. The measurements include voltage and frequency variations, flicker, transients and harmonics. The third part deals with future standards for measuring and testing wind turbine power quality. In the last part, regulatory requirements concerning the power quality of wind turbines are discussed. Special emphasis has been given to flicker and flicker calculations according to new recommendations for the grid connection of wind turbines. The new recommendations provide tools for predicting the interaction between wind turbines and the grid. Wind turbines which, in combination with the grid, are likely to cause power quality problems can at an early stage of planning be rejected and replaced by a more proper type of wind turbine.

3. Development of a standardized cup anemometer suited to wind energy applications, CLASSCUP (Authors: J-Å Dahlberg, T. F. Pedersen, D. Westermann)

The primary objective of the CLASSCUP project (EU-project co-ordinated by FFA with Risø and DEWI as partners) was to develop an optimum design for a cup anemometer, which is essentially free from the observed design faults associated with most of the instruments currently commercially available. The faults are specifically: no definition of what they measure, bad angular characteristics, high sensitivity to friction in bearings, and no documented sensitivity to dynamics. The secondary objective was to prepare a classification system, which will allow users of anemometers in the wind energy industry to select anemometers suited to their specific applications and requirements.

The approach of the project has been largely experimental with a clear practical objective. Extensive parametric studies were undertaken, and more than 400 cup anemometer configurations have been tested in wind tunnels.

The following has been achieved/studied:

- the new anemometer design;
- geometric parameters that affect the sensitivity of cup anemometers to out-of-plane wind speed components;
- parameters that affect the dynamic effects (over-speeding) of cup anemometers;
- results from field tests and wind tunnel tests with commercial anemometers and the new anemometer design;
- temperature effects of friction in bearings;
- dynamic effects such as over-speeding and filtering effects and the possible benefit of inclusion of de-convolution in the measurements;
- a classification system for cup anemometers;
- guidance on how the classification will be influenced by angular response and over-speeding (slope and saturation level) characteristics.

A thorough knowledge has been built up of important parameters for the performance of cup anemometers for different purposes. A new anemometer design has been developed with much improved angular characteristics compared to all known existing cup anemometers.

21.8.3 Offshore Siting

1. Nogersund

In 1990, the first offshore wind turbine was erected in Sweden, a 220-kW turbine at Nogersund.

2. Bockstigen, Valar

An offshore demonstration plant with five 500-kW turbines was erected in early 1998 four 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 2000, Enron/Tacke erected and commissioned a 10-MW wind farm consisting of seven 1.425-MW turbines south of the light-house Utgrunden in the sound, Kalmarsund, between the main land and the island Öland. The Utgrunden offshore wind farm is the first offshore wind energy project using machines in the megawatt class. The plant is built 12 km offshore from Bergkvara at the Swedish southeast coast and 9 km from Öland. It is expected to generate 38 GWh annually.

The rotor diameter is 70.5 m and the hub height 65 m. The foundation for each turbine consists of a steel pipe, over 30 m long, 3 m in diameter with a weight of more than 100 tons. The monopiles are hammered 19 m down into the sea floor. Water depth is around 8 m.

The turbines operate with full variable pitch and full variable speed that will smooth both the mechanical and electrical loads. With this ability to control the loads, a soft-soft monopile has been constructed with the wind turbine operating at a speed above the natural frequency of

Figure 21.6 Utgrunden Offshore 10-MW wind farm

monopile with tower. This approach saved 50 tons of weight. The maintenance strategies are based on further distance to service base.

The Utgrunden project started electricity generation in December 2000 as the largest offshore wind farm at sea in the world and it is sponsored by SNEA.

4. Other plans for wind power offshore

In the Öresund sound, between Sweden and Denmark, the company Eurowind has applied for permission for an offshore project using 48 1.5-MW wind turbines. Another project West of the city Karlskrona in southeast Sweden has had a feasibility study conducted by the utility Vattenfall for an offshore project with 3 to 4-MW wind turbines. In the city's preliminary oversight planning, the offshore site is planned for about 100 MW-size wind turbines.

The total number of large offshore wind farm projects in different planning and study phases in Sweden is very large.

Discussions are going on with local and regional authorities along several parts of the long Swedish coast—at the West Coast and in the Baltic Sea. The final outcome of these broad activities will depend on the results from the ongoing Governmental initiatives discussed earlier in this chapter. These include 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; and when the Government will determine a long-term national deployment target for wind power.

Authors: Susann Persson, the Swedish National Energy Administration and Kenneth Averstad, Vattenfall AB, Sweden

CHAPTER 22

22.1 INTRODUCTION

The UK Wind Energy program commenced in 1979, initially to determine the technical and economic feasibility of the technology. Since that time, the program has progressed from research, development, and assessment to commercial deployment. It now provides a technology push to complement the market pull created by market implementation mechanisms, currently the Non-Fossil Fuel Obligation (NFFO), to be replaced by the Renewables Obligation on electricity suppliers in 2001.

During the mid-1980s and early 1990s, the program concentrated on technology development and demonstration, which has helped to establish UK expertise in wind energy. Collaborative product development with the industry to develop turbines and key components is a core element of the program and accounts for the bulk of its external expenditure. The key objective of development, demonstration, and monitoring of new turbines or components, is to reduce the cost of wind energy and expand the UK share of the turbine and component markets. The other key element of the program is to enable the effective exploitation of the resource, and contribute to national targets for generation from renewables and emissions reduction.

22.2 NATIONAL POLICY

In February 2000, the UK government published its new policy on renewable energy. This has five key aims, which are as follows.

- To assist the UK in meeting national and international targets for the reduction of emissions, including greenhouse gases.
- To help provide secure, diverse, sustainable, and competitive energy supplies.
- To stimulate the development of new technologies necessary to provide the basis for continuing growth of the contribution from renewables in the future.
- To assist the UK renewables industry in becoming competitive in home and export markets and, in doing so, provide employment.
- To make a contribution to rural development.

The objective is to increase the contribution of electricity supplied from renewables to 5% by the end of 2003, rising to 10% by 2010, subject an acceptable consumer cost.

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 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 (see Section 22.4.1 for further details). Other policy strands are as follows.

- 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 overcoming non-technical barriers to deployment.

- 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 UK government R, D&D program, through the 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 New and Renewable Energy Programme supports the following items.

—Resource, technology, and environmental assessment.

—Research development and innovation in industry.

—Work to address non-technical barriers.

—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. An essential adjunct is dissemination of information arising from both directly funded work and from projects in the Renewable Energy Orders.

The program has increasingly encompassed the offshore sector, and the above activities apply equally to this new area.

22.2.3 Progress Towards National Targets

The Government is committed to a new and strong drive to develop renewable sources of energy, including those utilizing offshore resources. Since coming to power, the Government has issued a series of consultation papers relating to sustainable energy and climate change. In 2000, the Climate Change Programme and a statement on renewable energy policy were both published. In addition to the commitment to Kyoto, the Government has set its own domestic target of achieving a 20% reduction in CO_2 emissions by the year 2010.

The Government has expressed its intention to work toward 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 is due to come into effect in April 2001. This is a Levy on energy use by business to encourage low energy use, energy efficiency, and the use of low emissions energy sources. This levy on electricity sales will be set at 0.43p/kWh. Qualifying electricity from renewable sources will be exempt from the levy.

22.3 COMMERCIAL IMPLEMENTATION

22.3.1 Installed Capacity

The UK currently (as of the end of December 2000) has 75 wind schemes with 839 wind turbines operating with non-fossil fuel contracts, and these comprise 391 MW of installed capacity. This is much less than the 2,675.8 MW of wind capacity with power purchase contracts under NFFO (See Table 22.1).

The lack of progress with deployment primarily reflects difficulties with obtaining planning consent. Future capacity will also be limited by electricity network

Table 22.1 Size, timing, and progress on the renewable energy obligations

ORDER	EFFECTIVE START DATE	NO. PROJECTS CONTRACTED	NO. PROJECTS OPERATING	CONTRACTED CAPACITY MW RATED (approx.)	OPERATING CAPACITY MW RATED	NO. TURBINES INSTALLED*
NFFO-1	1990	9	7	28.0	27.63	75
NFFO-2	1992	49	25	196.0	122.41	355
NFFO-3 (>3.7 MW)	1995	31	9	339.0	88.64	153
NFFO-3 (<3.7 MW)	1995	24	9	46.0	18.14	34
NFFO-4 (>1.76 MW)	1997	48	1	768.0	6.50	5
NFFO-4 (<1.76 MW)	1997	17	4	24.2	6.60	6
NFFO-5 (>2.3 MW)	1998	33	—	768.0	—	—
NFFO-5 (<2.3 MW)	1998	36	2	67.0	3.30	5
SRO-1	1995	11	1	148.0	62.60	110
SRO-2	1997	7	—	101.0	—	—
SRO-3 (>2.3 MW)	1999	11	1	148.0	17.16	26
SRO-3 (<2.3 MW)	1999	17	1	33.0	2.00	1
NI-NFFO1	1994	6	6	29.0	30.00	60
NI-NFFO2	1996	2	2	6.0	6.28	9
TOTAL		**302**	**75**	**2659.0**	**391.26**	**839**

*Source: BWEA website

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.

Outside the NFFO, there are an additional 23 turbines with an installed capacity of 17.16 MW; three of the turbines are "additional," associated with NFFO schemes, and 20 are in a separate wind farm.

22.3.2 Rates and Trends in Deployment

Figure 22.1 shows a marked improvement in deployment in 2000, although the figure does not match the UK high in 1997 when 84.5 MW was installed. Obtaining planning consent remains the biggest impediment to deployment. There does not appear to have been a significant change in the success rate of planning applications, so this increase in deployment does not necessarily indicate a significant upturn for future years.

22.3.3 Contribution to National Energy Demand

In 1999—the most recent year for data on annual energy demand from all sources—2.8% of the national demand was met from renewable sources, with 0.25% specifically from wind energy. The largest single source of renewable energy came from hydro power, which contributed 1.5%, with land-fill gas and combustion of municipal solid waste forming the bulk of the remainder.

22.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

22.4.1 Main Support Initiatives and Market Stimulation Incentives

The main support mechanism for wind energy, and other renewables, to date has been a series of Renewable Energy Orders. Each order allows developers to bid for power supply contracts, which are index-linked for 15 years. A five-year planning and development window is allowed before the contract becomes active. Bids are assessed on a competitive basis, and an upper threshold is selected after a

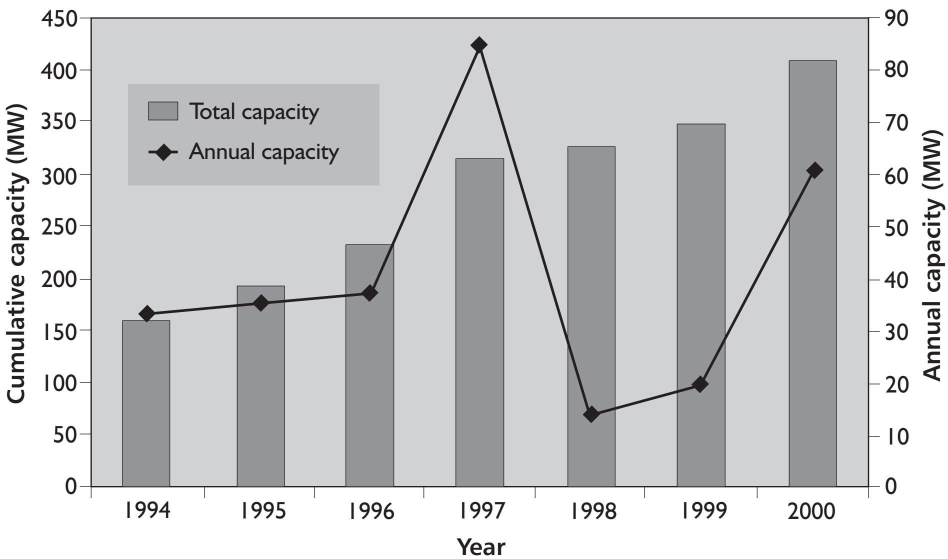


Figure 22.1 Wind turbine capacity and growth in the UK to 2000

pre-determined deadline. This mechanism has enabled the Government to achieve a progressive reduction in the bid price with each successive round. In England and Wales, there have been five successive rounds of the NFFO. This activity has been mirrored by three rounds of the Scottish Renewable energy Order (SRO) and two Northern Ireland rounds of NFFO.

Following response to the consultation paper published in 1999 "New and Renewable Energy: Prospects for the 21st Century," the Government decided on a new support mechanism for renewables, the Renewables Obligation, and this formed part of the Utilities Act 2000. 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. The percentage required will be set lower than this at first and gradually increase until the year 2010. However, the Obligation is expected to remain in place until 2026.

All eligible renewable generators will receive a certificate for each unit of electricity generated. 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 buy-out price. In the Government's consultation on the Obligation, also published in 2000, they proposed a buy-out price of 3 p/kWh.

The first period of the Obligation is likely to run from 1 October 2001 to 31 March 2003. After this, targets for suppliers will be set yearly. Targets have not yet been set.

22.4.2 Unit Cost Reduction

Onshore costs for most developments in the UK were slightly lower than previous years, assisted by a continuation of the favorable GBP/Euro exchange rate. An estimated 43.5 million GBP was invested during 2000. Offshore costs are higher than onshore—the 3.8-MW turbine installed at Blyth Harbour is reported as costing 4 million GBP.

Developers continue to be optimistic that onshore costs will fall further, to as low as 500 GBP/kW of rated power for some sites, due to larger, more efficient turbines and economies of scale. Similarly, for offshore sites, the opinion is that there is considerable room for cost reduction coming from greater experience, improved installation techniques, larger turbines, and larger schemes.

22.5 DEPLOYMENT AND CONSTRAINTS

22.5.1 Wind Turbines Deployed

There are now 862 turbines currently deployed throughout the UK at 76 sites, either as operating wind farms or single turbines. Future rates of deployment will depend on planning consent and the size of turbine likely to be acceptable to planning authorities. Possible changes to planning conditions and changes to the electricity market, together with the support mechanism for renewables, make future predictions extremely uncertain.

During 2000, 81 new machines, mostly of Danish manufacture, were installed on ten separate sites. There were several firsts for the UK including the following.

— The first large scale replanting of a UK wind farm: the replacement of ten 300-kW Carter turbines at Orton in Cumbria with six Vestas 660-kW turbines.

— Installation of a significant number of turbines without NFFO contracts. In Northern Ireland, this was in response to demand from the green electricity market (one additional 600-kW turbine at Lendrum's Bridge County Tyrone). There were also developments in Scotland (20 650-kW turbines at Hare

Hill, Ayrshire, and a 1.5-MW turbine on Orkney) and England (a 2-MW turbine at Blyth Harbour Offshore). The Hare Hill wind farm appears to have been built in anticipation of the introduction of the new Renewables Obligation and the Climate Change Levy, being developed and owned by an electricity supply company who will be directly affected by the Renewables Obligation.

— The first offshore installation at Blyth Harbour, Northumberland (see Section 22.8.3 for details).

— The first 2-MW turbines installed off shore at Blyth, and onshore for testing at a high-wind speed site on Orkney.

For the second year running, there were no new developments in Wales.

One landmark change in 2000 was the demolishing of the largest wind turbine in the UK—the WEG LS1, a 3-MW experimental machine on Orkney. This two-bladed machine was commissioned in 1987 and operated successfully for many years, but did not generate reliably for some time before it was demolished.

22.5.2 Operational Experience

The estimated output from UK wind farms with current NFFO contracts in 2000 is 524.8 GWh, with Northern Ireland producing 112.2 GWh, Scotland producing 158.7 GWh, and the remaining 253.9 GWh coming from England and Wales. These estimates are extrapolated from energy output data from the first three quarters of the year. The quarter-by-quarter output from the projects is shown in Figure 22.2.

No major operational problems were reported during 2000 and high availabilities were achieved.

Records from January 1999 of the earliest wind farms developed in the first two rounds of the NFFO were unavailable. Electricity produced by these wind farms is no longer traded via the NFFO system, hence information on the quantity of electricity generated is no longer obtainable. This is also true for new schemes without NFFO contracts. Therefore, output figures can only be estimated crudely from the installed capacity and a single assumed load factor. This approach gives an estimated output for 2000 of 370 GWh.

22.5.3 Main Constraints on Market Development

Although the new capacity installed increased in 2000, the deployment rate still reflects the difficulties encountered by developers in gaining planning consent. The figures presented in Table 22.1 clearly

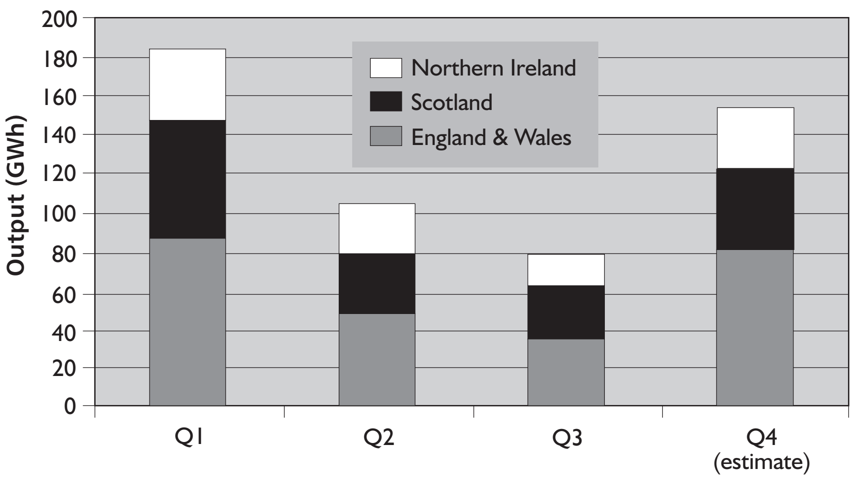


Figure 22.2 Wind energy output from current NFFO contracts during 2000

show that there are a large number of projects that could be developed.

To take forward the objective of getting more local involvement and ownership of environmental policy in 1999, the Government requested that the regions come forward with regional strategies and targets for renewable energy. These were to follow after an examination of the local resources and a full consultation with local groups of what can be 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 for this process to be complete by the end of 2000. Although studies of regional renewable energy resources are underway in many regions, none were completed or published as of December 2000.

Another positive step with regard to planning was the publication of new Scottish Planning Guidance for renewables. The wind industry has welcomed this—the guidance is generally positive in tone and has removed the requirement for wind farms to be approved by the Secretary of State, a step which delayed projects.

A new development for obtaining consent for wind farms this year is that, for the first time, developers have chosen to apply for consent to build very large wind schemes, with an installed capacity of more than 50 MW. All electricity-generating projects over 50 MW go through a different consenting mechanism, via the Secretary of State for the DTI, rather than the local planning authority, although the authority is still consulted. Decisions on these consents are expected in 2001.

Another constraint for onshore and off-shore wind deployment in the UK is the effect that wind farms may have on aviation, both in terms of navigational systems (radar) and low flying aircraft. There is a working group on wind farms and their impact on aviation interests that includes representatives from defense and civil aviation groups as well as DTI and UK industry. The aim of the working group is to provide information and advice to developers, planners, military, and civil aviation personnel on potential effects.

The transition from the Renewables Orders to the Renewables Obligation may cause a hiatus in further deployment, particularly for offshore schemes. This may be exacerbated by the uncertainty over how well wind energy will fare in the new electricity market in England and Wales. The New Electricity Trading Arrangements (NETA) will be introduced in 2001 and replace the Pool. The difference in the market, which affects small generators in general and wind energy in particular, is that it is structured to penalize unpredictable generation, either more or less than predicted. Generators are to declare their expected output three and a half hours prior to the trading (generating) period. It is not possible to estimate the effect that NETA might have on the price available for wind energy until the new market is operational for some time.

On the positive side, the Government recognized the difficulties that embedded generators (small generators connected to the distribution network, mostly renewables and combined heat and power) face; and in March 2000, the Government set up a working group to consider a range of issues and what could be done about them. The group is expected to report and make recommendations early in 2001.

22.6 ECONOMICS

22.6.1 Trends in Investment

1. Type of funding available

Finance for wind farms is obtained largely from corporate investors and banks, although there is a small amount of private investment. There has been no direct public funding available for capital investment in wind farms. The premium prices from the Renewables Energy Orders were considered sufficient incentive. Changes to the electricity trading system and support mechanism for renewables will need to be fully understood before any new phase begins in either corporate or individual investment.

The Government has announced that some limited capital grant funding for offshore wind schemes will be available beginning in 2001. This is in recognition of the fact that, while offshore wind is expected to make a significant contribution to renewable energy targets, electricity from offshore wind will be more expensive initially than that from the more established renewables. It will also be difficult for off-shore wind to compete on price under the Renewables Obligation. Grants will be assigned competitively, and the maximum level of funding will be 40%. A register for expressions of interest in the grants will be opened in January 2001, and competition is due to be closed by the end of the year. Grants are expected to be announced in September 2002.

2. Typical financial interest rates

Interest rates from 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 between 15% and 25%. Clearly, these figures can vary considerably from project to project. However, many of the recent developments are financed from the balance sheets 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

Table 22.2 shows the progressive reduction in the contract prices for generation for successive Renewable Energy Order tranches. It should be stressed that the contract period for the first two NFFO rounds lasted only until 1998, which meant that developers had between four and six years to recoup their investment. The comparatively high contract prices awarded during these first two rounds were designed to ensure that repayment on investment could be achieved in a short time.

Later rounds of NFFO and the SRO allowed a more reasonable planning window of five years, followed by 15-year, index-linked contracts. These figures show that, in real terms, contract prices have fallen in line with Government policy. Specific provision was made to encourage the development of smaller projects by landowners and other developers with limited resources. The higher costs associated with this approach are reflected in the higher contract prices awarded for the small bands in the last three NFFO tranches and the third round of the SRO.

Given the short time elapsed since the final two rounds of the NFFO, it is not surprising that few of these wind farms have been commissioned to date (see Table 22.1). The competitive system of the NFFO and SRO has undoubtedly achieved convergence with the market price for electricity. Whether developers can build wind farms at the low contract prices awarded in NFFO-4, NFFO-5, and SRO-3 rounds has yet to be fully demonstrated.

It is difficult to predict the price available to wind generators under the new Obligation. Generators will have two separate products to sell: the electricity (with the additional value of exemption from the Climate Change Levy) and the Renewable Obligation

Table 22.2 Contracted capacity and prices for wind energy schemes awarded UK Renewable Energy Orders

TRANCHE	EFFECTIVE START DATE	CONTRACTED CAPACITY (MW INSTALLED)	NO. OF SCHEMES CONTRACTED	PRICE RANGE p/kWh	AVERAGE PRICE p/kWh
NFFO-1	1990	28.0	9	10.0*1	—
NFFO-2	1992	196.0	49	11.0*2	—
NFFO-3 (>3.8 MW)	1995	339.0	31	3.98–4.80	4.32
NFFO-3 (<3.8 MW)	1995	46.0	24	4.49–5.99	5.29
NFFO-4 (>1.8 MW)	1997	768.0	48	3.11–3.80	3.53
NFFO-4 (<1.8 MW)	1997	24.0	17	4.09–4.95	4.57
NFFO-5 (>2.4 MW)	1998	768.0	33	2.43–3.10	2.88
NFFO-5 (<2.4 MW)	1998	67.0	36	3.40–4.60	4.18
SRO-1	1995	106.0	12	3.79–4.17	3.99
SRO-2	1997	101.0	7	2.74–2.94	2.86
SRO-3 (>2.3 MW)	1999	148.0	11	1.89–2.19	2.02
SRO-3 (<2.3 MW)	1999	33.0	17	2.63–3.38	3.04
NI-NFFO1	1994	29.0	6	N/A*3	N/A*3
NI-NFFO2	1996	6.0	2	N/A*3	N/A*3

*1Only the highest successful bid price was published for NFFO-1.

*2In NFFO-2 a single maximum strike price was offered to all contracts in the wind band.

*3Not available. For NI-NFFO-1 and -2 only the average price for all sucessful schemes was published – this was 6p/kWh for NI-NFFO-1 and 4p/kWh for NI-NFFO-2.

certificate. The value of the former depends on general electricity market prices (NETA is expected to reduce prices significantly) and the penalty that wind suffers from being unpredictable. The value of the latter depends on the demand for certificates and where the buy-out price is set.

22.7 INDUSTRY

22.7.1 Manufacturing

The UK 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 relatively static home market. The new support mechanism for renewables in the UK, and the expectation of increasing offshore development, offer better prospects at home in the medium term—and some export markets look buoyant.

During the year 2000, NEG-Micon reorganized all its UK interests as one company, named Aerolaminates Ltd. It opened a new blade manufacturing facility on the Isle of Wight, and the complete hub assembly center at Thorpe, Surrey, went into full operation. The latter produces 2-MW hubs intended primarily for offshore turbines.

UK small-scale turbine manufacturers continue to do well. The market for Marlec Engineering's small turbines (25 W to 340 W) is growing modestly and the market for Proven's larger products (500 W to 6 kW) is estimated to grow 30% to 40% per year.

The UK 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 UK industry is dominated by developers, the most prominent of which have much larger parent companies. An increasing number of UK utilities are becoming involved and developing their own skills in-house. 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 UK. Activity is particularly high in the Irish Republic, France, and the United States, but there are interest areas as far as China, Australia, the Caribbean, and other European countries. In 2000, a subsidiary of Renewable Energy Systems, one of the UK's largest developers, signed a contract to design and build what could become the largest wind farm in the world—a 160-MW project in Texas, USA.

There is growing interest in offshore investment, which has attracted new companies to the industry. The oil sector in particular is now forming partnerships with wind industry developers to exploit this resource. Companies with expertise in offshore engineering, construction, and provision of services are beginning to develop new business in this sector, including wind farm installations in other key European markets. For example, the UK marine contractor Seacore has made an agreement with NEG-Micon to collaborate on offshore installations.

22.8 GOVERNMENT SPONSORED R, D&D

Around 319,000.00 GBP was spent on the wind program area of the DTI's R&D Programme on New and Renewable Energy in 2000. The UK Government intends to increase the budget for support of renewables from 11.5 million GBP in 1999/2000, to 14 million GBP in 2000/2001 and 18 million GBP in 2001/2002. The proportion of these budgets assigned to wind energy has yet to be decided and will depend partially on the level of activity of the industry in the UK.

22.8.1 Priorities

The Government program continues to support a cost-shared program with industry, but as the technology achieves maturity, and is subject to the renewables review currently being undertaken, the trend is toward decreasing contributions from Government in the onshore technology. Greater attention is now being directed to the development of the offshore resource, which includes consents procedures; environmental considerations, including preliminary monitoring and technical innovation to develop foundations; and installation technology.

A series of generic projects were initiated or completed during 2000 to address barriers to deployment. These included onshore noise propagation; offshore noise effects; and other offshore environmental issues, including the effect on birds and coastal processes.

22.8.2 New R, D&D Developments

New projects to take effect in 2001 include: work on wind farm output forecasting techniques (to increase the value of wind energy under NETA) and examination of the issues in producing larger blades to be used on the multi-MW machines. Technical monitoring of the offshore farm at Blyth Harbour is expected to shed light on key issues for offshore wind because this site has interesting conditions, including a high tidal range and waves that break on the turbines.

22.8.3 Offshore Siting

The developer Border Wind, in collaboration with an oil company and a utility company, commissioned the UK's first offshore wind development in December 2000. The two 2-MW turbines are situated 1 km off the Northumberland port of Blyth, which is 15 km north of Newcastle-upon-Tyne. A picture of the wind farm is shown in Figure 22.3. Installation was delayed by bad weather but occurred without any major technical difficulties.

Figure 22.3 Blyth Harbour offshore wind farm

Crown Estates, who own the seabed around the UK to the territorial limit, announced the procedures for assigning leases for offshore wind farms in December. This will be a three-stage procedure: prequalification, site allocation, and the grant of an agreement for lease. The agreement for lease will give the applicant a three-year option on a lease, the lease itself being for 22 years. The first stage of this process should be completed by the end of March 2001 and the allocation of sites concluded by the end of May 2001.

Discussion has continued in 2000 between the relevant Government departments on the consenting procedure for offshore wind, and an announcement is expected early in 2001.

Author: Fiona Brocklehurst and Ian Fletcher, United Kingdom

CHAPTER 23

23.1 INTRODUCTION

Wind energy has been one of the fastest growing new sources of electricity generation for the last several years in the United States. This report describes 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) programs and their role in leading efforts to develop new wind energy technology that will be economically competitive with other electricity sources, without the need for subsidies.

23.2 NATIONAL POLICY

The Energy Policy Act of 1992, Public Law 102-486, provides the broad authority for the energy programs and policies in the United States. This legislation—with subsequent amendments, modifications, and extensions—is the primary basis for continuing research and development on wind and many other energy technologies, incentives for electricity production from renewable energy sources, and other DOE energy programs. The Wind Energy Program, conducted by the DOE, is focused on research and development efforts to help U.S. industry develop wind energy technology as an economically viable energy supply option that is competitive in the growing domestic and global markets. The Renewable Energy Production Incentive and Production Tax Credit, established by the Energy Policy Act of 1992, are designed to increase the use of wind and other renewable energy resources.

In the United States, deregulation of the electric power business is increasing competition and providing new options for consumers. To support the adoption of wind and other renewable energy sources, a variety of new policies and incentives are being promoted. Federal and state government agencies are expanding renewable energy use and incentive programs, many of which include wind systems. These agencies include the U.S. Department of Defense (DOD), Environmental Protection Agency (EPA), Agency for International Development (AID), and a growing number of state and local governments.

Environmental policy considerations are also driving wind development. The 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. Under that legislation, power plants are required to limit emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), and other emissions. This has had the effect of increasing the demand for wind power and other clean energy technologies.

23.2.1 Strategy

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. National laboratories operated by DOE conduct research for the wind program that is implemented with industry, electric utilities, universities, and other research organization partners that are selected through open competition. New technology developed under the DOE program is field tested, evaluated, and performance-verified in cooperative projects that are cost-shared by commercial users.

The DOE Wind Powering America initiative, begun in 1999, was designed and implemented to help facilitate the transition of wind energy technology into commercial markets. The five focus areas involved in the initiative follow.

1. Federal Green Power: Using wind and other renewable energy technologies to fulfill requirements for purchasing electricity from clean energy sources for use by U.S. government-owned facilities.

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. Power Partnerships: Working with power generators and suppliers to encourage them to install clean generating capacity, as well as working with large customers that are considering the purchase of clean power.

4. State-Level Support: Holding workshops on clean energy technologies and their benefits, and providing technical analysis and the information necessary for developing plans to include wind and other renewable energy sources in the power generation mix. This includes ensuring that clean energy sources receive balanced consideration during deregulation negotiations. This is especially important on issues relating to the operation and allocation of electricity transmission system resources and charges for ancillary services.

5. Outreach and Technical Support: Providing technical assistance on various 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 generated power.

Large-scale, grid-connected wind power plants are expected to continue to be the dominant application, but distributed generation is becoming increasingly important. The DOE is supporting this trend by expanding the development of small turbines, and by field testing wind turbines in projects in locations that would be impractical to connect to the national power grid. In addition, individual turbines and small clusters of machines are being installed by individual farmers, ranch owners, and now commercial merchant power producers dispersed throughout the grid system.

23.2.2 National Targets

Under the Wind Powering America initiative, goals for wind energy development in the United States have been established. These targets may be revised periodically depending on 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. Based on current projections for continuing progress on technology development programs, combined with financial incentives and outcomes of the Wind Powering America initiative, the following are the targets for wind power.

- Provide at least 5% of the nation's electricity from wind by 2020 with 10,000 MW online by 2010 and 80,000 MW by 2020.
- Double the number of states with more than 20 MW installed to 16 by 2005 and to 24 by 2010.
- Provide 5% of electricity used by the federal government (the largest single consumer of electricity in the United States) by 2010 (1,000 MW).

These goals directly support broader DOE strategic plans and objectives. Because wind resources are abundant and widely available in many parts of the country, and because the cost of wind power has dropped dramatically, wind energy is expected to play a key role in meeting Departmental objectives to increase energy security with resource diversification, emphasizing domestic sources.

23.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

Commercial implementation of wind power is directly dependent on the prevailing cost of electricity, growth in demand for electricity, and existing incentives to use conventional or renewable energy sources. These factors vary significantly and depend on the commercial domestic energy market segments, which are also evolving differently. Nationally, the average price for electricity is 0.067 USD/kWh and is essentially unchanged from 1999. Some states have much higher rates, up to 0.138 USD in Hawaii, and others are as low as 0.041 USD/kWh in Idaho. Generally, residential rates are highest, averaging 0.082 USD/kWh, and industrial rates are lowest, averaging 0.044 USD/kWh. California has the ninth highest residential rate, with an average of 0.107 USD/kWh. A discussion of the three distinct wind power market segments follows.

23.3.1 Large-Scale, Grid-Connected Wind Power Plants

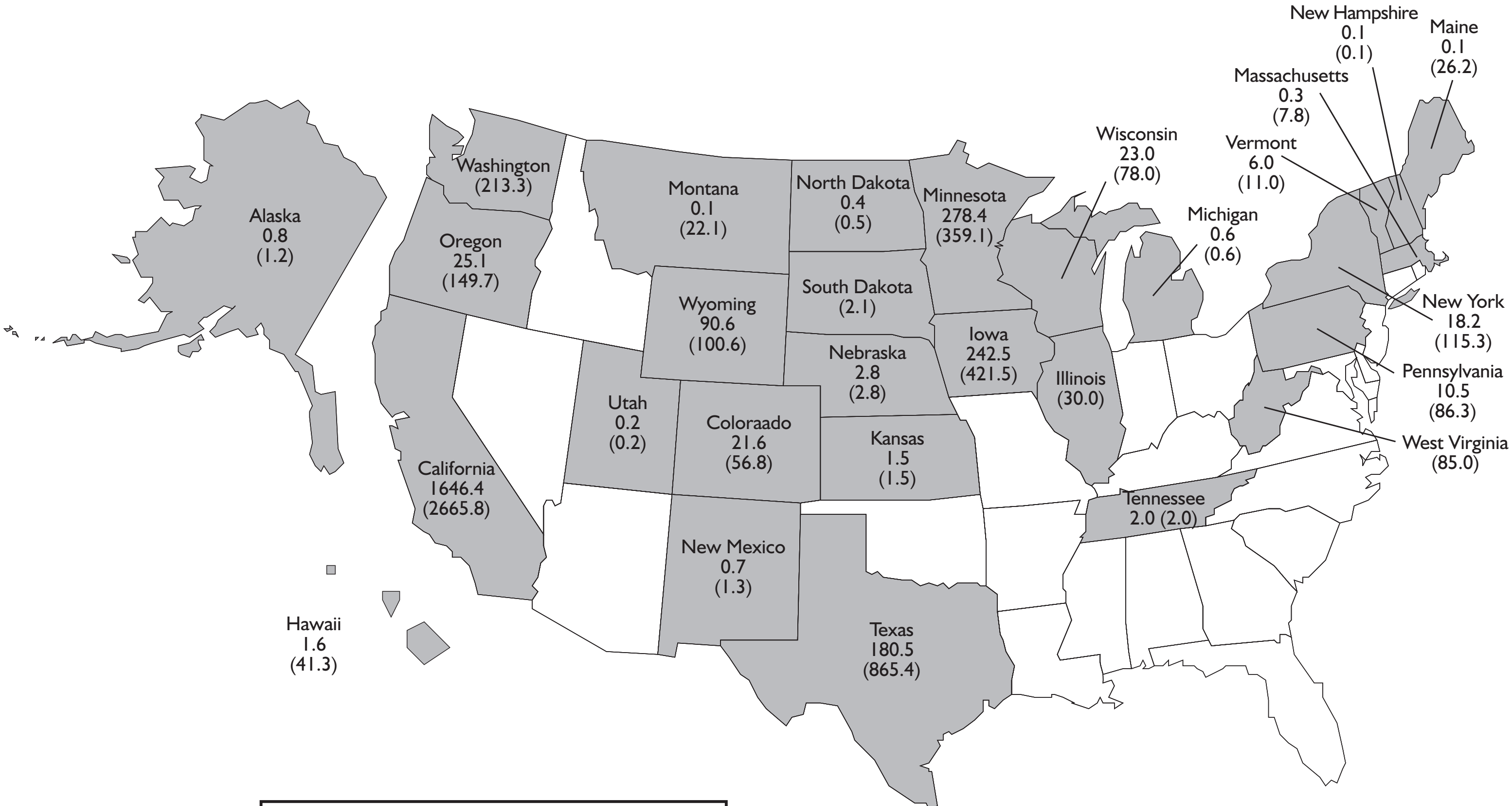
Large-scale, grid-connected wind power plants are the fastest growing market segment for the wind power business, and the growth is accelerating at an unprecedented rate. The national wind energy Production Tax Credit, combined with technology improvements, had been a catalyst for much of the growth in prior years. This tax credit expired in June 1999, but on 17 December 1999, it was retroactively extended through December 2001. This extension, combined with incentives at the state level and the emergence of deregulated power markets, has caused a surge in new wind project starts. Although it has taken some time for new projects to be developed and contracts issued, large-scale commercial installation of wind plants is now underway in many parts of the country.

During the year 2000, total installed capacity in the United States increased a modest amount, from 2,455 MW to about 2,554 MW. However, many new projects were started that are expected to add at least 2,700 MW of wind plants by the end of 2001, raising installed capacity to over 5,200 MW. This includes repowering some 400 MW of older plants by replacing outdated machines that will be removed from service. Figure 23.1 shows the current and projected distribution of wind power plant capacity across the United States. During 2000, wind power plants produced an estimated 6 TWh of electricity, which is less than 0.2% of national electric demand.

Regional development of wind power plants is influenced by local and state policies, and the additional price consumers are willing to pay for "green power." For example, in Pennsylvania's deregulated power market, green electricity products are being offered at prices ranging from 0.055 to 0.071 USD/kWh. The average price for consumers in the state during 2000 was approximately 0.064 USD/kWh. Figure 23.2 shows a 10.4-MW wind power plant located in Garrett County, Pennsylvania, with eight 1.3-MW Nordex turbines producing power for Green Mountain Energy Company. Several additional, larger plants are being built to supply this green power market.

23.3.2 Distributed Generation Wind Power

Distributed generation wind power is another emerging market segment. Although most of the wind power development in the United States is comprised of wind power plants ranging between 10 and



2,554 MW on-line as of 12/31/00
5,256 MW projected by 12/31/01*

*State estimates for end of 2001 are shown in parenthesis

Figure 23.1 Wind power plant installed capacity in the United States at the end of 2000 and projected by the end of 2001

Figure 23.2 The 10-MW wind power plant located in Garrett County, Pennsylvania

200 MW or more, there is increasing interest from businesses, farms, and landowners to install individual turbines or small clusters of machines to provide electricity for nearby loads. These grid-connected turbines range in size from 10 kW to over 1 MW. In some states, favorable "net billing" policies are in place that permit wind turbine owners to sell power to the grid for the same retail price as purchased power. In most cases, net billing is limited to installations under 100 kW, and if the net generation exceeds the customer's monthly electricity demand, then the price for the excess is usually the utility's avoided cost.

Distributed generation could account for 20% or more of new installations coming online in the next ten years. A study on the technical and economic issues in this market segment was completed in October 2000 for the National Wind Coordinating Committee. Study results showed that utilities in the United States have had little experience dealing with single turbines or small clusters of machines connected to their distribution lines. In some instances, distributed generation could reduce line losses and delay, or eliminate the addition of power distribution facilities needed to serve growing loads or to provide voltage support on weak lines. More often, however, distributed generation will provide modest-to-no power system benefits and may require reinforcement of the distribution grid.

23.3.3 Wind-Diesel Hybrid Power

Wind-diesel hybrid power for isolated communities is another growth market for wind power. Many locations are not connected to the electric power grid, so the use of wind can alleviate concerns over fuel cost, availability, delivery, and the environment. In Kotzebue, Alaska, a wind project has been operating successfully for three years. At this site, ten 65-kW Atlantic Orient Corporation (AOC) wind turbines have been connected to the isolated grid system, along with six existing diesel-powered generators, totaling 11 MW. Despite the severe arctic weather, turbine availability has been over 98%, and each wind turbine is saving over 6,000 gallons of diesel fuel annually. Two additional AOC turbines have been installed in the community of Wales, Alaska. This isolated village is located 177 km northwest of Nome, Alaska, and 80 km east of Russia and sees some of the strongest, steadiest winds in the state. This wind plant project is designed to evaluate the use of thermal sinks and batteries to store excess wind energy to provide heat and power during low wind periods. The wind system is expected to provide more than half of the electricity needs of the 165 residents of Wales.

23.4 MARKET DEVELOPMENT AND STIMULATION

Individual state policies and incentives are having an increasing influence on regional development of wind power. An increasing variety of approaches are being developed at both the 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-year) benefits and/or penalties, and freedom for suppliers and consumers to choose among the various renewable energy technologies.

23.4.1 Mechanisms Stimulating Wind Energy Markets

The following are examples of important mechanisms that are helping to expand wind energy use.

Wind energy production tax credit

A tax credit is available from the federal government for energy produced from wind and several other renewable energy sources. Under this program, a commercial wind plant owner is allowed a production tax credit of 0.017 USD/kWh, produced over a ten-year period and indexed to inflation. These plants must be brought online prior to 31 December 2001. This important incentive is one of the key drivers for the surge in wind plant development currently underway, and there are discussions of possible extension of the December deadline. In addition, some states also offer sales and property tax relief.

Renewable energy production incentive

For municipal utilities that do not pay taxes to the federal government, there is an incentive payment available from the DOE. Much like the tax credit described above, applicants can receive a payment of 0.017 USD/kWh produced over a ten-year period (indexed to inflation) for plants brought online prior to 31 December 2001. This payment is subject to available funding.

Green power purchasing choices

In an increasing number of states, residential and commercial customers can choose to purchase electricity from environmentally benign or so-called "green" sources. Many companies that are large power consumers are beginning to embrace green energy. One partnership, called the Green Power Market Development Group, is working to develop 1,000 MW of new "green" energy capacity. Companies in this consortium include DuPont, General Motors, IBM, Interface, Johnson & Johnson, Kinko's, and Pitney Bowes. Typically, a small premium is paid for green power that depends on the renewable resource and on the supplier. For wind power, the premium is as low as 0.01 USD/kWh, with an average of approximately 0.025 USD/kWh for all renewable technologies. More information is available from the "Green Power Network" at www.eren.doe.gov/greenpower. Green electricity rates and products are described and evaluated at www.powerscorecard.org.

Green Tag program

A new "Green Tag" program is being implemented in Pennsylvania and several other states and by the federal government. A green tag is an indirect way for a consumer to purchase power produced from renewable energy sources (See Figure 23.3). Under this program, the existing arrangement for power delivery does not change. The customer buying a green tag is

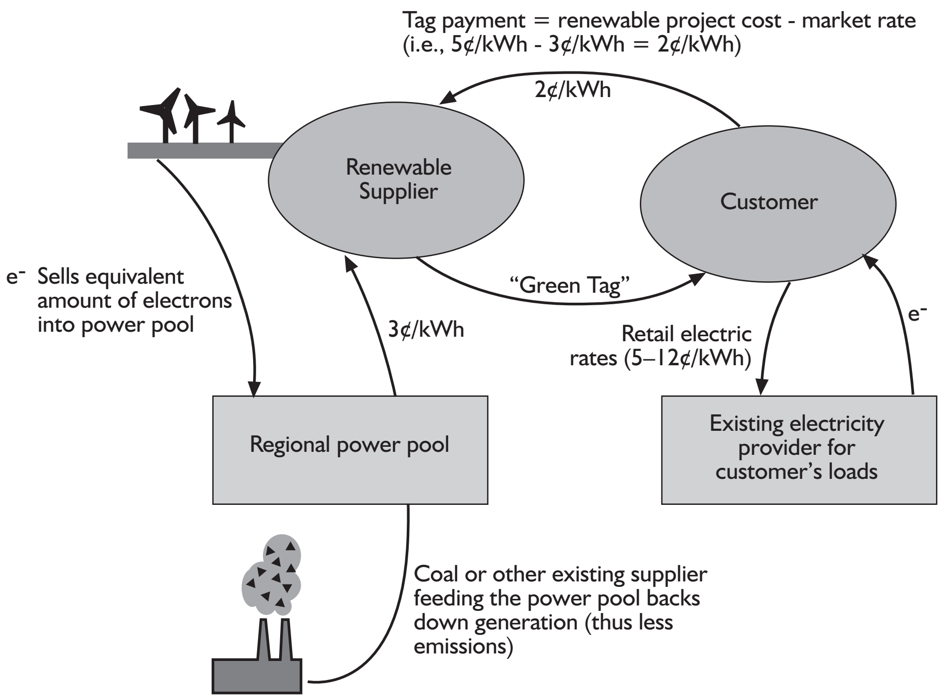


Figure 23.3 "Green tags" business and trading structure

merely purchasing 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 (separate from green attributes) at market price. As a result, green power is purchased and fed into the pool, thus avoiding an equivalent amount of fossil-fueled generation.

Renewable Energy Portfolio Standards

Some states are implementing requirements that a portion of the energy being sold by utilities come from renewables. In Texas, a Renewable Energy Portfolio Standard requires that 2000 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 are short. This Renewable Credits Trading Program will start 1 January 2002, and 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.

Rural economic development

Farmers and ranch owners in the United States are finding it attractive to harvest wind along with other crops. One U.S. farmer in the Midwest leases land to a developer for three 750-kW turbines. The machines occupy about 1.3 acres, including access roads, of his 100-acre farm. In return, the farmer receives 750 USD/yr per turbine, plus 2% of energy sales, for a total income of about 6,000 USD/yr.

Overall, distributed power generation can be good business for many farmers, and is a market that is expected to grow.

23.4.2 Cost Trends

Technology performance improvements resulting from R&D advances—complemented by increasing turbine production volume, larger size projects, and improved construction methods—are combining to reduce costs. Based on results from the DOE-Electric Power Research Institute (DOE/EPRI) assessment, Renewable Energy Technology Characterizations, and other data from commercial projects, turbine installations are currently estimated to cost between 850 and 1,220 USD/kW. This estimate includes both the turbines and 30 to 50 USD/kW electrical system interconnection and substation cost.

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, the power transmission and distribution systems 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 hydropower 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 are factored in. 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 in the range of 6 to 6.5 m/s (measured at 10 m above ground).

Environmental concerns can also be an issue in 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 landowners 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

The DOE Wind Systems Program has made major progress in reducing the cost of wind-generated electricity, but important targets have been set for further improvements. Since 1980, the cost of energy from wind systems has been reduced from 0.35 USD/ kWh (in 1980 dollars) to 0.04 to 0.06 USD/kWh today, at good wind sites and without including subsidies. Commercial project financing costs are assumed to be around 7.5% annual return on debt, and about 13% or less return on equity—both are considered to be reasonable rates for an established power generating company. But the cost of power purchased from wind plants varies widely, depending on the wind resource, state rules and incentives, project location, terrain, and project financial structure.

Future wind energy costs are projected to be among the lowest of five renewable energy technologies studied recently by the DOE and the EPRI. By 2010, wind is expected to be comparable to geothermal and hydro power and have the lowest Cost of Energy (COE), at 0.025 to 0.031 USD/kWh, compared to other intermittent technologies (e.g., solar thermal and photovoltaics) with similar project financing assumptions. The basis for these estimates and the projected evolution of wind and other renewable energy systems are discussed in a report titled, Renewable Energy Technology Characterizations, available on the DOE Office of Power Technologies web site at www.eren.doe.gov.

Growing demand for electricity in states like California is also benefitting the wind energy industry. The fact that wind plants can be installed and operating in less than a year increases their value significantly. Because electricity spot market prices can be extremely high during peak demand periods, in some cases over 0.35 USD/kWh in California, the excellent correlation between peak winds and maximum demand for electricity is increasingly important. For example, in Solano County, California, the peak wind period occurs during summer months and is nearly coincident with the peak yearly demand.

Until recently, the market for wind power was limited by low-cost power produced in plants using coal or natural gas. For the past several years, many power plants have switched from coal to cleaner natural gas. In addition, the EPA and state environmental agencies are increasing enforcement of the Clean Air Act, which limits emissions from many sources including electric power plants. Under that legislation, power plants are required to limit emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), and other emissions. This has had the effect of increasing the demand and the price for gas. The spot price for natural gas rose from 2.20 USD/thousand cubic ft in January 2000 to over 6 USD/thousand cubic ft this year. This price rise makes wind energy more cost competitive; and, more importantly, wind is immune to the price fluctuations associated with traditional fuels.

23.7 INDUSTRY

Six U.S. companies 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.

Some of the larger European wind turbine manufacturers are establishing assembly plants and plan to do component manufacturing in the Midwest. The Danish firm NEG Micon has opened a large turbine assembly facility in Illinois, and Vestas is considering similar options. In addition, LM Glasfiber is now building rotor blades in the United States. Projects are also being developed in Europe and Asia with turbines manufactured under licenses by American Companies. For example, Enron Wind Corporation, a subsidiary of Enron Corporation, opened its first wind turbine factory in Noblejas, Castilla-La Mancha, Spain. The factory, which began operation in June 2000 building 750-kW turbines, will have an annual production capacity of 720 MW and employ 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 and 10-kW turbines.

23.8 DOE-SPONSORED PROGRAMS

Key elements in the DOE Wind Energy Program and current fiscal year funding are shown in Figure 23.4. The program funding was 40 million USD in fiscal year 2001.

23.8.1 Priorities

The emphasis of the DOE Wind Energy Program has been research and technology development. The program is structured with the following three elements:

1. Applied Research: To develop the basic wind energy sciences and technology.

KEY ACTIVITIES	APPLIED RESEARCH	TURBINE RESEARCH	COOPERATIVE RESEARCH & TESTING
Elements	• Aerodynamics • Structural dynamics • Materials • Hybrid systems	• Industry partnerships for advanced turbines 5kW to 1.5 MW • Field verification	• National Wind Technology Center • Industry support • Certification testing and support • Wind plant monitoring • Wind farm monitoring
Fiscal Year 2001 Budget ($ millions)	15.0	12.4	12.6

Figure 23.4 Funding for the DOE Wind Energy Program for fiscal year 2001

2 Turbine Research: To develop and test advanced wind turbines in various sizes from less than 10 kW to more than 1 MW.

3. Cooperative Research and Testing: To support industry in resolving near-term technical issues, field verification testing and certification of new wind energy systems and technology, and the Wind Powering America Program.

R&D efforts are focused at the National Wind Technology Center (NWTC), at the National Renewable Energy Laboratory, located in Golden, Colorado, with support from the Sandia National Laboratories, Albuquerque, New Mexico. The NWTC has staff, laboratory facilities, and equipment to conduct research and wind turbine system and component certification testing. Both Sandia and the NWTC conduct in-house and contracted research, development, and testing for the DOE and U.S. industry.

23.8.2 Research and Development Programs

1. Applied research

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 research and design code validation is an area of emphasis. A series of key experiments were recently conducted by NREL in the wind tunnel at the National Aeronautics and Space Administration (NASA) Ames Laboratory in California. A 30-foot diameter, 19-kW, experimental wind turbine was tested in different configurations in the 80 x 120-foot section of the open throat wind tunnel in June 2000. The NASA tunnel, shown in Figure 23.5, is normally used for testing full-scale models of subsonic aircraft.

Aerodynamic research groups from around the world were invited to participate in the NREL/NASA tunnel test using a "blind comparison" method for verifying load prediction capabilities of various aerodynamics computer models. Research teams involving 30 individuals from 18 organizations (12 European) generated performance predictions using different models of the experimental wind turbine. Participants were surprised by preliminary results, which indicate substantial differences between various codes some significant deviations from measured wind tunnel test results. More disconcerting was the scatter evident under supposedly easy-to-predict typical turbine operating conditions (e.g., no-yaw, steady-state,

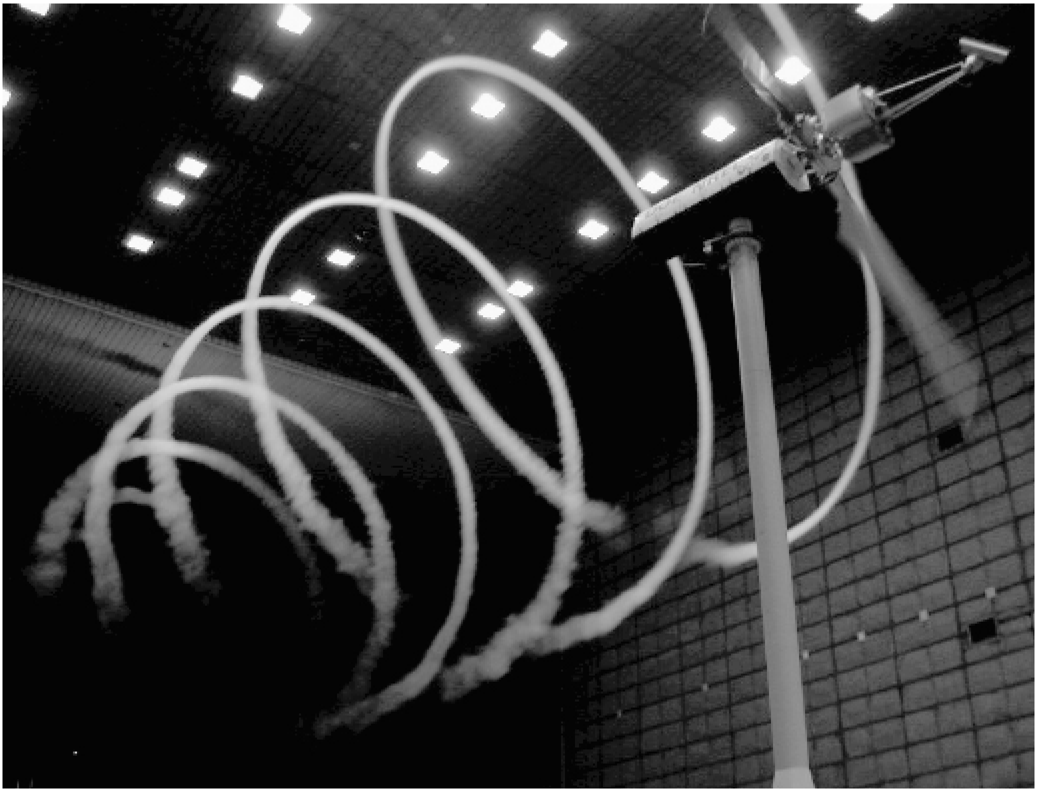


Figure 23.5 Experimental wind turbine airflow visualization study in NASA Ames 80 x 120-foot wind tunnel

attached-flow) for which power predictions ranged from 25% to 175% of measured values, and blade bending from 85% to 150% of measured values. Results are still being analyzed and consideration is being given to possibly continuing the collaboration under an IEA Task.

Another element of the DOE Applied Research program is a joint research task underway between NREL and Sandia Laboratories, called the Long-term Inflow and Structural Test (LIST) Program to test effects of atmospheric turbulence and wind shear on blade structures. Comprehensive measurements are planned on two full-scale turbine rotors, in an effort to relate types of atmospheric events to blade fatigue damage. A full season of wind data will be collected at two sites with different wind regimes, one on a small turbine located on flat terrain in Texas and the second on a larger machine located at the NWTC.

In 1999, the DOE began WindPACT, or Wind Partnerships for Advanced Component Technologies, to support development of new high-risk technologies. Current studies are focused on advanced flexible rotors and new drive trains, and on better methods for manufacturing, transporting, and installing wind turbines. Preliminary results of this research at the national laboratories and by several teams of contractors will be completed during 2001. The most promising concepts will be selected for component fabrication and operational testing.

2. Turbine research

The role of turbine research activity is to provide an opportunity for U.S. industry to apply the new technology and design tools resulting from applied research in developing advanced technology wind turbines. This role is implemented through close partnerships between the Wind Program's National Laboratories and U.S. companies via competitively awarded, cost-shared turbine development subcontracts. These subcontracts include research and development of wind systems for a variety of applications and in different turbine sizes from 5 kW to over 1 MW.

The program goal for utility-scale, grid-connected wind power systems is to develop proven technology by 2003 that is capable of producing electricity at a cost of 0.025 USD/kWh, at good wind sites with 6.7 m/s (15 MPH) average wind speed measured at 10 m height and with low-cost financing. This cost of energy target includes all turbine, land lease, and balance-of-station costs for a 50-MW wind power plant project located near power transmission lines. For the DOE small turbine development program, the cost goal is to significantly reduce the cost of energy from machines with peak power ratings from 5 kW down to 50 kW. Specific machine goals depend on the type of turbine and the planned operating environment and application requirements.

Subcontracts to develop and test next-generation turbines are in place with Enron Wind, Inc. in Tehachapi, California, and the Wind Turbine Company in Belleview, Washington. Each company will cost-share about 30% of their 20 million USD contracts.

The Wind Turbine Company machine has a unique down-wind rotor design with individually hinged blades. A sub-scale proof-of-concept turbine has been installed at the NWTC, and has been undergoing testing since April 2000.

Enron's new variable-speed, 1.5-MW turbine incorporates advanced electronics and aerodynamics that capture significantly more energy than constant-speed wind turbines, at a lower cost. While constant-speed rotors must be designed to resist high loads when subjected to wind gusts, Enron's variable-speed PowerMax system enables the loads from the gusts to be absorbed and converted to electric power. By adjusting blade pitch through the turbines' variable pitch operation, rotor speed is controlled. Generator torque is controlled through the frequency converter. This combined control strategy allows higher rotor rpm in strong, gusty winds, thereby reducing torque loads in the drive train.

NWTC engineers performed power performance and quality tests on Enron's new machine (see Figure 23.6), which is installed at the Enron wind power plant in Tehachapi, California. Test results show that the 1.5-MW turbine met and exceeded its power curve projections, and it generates high-quality power that is fully compliant with the Institute of Electrical and Electronic Engineers-519 power quality requirements. In addition, acoustic noise tests performed by an outside contractor report that the machine is the quietest in its class.

Enron's 1.5-MW turbine will be the first of its size class to be produced commercially

Figure 23.6 Enron Wind 1.5-MW turbine located near Tehachapi, California

in the United States. By the end of 2001, Enron expects to have installed 350 of these machines in domestic projects.

Five companies are developing smaller turbines for both grid-connected and off-grid power generation. The companies selected under the DOE program to develop the new machines are: Southwest Windpower in Flagstaff, Arizona, for a 6-kW turbine (the design was acquired from World Power Technologies, Inc.); the Atlantic Orient Corporation in Norwich, Vermont, for an 8-kW turbine (acquired from WindLite Company) and for improvement of their 50-kW machine; and Bergey Windpower from Norman, Oklahoma, for a 50-kW turbine (See Figure 23.7). Northern Power Systems, located in Moretown, Vermont, is developing an innovative, direct drive, 100-kW turbine under a cooperative program between NASA, the National Science Foundation, and the DOE. This machine is being designed for use in the frigid environments of northern Alaska and Antarctica. The unique turbine design was recognized by R&D Magazine as one of the top three of the best 100 new products chosen for "technological significance."

Figure 23.7 Bergey 50-kW turbine rendering

3. Cooperative Research and Testing activity

Cooperative Research and Testing activity includes a wide range of 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 recently awarded to industry, electric utilities, and state energy offices to encourage development of wind power in a variety of applications in projects in ten states.

The wind Turbine Verification Program (TVP) is another continuing collaborative effort of the DOE, the EPRI, and host utilities and operators. The TVP program began in 1992, and currently supports seven wind projects at U.S. locations that represent a range of site characteristics, new wind turbine designs, and operation and maintenance approaches. The wind projects are located in Ft. Davis, Texas; Searsburg, Vermont; Glenmore, Wisconsin; Algona, Iowa; Springview, Nebraska; Kotzebue, Alaska; and Big Spring, Texas. The wind turbines in these TVP projects include twelve 500-kW Zond Z-40A, eleven 550-kW Zond Z-40FS, five 750-kW Zond Z-50s, two 600-kW Tacke 600e, ten 66-kW AOC 15/50, forty-two 660-kW Vestas V47, and four 1.65-MW Vestas V66 turbines. Additional information on the TVP, including specific information from each project, is available from EPRI at www.epri.com.

The NWTC works closely with the International Energy Agency (IEA) to develop recommended practices, and with the International Electrotechnical Commission (IEC) to develop appropriate international standards and testing procedures. In addition, NWTC is now an accredited testing laboratory for certification of wind turbines for international markets.

Although there are currently no domestic requirements for turbine certification in the United States, the NWTC is now accredited by the American Association of Laboratory Accreditation for conducting wind turbine power performance, structures, and noise certification testing. The certification test results from NWTC 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. industries' machines. UL has completed, 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 Northern Power 100-kW turbine.

23.8.3 Offshore Siting

Offshore installations of wind plants are being considered in New England, but no plants have been built to date.

Authors: Stanley D. Calvert, DOE; Susan M. Hock, NWTC; Daniel F. Ancona, Princeton Energy Resources International, United States.

Attendees of the 46th Executive Committee meeting in Naples, Italy.

APPENDIX A

APPENDIX B

IEA R&D EXECUTIVE COMMITTEE 2000
M = Member A = Alternate Member

CHAIR		Mr. J. 't HOOFT (Jaap) NOVEM P.O. Box 8242 3503 RE UTRECHT THE NETHERLANDS	Tel +31 30 2393 468 Fax +31 30 2316 491 Email: j.t.hooft@novem.nl
SECRETARY		Ms. P. WEIS-TAYLOR (Patricia) PWT Communications 5191 Ellsworth Pl. BOULDER, CO 80303 USA	Tel +1 303 545 2068 Fax +1 303 413 1924 Email: PWTCommunications @compuserve.com
AUSTRALIA	M	Mr. R. STEWART (Rob) Hydro TASMANIA GPO Box 355D HOBART, TASMANIA 7001	Tel +61 36 2305 272 Fax +61 36 2305 266 Email: robert.stewart@ hydro.com.au
AUSTRIA	M	Prof. H. DETTER Forchungszentrum Seibersdorf Arbeitsgebiet Erneuerbare Energie Sterneckstraae 15a 9020 KLAGENFURT AUSTRIA	
CANADA	M	Mr. R.S. RANGI (Raj) Natural Resources Canada CANMET/EAETB 580 Booth Street, 13th Floor OTTAWA, ON CANADA K1A OE4	Tel + 1 613 992 9672 Fax + 1 613 996 9416 Email: raj.rangi@ nrcan.gc.ca
	A	Mr. M. OPRISAN (Morel) Natural Resources Canada CANMET/EAETB 580 Booth Street, 13th Floor OTTAWA, ON CANADA K1A OE4	Tel +1 613 992 8599 Fax + 1 613 996 9416 Email: morel.oprisan@ nrcan.gc.ca
DENMARK	M	Mr. P.H. MADSEN (Peter Hauge) Risø National Laboratory P.O. Box 49 DK-4000 ROSKILDE DENMARK	Tel +45 46775011 Fax +45 46775970 Email: peter.hauge@ risoe.dk
	A	Mr. J. LEMMING (Joergen) Danish Energy Agency 44 Amaliegade Copenhagen 1256 DENMARK	Tel +45 33927507 Fax +45 33114743 Email: jle@ens.dk

EUROPEAN COMMISSION	M	Dr. S. FANTECHI (Sophia) European Commission Directorate-General for Research Rue de la Loi, 200-M075 B-1049 BRUXELLES, BELGIUM	Tel +32 2 295 6469 Fax +32 2 299 3694 EMAIL: sophia.fantechi@ cec.eu.int
	A	Mr. A. KOTRONAROS European Commission Directorate General for Transport and Energy Rue de la Loi 200 B-1049 BRUXELLES, BELGIUM	Tel +32 2 296 0060 Fax +32 2 295 0150 Email: alexandros. kotronaros@ cec.eu
FINLAND	M	Mr. J. WOLFF (Jonas) VTT Energy P.O. Box 1606 VTT, FINLAND	Tel +358 9 456 5790 Fax +358 9 456 6538 Email: jonas.wolff@vtt.fi
	A	Mr. E. PELTOLA (Esa) Kemijoki Arctic Technology P.O. Box 50 0048 Fortum, FINLAND	Tel +358 9 0529 8255 Fax +358 9 694 1846 Email: esa.peltola@vtt.fi
GERMANY	A	Dr. N. STUMP (Norbert) Forschungszentrum Jülich GmbH D-52425 JÜLICH, GERMANY	Tel +49 24 6161 4744 Fax +49 24 6161 2480 Email: n.stump@ Fz-juelich.de
GREECE	M	Mr. P. VIONIS (Pantelis) C.R.E.S. 19th km Marathonos Av. GR-190 09 PIKERMI, GREECE	Tel +30 1 6039 900 Fax +30 1 6039 905 Email: pvioni@cres.gr
	A	Dr. E. MORFIADAKIS (Evangelos) C.R.E.S. 19th km Marathonos Av. GR-109 09 PIKERMI, GREECE	Tel +30 1 6039 900 Fax +30 1 6039 905 Email: emorf@cres.gr
ITALY	M	Dr. C. CASALE (Claudio) CESI S.p.A. SFR-ERI Via Rubattino 54 20134 Milano ITALY	Tel +39 02 2125 5681 Fax +39 02 2125 5626 Email: ccasale@cesi.it
	M	Dr. L. BARRA (Luciano) ENEA Casaccia Via Anguillarese 301 I-00060 S. Maria di Galeria, ROME, ITALY	Tel +39 06 3048 3300 Fax +39 06 3048 4643 Email: barra@casaccia.enea.it

ITALY (continued)	A	Dr. L. PIRAZZI (Luciano) ENEA Casaccia Via Anguillarese 301 I-00060 S. Maria di Galeria, ROME, ITALY	Tel +39 06 3048 4328 Fax +39 06 3048 6452 Email: pirazzi@casaccia. enea.it
JAPAN	M	Mr. M. YONEKURA (Minoru) AIST, MITI Kasumigaseki 1-3-1 Chiyoda-ku TOKYO 100-8921, JAPAN	Tel +81 33501 9271 Fax +81 33501 9489 Email: yonekura-minoru @miti.go.jp
	A	Dr. H. MATSUMIYA (Hikaru) Mechanical Engineering Laboratory MITI 1-2 Namiki TSUKUBA 305-8564, JAPAN	Tel +81 29861 7237 Fax +81 29861 7275 Email: m1330@mel.go.jp
MEXICO	M	Mr. M.A. BORJA (Marco) IIE Avenida Reform 113 Col. Palmira, Temixco, MORELOS G.P. 62490, MEXICO	Tel +52 73 18 38 11, ext 7251 Fax +52 73 18 24 36 Email: maborja@iie.org.mx
NETHERLANDS	MEMBER IS CHAIR		
	A	Mr. L.G.J. JANSSEN (Bert) ECN P.O. Box 1 1755 ZG PETTEN (NH) NETHERLANDS	Tel +31 224 564 664 Fax +31 224 563 214 Email: l.janssen@ecn.nl http://www.ecn.nl/
NEW ZEALAND	NO CONTACT INFORMATION AVAILABLE		
NORWAY	M	Mr. H. BIRKELAND (Harald) Norwegian Water Resources and Energy Directorate (NVE) Postbox 5091 Maj N 0301 OSLO, NORWAY	Tel +47 2295 9323 Fax +47 2295 9053 Email: hbi@nve.no
SPAIN	M	Mr. F. AVIA (Felix) CIEMAT Departamento de Energias Renovables Avda Complutense 22 280 40 MADRID, SPAIN	Tel +34 91 346 6422 Fax +34 91 346 6037 Email: felix.avia@ ciemat.es
	A	Mr. E. SORIA (Enrique) CIEMAT Departamento de Energias Renovables Avda Complutense 22 280 40 MADRID, SPAIN	Tel +34 91 346 6101 Fax +34 91 346 6037 Email: none

SWEDEN	M	Ms. S. PERSSON (Susann) Swedish National Energy Administration Box 104 S-6304 ESKILSTUNA, SWEDEN	Tel +46 16 544 2094 Fax +46 16 544 2261 Email: susann.persson@ stem.se
	A	Mr. K. AVERSTAD (Kenneth) Vattenfall AB Lokal Energi SE-162 87 STOCKHOLM, SWEDEN	Tel +46 8 739 66 72 Fax +46 8 739 58 22 Email: kenneth.averstad@ vattenfall.com
UNITED KINGDOM	M	Mr. D.M. BRAMBLE (David) Dept. of Trade and Industry 1 Victoria Street London SW1H OET, UNITED KINGDOM	Tel +44 20 7215 6481 Fax +44 20 7215 2674 Email: david.bramble@ dti.gov.uk
	A	Ms. C. MURRAY (Catherine) DTI 1 Victoria Street London SW1H OET, UNITED KINGDOM	Tel +44 20 7215 6153 Fax +44 20 7215 2674 Email: catherine.murry@ dti.gov.uk
UNITED STATES	M	Mr. P. GOLDMAN (Peter) Wind Energy Program EE-11 United States Department of Energy 1000 Independence Avenue, SW WASHINGTON, D.C. 20585 UNITED STATES	Tel +1 202 586 1995 Fax +1 202 586 5124 Email: peter.goldman@ hq.doe.gov
	A	Dr. R.W. THRESHER (Bob) National Renewable Energy Laboratory 1617 Cole Boulevard Golden, CO 80401 UNITED STATES	Tel +1 303 384 6922 Fax +1 303 384 6999 Email: robert_thresher@ nrel.gov

OPERATING AGENTS

ANNEX XI Base Technology Information Exchange

Mr. S-E THOR (sven-erik)
Aeronautical Institute of Sweden
FOI, Aeronautics, FFA
SE-172 90 Stockholm
SWEDEN
Tel +46 8 55 50 4370
Fax +46 8 253 481
Email: sven-erik.thor@foi.se

ANNEX XV Wind Energy Implementation Progress

Dr. I. FLETCHER (Ian)
Energy Technology Support Unit
B153 Harwell
DIDCOT
Oxfordshire OX11 OQJ
UNITED KINGDOM
Tel +44 01235 43 3266
Fax +44 01235 43 3434
Email: ian.fletcher@aeat.co.uk

ANNEX XVI Round Robin Test Program

Mr. H. LINK (Hal)
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401
UNITED STATES
Tel +1 303 384 6912
Fax +1 303 384 7053
Email: linkh@tcplink.nrel.gov

ANNEX XVII Database on Wind Characteristics

Mr. G. C. LARSEN (Gunner)
Risø National Laboratory
P.O. Box 49
DK-4000 Roskilde
DENMARK
Tel +45 4677 5056
Fax +45 4677 5083
Email: gunner.larsen@risoe.dk

ANNEX XVIII Enhanced Field Rotor Aerodynamic Database (EFRAD)

Mr. L.G.J. JANSSEN (Bert)
ECN Research Centre
P.O. Box 1
1755 ZG PETTEN (NH)
NETHERLANDS
Tel +31 224 564 664
Fax +31 224 563 214
Email: l.janssen@ecn.nl
hhtp://www.ecn.nl/

INTERNATIONAL ENERGY AGENCY

Mr. R. SELLERS (Rick)
Office of Energy Efficiency,
Technology and R&D
9, rue de la Federation
75739 PARIS Cedex 15
FRANCE
Tel. +33 1 4057-6563
Fax +33 1 4057-6759
Email: Rick.Sellers@iea.org

NEWSLETTER EDITOR

Mr. Marc CHAPPELL
MSC Enterprises
2029 Kilborn Ave.
Ottawa, Ontario
CANADA
Tel. +1 613 738 3312
Fax +1 613 738 3781
Email: chappell@sympatico.ca

APPENDIX C

Exchange rate average for 2000 calculated from monthly averages

COUNTRY	CURRENCY	RATE/USD	RATE/EURO
Australia	AUD	1.719	1.588
Canada	CND	1.486	1.372
Denmark	DKK	8.094	7.474
Finland	FIM	6.439	5.946
Germany	DDM	2.118	1.956
Greece	GRD	365.862	337.834
Italy	ITL	2096.911	1936.270
Japan	JPY	107.823	99.562
Mexico	MPS	9.459	8.734
Netherlands	NLG	2.468	2.204
New Zealand	NZD	2.189	2.022
Norway	NOK	8.811	8.136
Spain	SPP	186.323	166.386
Sweden	SEK	9.175	8.472
United Kingdom	GBP	0.660	0.609
United States	USD	1.000	0.923

Source: http://www.stls.frb.org/fred/data/exchange.html
Federal Reserve Bank of Saint Louis

PRODUCTION CREDITS

Technical Editors
Patricia Weis-Taylor
Michelle Dorsett

Cover Design
Joe Woodburn

Document Layout and Computer Graphics
Joe Woodburn

Produced for IEA R&D Wind by

National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

NREL is a U.S. Department of Energy National Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel
Contract Number DE-AC36-98-GO10337

For orders call +1 303 384-6963
Printing paid for by IEA

BK-500-29436
May 2001

IEA WIND ENERGY ANNUAL REPORT 2000

The value of wind energy to generate electricity has been increasingly recognized by governments across the world. As a result, worldwide growth of wind generation since reporting began in 1994 has proceeded at 30% per year or higher. This sustained growth in capacity of wind energy is being driven by improved technology, supportive government policies, and improved information about the advantages of wind energy. By the close of 2000, the global capacity of installed wind generation reached 17.6 gigawatts (1,000 megawatts, (GW)). The value of this global wind market in 2000 is estimated at around four billion US dollars.

The International Energy Agency Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind) was begun in 1977 to facilitate development of wind energy technology. Under this agreement, parties from 17 countries and the European Commission improve information exchange and collaborate in wind energy research and development. Within these member countries, the total installed wind generating capacity reached 15.4 GW in 2000, or 88% of global installed capacity. The detailed activities and policies within each member country, as well as the progress of the joint projects conducted during 2000, are reviewed in this Annual Report.

Produced for IEA R&D Wind by

NREL

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
United States of America