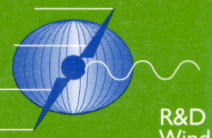
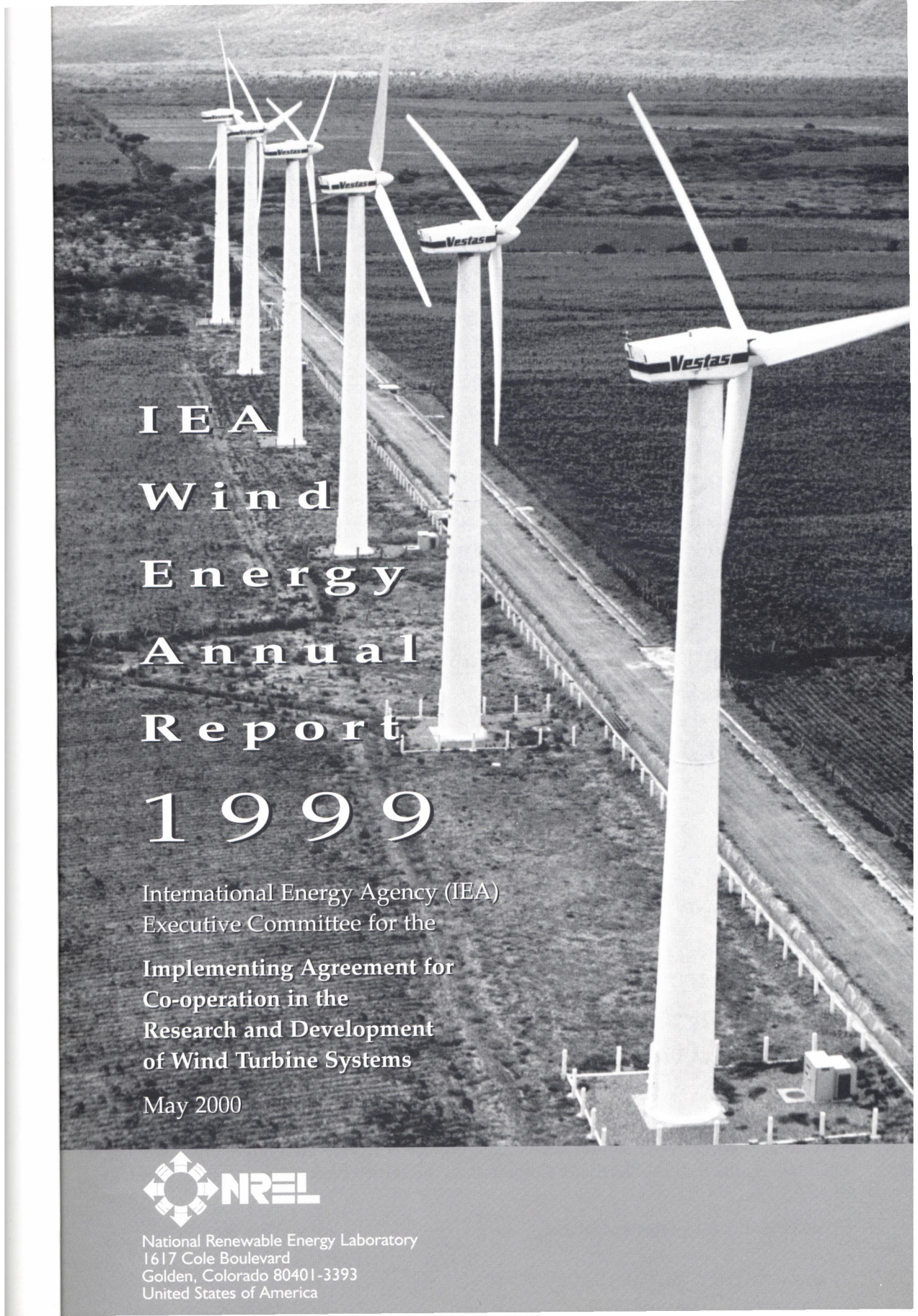


IEA
WIND
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ANNUAL
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1999

International
Energy
Agency



R&D
Wind



IEA
Wind
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Annual
Report
1999

International Energy Agency (IEA)
Executive Committee for the
Implementing Agreement for
Co-operation in the
Research and Development
of Wind Turbine Systems

May 2000



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

Cover Photo

This 1.5-MW wind power station at La Venta, Oaxaca, Mexico went on line in 1994. Operated by the Federal Electricity Commission, the station has a mean capacity factor of 40%.

Photo Credit: Raúl González Galarza

The International Energy Agency (IEA), was founded in November 1974 as an autonomous body within the Organization for Economic Co-operation and Development (OECD), to implement an international energy program. IEA carries out a comprehensive program of cooperation among 24 of the 29 OECD member countries.

This twenty-second IEA Wind Energy Annual Report reviews the progress during 1999 of the activities in the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems under the auspices of the 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.

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 (ExCo). It is edited by P. Weis-Taylor with contributions from experts from participating organizations in Australia, Canada, Denmark, the European Commission, 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

I. EXECUTIVE SUMMARY	1
II. THE IEA R&D WIND PROGRAM	5
1. The Implementing Agreement	5
2. Task XI - Base technology information exchange	8
3. Task XV - Annual review of progress in the implementation of wind energy by the IEA member countries	11
4. Task XVI - Wind turbine round robin test program	12
5. Task XVII - Database on wind characteristics	14
6. Task XVIII - Enhanced field rotor aerodynamic database	17
III. NATIONAL ACTIVITIES	21
7. Overview	21
8. Australia	29
9. Canada	43
10. Denmark	47
11. Finland	61
12. Germany	67
13. Greece	79
14. Italy	87
15. Japan	99
16. Mexico	107
17. The Netherlands	111
18. Norway	125
19. Spain	129
20. Sweden	137
21. United Kingdom	147
22. United States	157
23. European Commission	169
APPENDICES	173
A. The 43rd Executive Committee (photo)	173
B. List of Executive Committee Members, Alternate Members, and Operating Agents	175

CHAPTER 4—TASK XVI – WIND TURBINE ROUND ROBIN TEST PROGRAM

- Figure 4.1 The AOC 15/50 turbine being tested at the Atlantic Wind Test Site, Prince Edward Island, Canada13

CHAPTER 5—TASK XVII – DATABASE ON WIND CHARACTERISTICS

- Figure 5.1 Example of simultaneously extreme wind speed (down) gust and wind direction change identified using database search and analysis tools.15

CHAPTER 7—OVERVIEW

- Figure 7.1 IEA countries wind capacity from 1994 to 199821
- Figure 7.2 Wind energy market prices compared to industrial electricity prices23

CHAPTER 8—AUSTRALIA

- Figure 8.1 Target for new renewable electricity generation31
- Figure 8.2 Possible contribution to renewable generation target by source32
- Figure 8.3 Showcase installation at Denham, Australia (0.69MW)33
- Figure 8.4 Huxley Hill wind-diesel installation, Australia36
- Figure 8.5 Crookwell Wind Farm, Australia (5MW)36
- Figure 8.6 Yearly installed capacity of wind generation in Australia37
- Figure 8.7 Contribution of wind to national energy demand37

CHAPTER 10—DENMARK

- Figure 10.1 Development of specific investment defined as ex-works turbine price divided by annual production in roughness class 1.51
- Figure 10.2 Estimated costs of wind generated electricity in Denmark.55

CHAPTER 11—FINLAND

- Figure 11.1 Targets for renewable energy sources in Finland (Mtoe)61
- Figure 11.2 Targets for electricity production by RES (TWh)62
- Figure 11.3 Location of installed wind turbines in Finland63
- Figure 11.4 An overview of the 8-MW wind farm in Pori in the west of Finland66

	Page
CHAPTER 12—GERMANY	
Figure 12.1 WECS types by December 31, 1999	70
Figure 12.2 Failure and repair statistics for all WECs in the WMEP program ..	72
Figure 12.3 Full load hours “250 MW Wind”	76
CHAPTER 13—GREECE	
Figure 13.1 Total installed capacity in Greece by year	80
Figure 13.2 Electricity produced and capacity factor	81
Figure 13.3 This 1.2-MW wind farm on Milos island, consists of 2 Vestas V42 600-kW wind turbines.	84
CHAPTER 14—ITALY	
Figure 14.1 Trend of Italy’s installed wind capacity	90
Figure 14.2 Market shares of wind turbine manufacturers at the end of 1999	92
Figure 14.3 Contribution by electricity producers from wind at the end of 1999	93
Figure 14.4 Machine erection at the wind farm built by FilippoSanseverino near Castelfranco in Miscano (Campania) with 50 units totaling 30 MW	93
CHAPTER 15—JAPAN	
Figure 15.1 History of wind turbine capacity in Japan	100
Figure 15.2 Operational technical performance of Tappi Wind Park	102
Figure 15.3 Shukutsu Wind Power Generation System, Muroran City in Hokkaido	103
Figure 15.4 Shares among manufacturers in WTGS capacity (%)	103
CHAPTER 16—MEXICO	
Figure 16.1 Distribution of wind turbine installations in Mexico	107
CHAPTER 17—NETHERLANDS	
Figure 17.1 Installed, removed and operational wind capacity	113
Figure 17.2 Average capacity, area/power and hub height of installed turbines in the period 1987-1999	115
Figure 17.3 Wind farm of 11.4 MW consisting of 19 NEG-Micon 600-kW, 48m diameter turbines in typical farming country.	122
CHAPTER 18—NORWAY	
Figure 18.1 Wind energy capacity 1988-1999, [kW]	126
Figure 18.2 Spot market price of electricity 1997-1999	128

CHAPTER 19—SPAIN

- Figure 19.1 Cabanilles 30-MW Wind Farm
(50 wind turbines Ecotecnia 600 kW)129
- Figure 19.2 Total number of wind installations in Spain132

CHAPTER 20—SWEDEN

- Figure 20.1 Wind Power Generation (Gwh)138
- Figure 20.2 Wind Power Capacity (MW)139
- Figure 20.3 Unit costs in SEK/kW with wind power projects grouped
per capacity140
- Figure 20.4 Number of wind turbines of specific capacity in projects
in the investment subsidy program141
- Figure 20.5. (Photo) Reindeers in the vicinity of wind turbines
at the Härjedalen site144

CHAPTER 21—UNITED KINGDOM

- Figure 21.1 Technology contribution, assuming 10% of total 2010
electrical energy supplied from renewable sources148
- Figure 21.2 Wind turbine capacity and growth in the UK150
- Figure 21.3 Wind energy output during 1999152

CHAPTER 22—UNITED STATES

- Figure 22.1 This 193-MW wind power plant at Storm Lake, Iowa
uses Zond Energy Systems 750-kW turbines159
- Figure 22.2 States that have issued deregulation orders
and/or restructuring legislation as of October 1, 1999161
- Figure 22.3 U.S. DOE Wind Energy Program and Funding163
- Figure 22.4 New 2.0-MW wind turbine dynamometer
located at the National Wind Technology Center164
- Figure 22.5 Aerodynamics research wind flow visualization study test
at National Wind Technology Center165
- Figure 22.6 Inlet for the NASA Ames wind tunnel
being used for testing wind turbine rotor and blade configurations165
- Figure 22.7 Wind turbines under development by industry
with DOE/NREL support166
- Figure 22.8 This 250-kW proof-of-concept turbine
has hinged rotor blades168

CHAPTER 23—EUROPEAN COMMISSION

Figure 23.1 EESD Programme, first call for proposals 1999: number of supported projects per sector of RES (R and DEMO)	170
Figure 23.2 EESD Programme, first call for proposals 1999: distribution of funds per sector of RES (R and DEMO)	170
Figure 23.3 EESD Programme, first call for proposals 1999: distribution of research projects supported by FP5 in 1999	171
Figure 23.4 EESD Programme, first call for proposals 1999: distribution of support given by FP5 in 1999 to research projects	171
Figure 23.5 EESD Programme, first call for proposals 1999: support given to wind energy projects (key action 5 and key action 6 of the work programme)	171

CHAPTER 1—THE IMPLEMENTING AGREEMENT

Table 1.1 Contracting parties to the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems—1999	5
Table 1.2 Participation by country in current Tasks.	6
Table 1.3 IEA R&D Wind tasks defined in Annexes to the Implementing Agreement	7

CHAPTER 2—TASK XI – BASE TECHNOLOGY INFORMATION EXCHANGE

Table 2.1 List of documents in the series <i>Recommended Practices for Wind Turbine Testing and Evaluation</i>	9
Table 2.2 List of Topical Expert Meetings held since 1978	10

CHAPTER 7—OVERVIEW

Table 7.1 Status of national manufacturing industries	24
Table 7.2 Exchange rates as of December 31, 1999	26
Table 7.3 Capacity and output data	28

CHAPTER 8—AUSTRALIA

Table 8.1 Australian wind turbine installations at end of 1999 (over 20kW)	34
Table 8.2 Planned Australian wind turbine installations at the end of 1999	35
Table 8.3 Deployment by ownership and application.	40
Table 8.4 Deployment by State	40

CHAPTER 10—DENMARK

Table 10.1 Policy instruments used in 1998 to promote wind turbine technology and installations	47
Table 10.2 Estimated wind turbine capacity and production in Denmark	49
Table 10.3 Status for wind turbines in Denmark by the end of 1999	49
Table 10.4 Installed wind turbine capacity and development in size	50
Table 10.5 Bodies authorized by the Danish Energy Agency to provide services under the Danish scheme for certification and type-approvals for wind turbines (1999)	51
Table 10.6 Annual operational and maintenance costs in % of the investment in the wind turbine	53
Table 10.7 Cost of a 750 wind turbine project.	54
Table 10.8 Wind turbines (> 100 kW) on the Danish market. Energi-og Miljødata (EMD), Dec. 1999	56

CHAPTER 11—FINLAND

Table 11.1 Installed capacity and production of wind energy in Finland	62
Table 11.2. Number of new wind turbines in Finland installed each year	64

CHAPTER 12—GERMANY

Table 12.1 Development of wind power in Germany; “250 MW Wind” and total by December 31, 1999	68
Table 12.2 Regional distribution of wind energy utilization	69
Table 12.3 Ownership of WECS of “250 MW Wind” Program by January 1998 . .	71
Table 12.4 Market shares in Germany (DEWI), 1999	73
Table 12.5 New installations in October 1999, total 130 MW	74
Table 12.6 Recent energy R&D projects and the WMEP Phase III	77

CHAPTER 14—ITALY

Table 14.1 Deployment goals set by the Italian White Paper for renewable energy sources in the electricity sector	88
--	----

CHAPTER 15—JAPAN

Table 15.1 The new primary energy supply plan by 2010	99
Table 15.2 Installation of WTGS in Japan	101
Table 15.3 Recent and future national wind energy activities in Japan	104
Table 15.4 Budget for national wind energy projects in MJPY	105

CHAPTER 16—MEXICO

Table 16.1 Wind turbine installations in Mexico by the end of 1999	108
Table 16.2 Wind power plants in negotiation	109
Table 16.3 Average electricity prices in Mexico during 1999	110

CHAPTER 17—NETHERLANDS

Table 17.1 Renewable energy targets in annual avoided fossil primary energy (PJ)	111
Table 17.2 Rough estimate of installed capacity to meet the targets for wind energy	112
Table 17.3 Electricity production, avoided fuel and emissions	114
Table 17.4 Distribution of new wind turbines by manufacturer	115
Table 17.5 Size of wind farms installed in 1999	116
Table 17.6 Investment costs per kW, m ² and cumulative invested capital	118
Table 17.7 Tax rate	119
Table 17.8 Levels of R, D&D funding in the Netherlands 1991-1999 in NLG million	123

CHAPTER 18—NORWAY

Table 18.1 Norwegian wind turbines and their energy production	126
--	-----

CHAPTER 19—SPAIN

Table 19.1 Primary energy balance for 1998	129
Table 19.2 Estimate of future wind power installations	131
Table 19.3 Spain's installed wind power capacity	131
Table 19.4 Distribution by Autonomies (31/12/1999)	132
Table 19.5 Price comparison of renewable energies in Spain	133
Table 19.6 Spain's main centers involved in wind R&D projects	135

CHAPTER 20—SWEDEN

Table 20.1 Total installed electricity capacity and generation in Sweden 1999 . .	139
Table 20.2 Price of network service and electricity, excluding taxes, on January 1, 1999 in sales of electricity to various typical customers	142

CHAPTER 21—UNITED KINGDOM

Table 21.1 Size and timing of the renewable energy obligations	149
Table 21.2 Contracted capacity and process for wind energy schemes awarded UK Renewable Energy Orders	154

I. EXECUTIVE SUMMARY

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. In the more than 20 years since the Agreement began, modern wind energy systems have developed from preliminary concepts to commercial products. The development and use of wind energy has become possible and continues to advance thanks to vigorous efforts by each country in research, system deployment, demonstration, and financial incentives. By providing a flexible framework for cost-effective joint international research projects and information exchange, the IEA R&D Wind has played and continues to play an important role in the development of wind energy.

Since the inception of IEA R&D Wind, worldwide deployment of wind energy has expanded significantly. As IEA R&D Wind approaches its 23rd year, global deployment of wind power has risen to around 10,000 Megawatts (MW) with annual growth rates sometimes exceeding 33% per year.

Leadership in the manufacture of wind turbine generators has been assumed by the European wind industry. Several manufacturers in Europe are now building and shipping new turbines at the rate of one megawatt per day. Furthermore, in efforts to reduce pollution, many European countries have established higher than market prices to suppliers of electricity from wind turbines and offer other attractive financial incentives. These factors have accelerated the deployment of wind energy in Europe and make the European market for wind turbines very promising.

Countries around the world are building both new grid-connected wind power

plants and off-grid power projects. For example, the European Union's (EU) White Paper on Renewable Energy estimates that EU wind power installations will total more than 40,000 Megawatts (MW) by the end of 2010. The United States expects to have between 10,000 and 30,000 MW of wind power by 2010. Non-OECD countries such as India and China have also set challenging goals for wind energy utilization. With this rising global interest, the wind industry's sales in 1999 were estimated to be more than USD 2 billion.

The development and maturing of wind energy technology has resulted from evolutionary national programs. As national R&D programs have changed, the character of the cooperation within IEA R&D Wind has also been changing. For example, as countries have introduced substantial incentive programs to stimulate market development, IEA R&D Wind has developed tasks to promote information exchange on incentive and deployment issues. Also, advanced technology research is still needed to improve wind turbine performance and reduce costs.

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.

- Encourage cost-effective international cooperation on advanced wind energy related research and development.
- Exchange information and state-of-the-art assessments on wind energy technology, policy, and deployment.
- Extend 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, research, development, demonstration, and promotion of wind energy technology. They are concerned with work both within their own countries and elsewhere. A summary of progress in each country is given in the following Chapters.

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 countries both within and outside the Organization for Economic Cooperation and Development (OECD). This interest is being encouraged and prospective members attend IEA Wind Executive Committee (ExCo) meetings to observe first-hand the benefits of participation.

COLLABORATIVE ACTIVITIES

Participants in the IEA R&D Wind Agreement are currently working on five Tasks,

called Annexes, and several additional Tasks are being planned. To date, 11 Tasks have been successfully completed. 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. Some Tasks are a combination of cost- and task-shared work. Reviews of the progress in each active Task are given in Chapters 2 – 6. A brief account of the status of Tasks follows here. To obtain more information about these activities, contact the Operating Agent for each task. Contact information for Operating Agents is listed in Appendix B.

Task XI - Base Technology Information Exchange

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

There are two main activities of this Task.

1. 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.
2. To conduct Topical Expert Meetings and Joint Actions in specific research areas designated by the IEA R&D Wind Executive Committee (ExCo).

Members voted to extend the original Task through December 2001.

Recommended Practices

In 1999, the Experts Group on point wind speed measurements finalized a recommended practices document titled, "*Wind Speed Measurement and Use of Cup Anemometry.*"

Expert Meetings and Joint Actions

In 1999, the 13th symposium within the Joint Action on Aerodynamics of Wind Turbines was held in Stockholm, Sweden. IEA also supported the 32nd Meeting of Experts on the State-of-the-Art on Wind Energy Under Cold Climate Conditions in Helsinki, Finland.

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 three annual overviews of the progress in commercial development of wind turbine systems in the IEA R&D Wind member countries. The reports are intended for decision makers in government, planning authorities, the electricity supply industry, financial institutions, and the wind industry. A final report combining information for 1995, 1996, and 1997 was completed in 1999.

This task was extended to May 2001 by the ExCo.

TASK XVI - Wind turbine round robin test program

Operating Agent: National Renewable Energy Laboratory–NREL, United States.

The objectives of this program are to validate wind turbine testing procedures, analyze and resolve sources of discrepancies, and improve the testing methods and procedures. A standard turbine is undergoing tests at several different sites around the world. Preparation for testing includes drafting test plans, initiating anemometer wind tunnel calibrations, and initiating 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 1999. One at Canada's Atlantic Wind Test Site, one at the United States NREL National Wind Technology Center, and one in Denmark at RISØ. The turbine under test in Denmark was shipped to CRES in Greece for installation and testing in 1999. A status meeting was held to continue formalizing the test plan. The ExCo voted to extend work on this Task for another year.

TASK XVII - Database on wind characteristics

Operating Agent: RISØ National Laboratory, Denmark.

A new Task was begun in 1999 to extend, maintain, and make available a database on wind characteristics developed under a European Union project DG XII (JOULE). The database was developed by 14 institutes from 13 different European countries to provide wind turbine designers easy access to quality-controlled field data in a standardized format. In 1999, the database contained more than 53,000 hours of meteorological data from 23 sites in Europe and the U.S.

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 extensive use of the database can be expected for years to come. The work of Task XIV was documented in 1997 *Final Report of IEA Annex XIV: Field Rotor Aerodynamics*. As a result of the four years of work, a well-documented database of measured aerodynamic profile characteristics under three-dimensional, rotating atmospheric turbulent conditions is available on CD-ROM and is accessible on an ftp site at ECN.

In 1999, the database was extended and has been supplied to 11 outside parties conducting research on wind turbine aerodynamics.

EXECUTIVE COMMITTEE ACTIVITIES

Officers

J. 't Hooft (the Netherlands) served as Chair and F. Avia (Spain) served as Vice-Chair for 1999. J. 't Hooft and F. Avia were reelected. P. Goldman (United States) was elected to serve as Co-Vice-Chair.

Participants

In 1999, 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, representatives from France and Ireland attended ExCo meetings as observers.

Meetings

The Executive Committee meets twice a year for members to review ongoing Tasks; it reports on national wind energy research, development, and deployment activities (R, D&D); it identifies, plans, and manages cost-effective cooperative actions under the Agreement.

The 43rd ExCo meeting hosted by CIEMAT, was held in May 1999, in Madrid, Spain. There were 26 participants from 14 of the 19 contracting parties. A representative from IEA Headquarters attended the meetings.

The ExCo issued a press release through IEA headquarters announcing achievement of 10,000 MW of wind generating capacity. The Committee also approved a proposal to produce and distribute an annual newsletter.

The 44th ExCo meeting, hosted by IIE, was held in November 1999, in Cuernavaca, Mexico. There were 27 participants representing 12 of the 19 contracting parties.

Prior to the ExCo meeting, an all-day seminar sponsored jointly by the ExCo and the Electrical Research Institute of Mexico (IIE) was held Mexico City. The program addressed specific questions on

the implementation of wind energy in Mexico. The audience included representatives from the Ministry of Energy, the Energy Regulatory Commission, the Federal Electric Commission, the Federal Mexican Congress, the National Commission for Energy Conservation, the Ministry of Environment, the Electrical Research Institute, the Chamber of Electrical Industry, Private Companies, and Financial Institutions.

The ExCo Secretariat budget for 2000 was approved. The audit report for 1998 was accepted.

The Annual Report for 1998 was distributed to members.

On April 22, the Committee visited the Sierra Del Madero Wind Farm hosted by MADE, Tecnologias Renovables, S.A. in Spain. On November 13, the Committee visited the Instituto de Investigaciones Electricas (IIE) in Cuernavaca, Mexico.

CHAPTER I

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, 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 1999 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.

Table 1.1 Contracting parties to the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems—1999

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
Australia	x				
Canada	x		x		
Denmark	OA	x	x	OA	x
European Commission	x	x			
Finland	x				
Germany	x	x			
Greece	x	x	x		
Italy	x	x			
Japan		x			x
Mexico	x				
Netherlands	x	x		x	OA
New Zealand	x	x			
Norway	x	x		x	
Spain	x				
Sweden	x	x		x	
United Kingdom	x	OA			
United States	x	x	OA	x	x

Member countries also share the cost of administration for the governing body of the Agreement, the ExCo. The ExCo meets twice each year to exchange information on 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. 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. Some Tasks are organized as cost-shared and task-shared. 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 Operating Agent: The National Swedish Board for Energy Source Development Completed in 1981.
Task II	Evaluation of wind models for wind energy siting Operating Agent: U.S. Department of Energy - Battelle Pacific Northwest Laboratories Completed in 1983.
Task III	Integration of wind power into national electricity supply systems Operating Agent: Kernforschungsanlage Jülich GmbH, Germany Completed in 1983.
Task IV	Investigation of rotor stressing and smoothness of operation of large-scale wind energy conversion systems Operating Agent: Kernforschungsanlage Jülich GmbH, Germany Completed in 1980.
Task V	Study of wake effects behind single turbines and in wind turbine parks Operating Agent: Netherlands Energy Research Foundation Completed in 1984.
Task VI	Study of local flow at potential WECS hill sites Operating Agent: National Research Council of Canada Completed in 1985.
Task VII	Study of offshore WECS Operating Agent: UK Central Electricity Generating Board Completed in 1988.
Task VIII	Study of decentralized applications for wind energy Operating Agent: UK National Engineering Laboratory Technically completed in 1989. Final report published in 1994.
Task IX	Intensified study of wind turbine wake effects Operating Agent: UK National Power plc Completed in 1992.
Task X	Systems interaction Deferred indefinitely.
Task XI	Base technology information exchange Operating Agent: FFA, Sweden Continuing through 2001.
Task XII	Universal wind turbine for experiments (UNIWEX) Operating Agent: 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 Operating Agent: National Renewable Energy Laboratory (NREL), USA Completed in 1994. Final report published in 1995.
Task XIV	Field rotor aerodynamics Operating Agent: 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 Operating Agent: ETSU, on behalf of the United Kingdom Continuing through 2001.
Task XVI	Wind turbine round robin test program Operating Agent: the National Renewable Energy Laboratory (NREL), United States To be completed in 2000.
Task XVII	Database on wind characteristics Operating Agent: RISØ National Laboratory, Denmark. Continuing through 2001.
Task XVIII	Enhanced field rotor aerodynamics database Operating Agent: Netherlands Energy Research Foundation - ECN, the Netherlands Extend the database developed in Task XIV and disseminate the results. Continuing through 2001.

CHAPTER 2

Task XI - Base Technology Information Exchange

The objective of this Task is to promote wind turbine technology by cooperative activities and information exchange on R&D topics of common interest. These particular activities have been part of the Agreement since 1978, when they were carried out before the formal annex was adopted in 1987.

The task includes activities in two subtasks. The first subtask is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. For example, the Experts Group on wind speed measurements finalized a draft in 1998 and the document titled "Wind Speed Measurement and Use of Cup Anemometry" was published in 1999.

The second subtask is to conduct joint actions in specific research areas designated by the IEA R&D Wind Executive Committee. The Executive Committee sets up Joint Actions in research areas of current interest, where a periodic exchange of information is deemed necessary. 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 twenty-one years since these activities were initiated, 32 volumes of proceedings from Expert Meetings (Table 2.2), 13 volumes of proceedings from symposia on Aerodynamics of Wind

Turbines, five from symposia on Wind Turbine Fatigue, and two from symposia on Wind Characteristics have been published. In the series of Recommended Practices, 11 documents have come out. Five of these have appeared in revised editions (Table 2.1).

The Annex was extended in 1999 for the years 2000 and 2001. From January 1, 2000, a new Operating Agent is taking over. The Technical University of Denmark is being replaced by FFA, Sweden, with Sven-Erik Thor as the person in charge.

In 1999, four meetings have taken place. The 32nd Expert Meeting on Wind Energy under Cold Climate Conditions was held in Helsinki, Finland with 13 participants from seven countries. Eleven presentations were made. The Second Symposium on Wind Characteristics took place at RISØ National Laboratory, Denmark. Twelve papers were presented by 11 participants from five countries. The 5th Symposium on Wind Turbine Fatigue was held at DTU Delft, the Netherlands with 14 participants from four countries and 10 presentations given, and finally the 13th Symposium on Aerodynamics of Wind Turbines took place at FFA, Stockholm, Sweden. Here 19 participants from six countries were present, and 15 papers were presented.

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

The Operating Agent of Annex XI also acts as the official IEA observer on Technical Committee No. 88, Wind Turbine Generator Systems, of the International Electrotechnical Commission (IEC TC88). The IEC is an international body, which generates

Table 2.1 List of documents in the series *Recommended Practices for Wind Turbine Testing and Evaluation*

VOLUME	TITLE	1ST ED.	2ND ED.	3RD ED.
1	POWER PERFORMANCE TESTING Describes in detail in what way measurements shall be performed in order to get correct power curve for a wind turbine.	1982	1990	
2	ESTIMATION OF COST OF ENERGY FROM WIND ENERGY CONVERSION SYSTEMS States all the various elements and assumptions that enter a cost calculation.	1983	1994	
3	FATIGUE LOAD CHARACTERISTICS The correct procedure is described for getting a valid estimate of the fatigue life for the components of a wind turbine.	1984	1989	
4	MEASUREMENT OF NOISE EMISSION Noise being one of the potential nuisances caused by a wind turbine, the correct measurement of noise output is vital.	1984	1988	1994
5	ELECTROMAGNETIC INTERFERENCE This other possible source of disturbance caused by a wind turbine must be evaluated carefully and accurately.	1986		
6	STRUCTURAL SAFETY Outlines a rational procedure for setting up standards of safety.	1988		
7	QUALITY OF POWER The quality of the power output from a wind turbine needs to be described unambiguously.	1984		
8	GLOSSARY OF TERMS A comprehensive collection is compiled of the special terms used in the trade, with their proper definitions.	1987	1993	
9	LIGHTNING PROTECTION OF WIND TURBINE GENERATOR SYSTEMS	1997		
10	NOISE IMMISSION MEASUREMENTS	1997		
11	WIND SPEED MEASUREMENT AND USE OF CUP ANEMOMETERS	1999		

international standards in cooperation with ISO. The standards which are emerging often take the IEA Recommended Practices as precursors.

Author: B. Maribo Pedersen, DTU, Denmark

Table 2.2 List of Topical Expert Meetings held since 1978

32	Wind energy under cold climate conditions	22-23 Mar 1999	Helsinki, Finland
31	State of the art on wind resource estimation	29-30 Oct 1998	Lyngby, Denmark
30	Power performance assessments	8-9 Dec 1997	Athens, Greece
29	Aero-acoustic noise of wind turbines	17-18 Mar 1997	Milano, Italy
28	State of the art of aeroelastic codes for wind turbines	11-12 Apr 1996	Lyngby, Denmark
27	Current R&D needs in wind energy technology	11-12 Sept 1995	Utrecht, Netherlands
26	Lightning protection of wind turbine generator systems and EMC problems in the associated control systems	8-9 Mar 1994	Milan, Italy
25	Increased loads in wind power stations	3-4 May 1993	Gothenburg, Sweden
24	Wind conditions for wind turbine design	29-30 Apr 1993	Risø, Denmark
23	Fatigue of wind turbines, full-scale blade testing	15-16 Oct 1992	Golden, Colorado,
22	Effects of environment on wind turbine safety and performance	16-17 June 1992	Wilhelmshaven, Germany
21	Electrical systems for wind turbines with constant or variable speed	7-8 Oct 1991	Gothenburg, Sweden
20	Wind characteristics of relevance for wind turbine design	7-8 Mar 1991	Stockholm, Sweden
19	Wind turbine control systems—strategy and problems	3-4 May 1990	London, England
18	Noise generating mechanisms for wind turbines	27-28 Nov 1989	Petten, Netherlands
17	Integrating wind turbines into utility power systems	11-12 Apr 1989	Herndon, USA
16	Requirements for safety systems for LS WECS	17-18 Oct 1988	Rome, Italy
15	General planning and environmental issues of LS WECS installations	2 Dec 1987	Hamburg, Germany
14	Modelling of atmospheric turbulence for use in WECS rotor loading calculations	4-5 Dec 1985	Stockholm, Sweden
13	Economic aspects of wind turbines	30-31 May 1985	Petten, Netherlands
12	Aerodynamic calculation methods for WECS	29-30 Oct 1984	Copenhagen, Denmark
11	General environmental aspects	7-9 May 1984	Munich, Germany
10	Utility and operational experience from major wind installations	12-14 Oct 1983	Palo Alto, California
9	Structural design criteria for LS WECS	7-8 Mar 1983	Greenford, UK
8	Safety assurance and quality control of LS WECS during assembly, erection and acceptance testing	26-27 May 1982	Stockholm, Sweden
7	Costing of wind turbines	8-19 Nov 1981	Copenhagen, Denmark
6	Reliability and maintenance problems of LS WECS	29-30 Apr 1981	Aalborg, Denmark
5	Environmental and safety aspects of the present LS WECS	25-26 Sept 1980	Munich, Germany
4	Rotor blade technology with special respect to fatigue design	21-22 Apr 1980	Stockholm, Sweden
3	Data acquisition and analysis for LS WECS	26-27 Sept 1979	Blowing Rock, USA
2	Control of LS WECS and adaptation of wind electricity to the network	4 Apr 1979	Copenhagen, Denmark
1	Seminar on structural dynamics	12 Oct 1978	Munich, Germany

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. ETSU, on behalf of the United Kingdom, is the Operating Agent for this Task.

3.1 OBJECTIVE

The objective of this Task is 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 annual review is based on the annual national reports submitted to the Executive Committee. A summary of progress in the implementation of wind energy during 1999 is included in this Annual Report, and a full review will be published shortly afterwards as a stand-alone document, with references to the annual report, for those seeking more detailed information. A final report will be prepared after three years on completion of the Annex.

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 e l'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 also 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, 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, 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 Wind Energy Agreement was approved with a starting date of

April 1996. After the program kickoff meeting, in April 1996, participants began detailed preparations for testing. These included drafting of test plans, initiation of anemometer wind tunnel calibrations, and initiation of 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 are being calibrated in ten wind tunnels. Final calibrations have been completed but the results have not been made available. Annex participants agreed to conduct a follow-on calibration of anemometers at CRES. These tests were complete in March 1999 and portions of the results were presented at the European Wind Energy Conference in Nice. The principal investigator of this phase of testing, Dr. Kostas Papadopoulos, is planning on submitting 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 in 2000.

The Standard Turbine is an AOC 15/50, a 50 kW, free-yaw turbine that is relatively easy to transport and install. Participants will complete tests on three of these turbines, one at Canada's AWTS, one at the United States' National Wind Technology Center at NREL, and one at two test stations in Europe. The first two turbines have been in operation for several years with both NREL and AWTS engineers having completed several

operational tests of their turbines. NREL has also completed noise, power performance, and structural loads testing of their turbine. AWTS plans to complete power performance and loads testing by spring 2000.

The third turbine was shipped to Denmark and began operation at RISØ in early December 1997. RISØ completed power performance and loads tests in June 1998. The turbine was then shipped to CRES where testing is scheduled to begin in February 2000 and be completed by spring 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 2000. The Executive Committee has approved two, one-year extensions for the Annex to accommodate the delayed production of the European test turbine and to accommodate the change in test sites from ENEA to CRES. Final reports are expected to be completed by October 2000.

Some comparisons of test results have begun. However, detailed investigations are not planned until tests at AWTS, CRES, and NREL are completed in 2000.

Author: Hal Link, NREL, United States



Figure 4.1 The AOC 15/50 turbine being tested at the Atlantic Wind Test Site, Prince Edward Island, Canada

CHAPTER 5

Task XVII – Database on Wind Characteristics

5.1 INTRODUCTION

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

As a follow-up to the JOULE project, Task XVII (also known as Annex XVII), within the auspices of the IEA, has been formulated with Sweden, Norway, U.S.A., The Netherlands, (Japan) and Denmark as active participants. The Annex was initiated on 1 January 1999, and will remain in force for an initial period of two and a half years.

The main purpose of this Annex is to provide wind energy planners, designers and researchers, as well as the international wind engineering community in general, with a source of actual wind field time series observed in a wide range of different wind climates and terrain types. For convenience all available data are presented in a common format.

5.2 OBJECTIVES

The objective of Annex XVII is to maintain and extend the database, and in addition, to disseminate the knowledge of it. The work is organized into three work tasks:

- a. Maintain the database in order to ensure that the data, as well as the hardware and software, will also be on-line and available;
- b. Extend the database developed in the JOULE-project;

- c. Disseminate the knowledge of the database and the possibilities for use of the data.

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

5.3 STATUS

Presently, the database contains more than 53,000 hours of meteorological data from 23 sites in Europe and the U.S., representing a wide variety of wind climates, terrain types and wind turbine wake situations. The data have a typical temporal resolution of 1-20 Hz and are thus mainly intended for investigations of design wind loads and phenomenological studies. On top of that, an advanced data selection system is supplied that fully utilizes the interactive nature of the World Wide Web. Tools are provided for simple data analysis (i.e. analyses of wind speed gusts, wind direction gusts and studies of wind shear); data presentation (on-line plot facility); and download of time series for further processing.

An example is presented in Figure 5.1 of simultaneously extreme wind speed (down) gust and wind direction change identified by use of the database search/analysis tools.

5.3.1 Maintenance

The maintenance of the database includes both routine software updates and routine hardware updates. In 1999, the JukeBox software was upgraded and reconditioned and a new hard disc was installed on the Web-server.

5.3.2 Extension

This work task comprises the development of the database in a broad sense. It includes development of the software facilities as well as implementation of

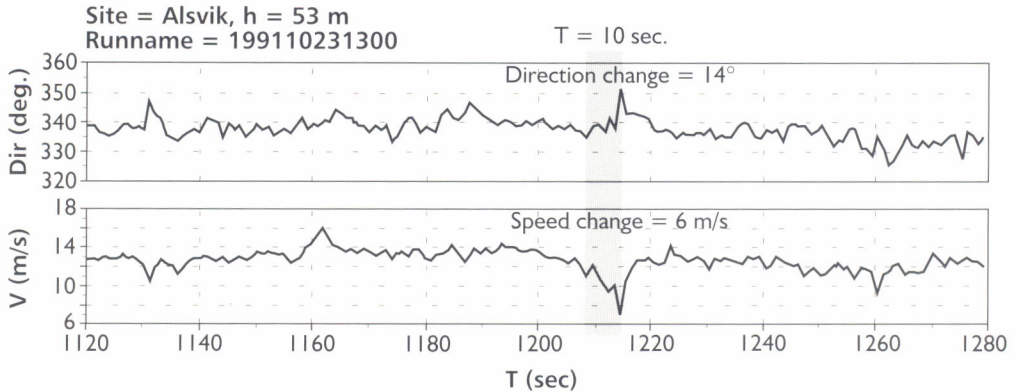


Figure 5.1 Example of simultaneously extreme wind speed (down) gust and wind direction change identified using database search and analysis tools.

meteorological data from new sites and extension of available data from existing sites. The effort performed within upgrade of the database facilities as well as within extension of the amount of available wind field time series is outlined below.

Database Utilities:

- Design and implementation of a new version of the Web server pages;
- Organization and implementation of the fee system associated with user registration including limitation of ftp-server access to registered users;
- Implementation of a new data quality element aimed at identifying time series in which the signal displays periodically fall out;
- Implementation of a new site search facility, which, in addition to conventional search tools, includes access to a number of (boolean) data quality specifications;
- Implementation of an on-line plot facility;
- Update and preparation of the Dbwind.exe software, which is responsible for multiple downloads from the ftp-server, for registered users only.

Database Bank:

- Implementation of Oak Creek data (1825 hours of high wind data from a complex terrain site in U.S.);
- Implementation of 13,174 hours of measurements (including very high winds) from the Skipheia site in Norway;
- Implementation of 3D sonic wind speed measurements and wave height measurements from the Danish Vindeby off-shore site;
- Implementation of 405 hours of meteorological data from the Scottish wind farm Windy Standard.

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 Annex XVII has a high priority. The following initiatives have been taken in 1999:

- Presentation of the paper "<http://www.winddata.com/>" at European Wind Energy Conference, Nice, 1-5 March 1999. In addition, two other papers at the same conference were partly based on data originating from the database.

Finally, the database has been demonstrated at the RISØ exhibition stand at EWEC on the 3rd of March 1999.

- Preparation of a leaflet describing the database and its potential. This leaflet has subsequently been distributed at the European Wind Energy Conference, Nice, 1-5 March 1999, at the 10th International Conference on Wind Engineering, 21-24 June, 1999, Copenhagen and at the Windpower'99 conference, Burlington, Vermont, U.S.A., June 20-23, 1999;
- Mailing of a detailed report on the database (Hansen, K. S. and Courtney, M. S. (1999): Database on Wind Characteristics) to selected organizations.
- Presentation of the database at the OWEN workshop on off-shore wind energy at CLRC Rutherford Appleton Laboratory in Oxfordshire U.K., 8th of November, 1999;
- Presentation of the database at 19th IMTS at Ciemat, Madrid, Spain, 18-19 October, 1999;
- Description of "Database on Wind Characteristics" and Annex XVII distributed on AWEA's mailing list;
- "Database on Wind Characteristics" has been utilized in a number of ongoing research projects (the JOULE project NewGust and a national Danish project on non-Gaussian turbulence). Moreover RISØ and Technical University of Denmark have applied for funding for two national projects in which the data base plays an prominent role;
- The database has also been utilized in a master dissertation on simulation of low cycle variations in electrical grids with wind turbines connected up (DTU), and in a PhD. work on non-linear time series analysis and phase space methods of non-linear dynamics (Max Planck

Institute for Physics of Complex Systems, Dresden, Germany).

The database is available on the Web server (and the use is free of charge for users from IEA Annex XVII participating countries.

Authors: Gunner. C. Larsen, RISØ National Laboratory; and Kurt S. Hansen, DTU, Denmark

CHAPTER 6

Task XVIII – Enhanced Field Rotor Aerodynamic Database

6.1 INTRODUCTION/OBJECTIVE

IEA Annex XVIII is an extension of the IEA Annex XIV project in which five parties (DUT, ECN, NREL, RISO, 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 [1]. In conventional measurement programs, the aerodynamic behavior of a wind turbine has to be analyzed by means of measurements of integrated, total (blade or rotor) loads. These loads consist of an aerodynamic and a mass induced component and they are integrated over a certain spanwise length. This gives only indirect information about the aerodynamics at the blade element level.

The supply of local aerodynamic measurements, as carried out in Annex XIV, is a major step forward in understanding the aerodynamic behavior of wind turbines. Note that the main emphasis was on understanding the aerodynamic behavior at stalled conditions. The IEA Annex XIV database is stored on CD-ROM and on an ftp-site, which is protected by a password. The CD-ROM and/or the password are available for outside parties under the condition that they inform the IEA Annex XIV participants about experiences gained with the database. In October 1999 the database has been supplied to:

- Garrad Hassan and Partners (UK)
- OFFA (Sw)
- University of Glasgow (UK)

- University of Illinois (USA)
- University of Arizona (USA)
- University of Quebec (Can)
- Carlos III University (Sp)
- ONEG-Micon (Dk)
- Rzeszow University (PI)
- NASA-Ames (USA)
- Technical University of Denmark
- AEU-JOULE project group: 'VISCEL', coordinated by CRES (Gr).
- Georgia Institute of Technology, Atlanta (USA)

The present project has been defined on the basis of the recommendations which have been formulated at the end of IEA Annex XIV. The main objectives of IEA Annex XVIII are:

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

The participants in IEA Annex XVIII are:

Netherlands Energy Research Foundation, ECN (The Netherlands), Operating Agent

Delft University of Technology, DUT (The Netherlands)

ORISO, The Test Station for Wind Turbines (Denmark)

National Renewable Energy Laboratory, NREL (United States)

Mie University, The Department of Mechanical Engineering (Japan)

6.2 CHARACTERISTICS AND STATUS OF THE TEST FACILITIES

ECN

- a. D=28m
- b. Two blades
- c. Blades with twist and taper
- d. Instrumented at three radial stations, measured simultaneously
- e. The tests are completed. Much data have been collected, both for standstill as well as rotating conditions. The data are entered into the Annex XIV database. However the data have been reprocessed recently, such that the angle of attack is determined in a more advanced way.

RISØ

- a. D=19m
- b. Three blades
- c. Blades with twist and taper
- d. Instrumented at three radial stations, measured simultaneously
- e. Much data have been collected and entered into Annex XIV database. The tests are completed.

NREL

- a. D=10 m
- b. The experiments are carried out in different phases.
 - i. Phase II: Three bladed. Blades without twist and taper.
 - ii 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.
 - iii. Phase V: Two bladed; Blades with constant chord, twisted.
- c. Instrumented at 4 (or 5) radial positions, measured simultaneously
- d. Much data have been collected. Phases II, III and IV are completed and data entered into the Annex XIV database.

Mie University

- a. D=10 m
- b. Three blades
- c. Blades with twist and taper

d. Instrumented at 4 radial stations, partly measured simultaneously

e. The experiments are carried out in different phases.

- i. In the first phase the turbine operates at constant speed. These measurements started in February 1999.
- ii. In the second phase the turbine operates at variable speed. These measurements are expected to start in the beginning of 2000.

DUT

- a. D=10 m
- b. Two blades
- c. Blades without twist and taper
- d. Instrumented at four radial positions. Until 1999 these stations could not be measured simultaneously. From January 1999 two stations can be measured simultaneously.
- e. Much data have been collected for the 30%, 50% and 70% sections, which were measured independently. Data for the 70% section are entered into the database. However the data are at present reprocessed, such that the angle of attack is determined in a more advanced way. The measurements on the other sections will be stored soon. In addition measurements with boundary layer manipulators are expected to be entered into the database.

CRES

- a. D=19m
- b. 3 blades
- c. Blades with twist and taper
- d. Instrumented at three radial positions
- e. The instrumentation is at present carried out. This imposes some risk because it cannot be guaranteed that the measurements are supplied within the contract period of the present project. Nevertheless the measurements will be very valuable because both the turbine and the site are very well known from EU-JOULE projects, on which, however, no detailed aerodynamic measurements could be performed. It will be very interesting to connect the

existing knowledge on the site and the turbine to the local aerodynamic behavior, which is measured in present project.

6.3 STATUS OF THE DATABASE

Since the start of Annex XVIII the following extensions have been added to the database.

1. Measurements of profile and turbine characteristics are entered into the database. Both 2D (wind tunnel) as well as 3D (rotating) profile characteristics have been stored. The 3D profile characteristics have been supplied for different pitch angles, since the 3D stall effects appear to be dependant on the pitch angle [1].
2. ECN developed Fortran programs for the selection of the most "popular" data in the database for the NREL and RISØ measurements. These programs are supplied to the database.
3. An Internet site has been developed for the Annex XVIII project. The site contains a short description of the project and an introduction to the database. A link to the database and the final reporting will also be provided. Feedback from users is assured by a registration form, which has to be filled out before access to the database is possible.
4. ECN has reprocessed their measurements —The angle of attack and the pressure have been determined in a more reliable way. Furthermore, the measurements did not obey all IEA Annex XVIII conventions. In the reprocessed measurements this has been improved.
5. New time series from NREL have been entered into the database. These measurements are taken at different pitch angles.
6. DUT supplied reprocessed measurements from the 70% station. They still need to be entered into the database.

6.4 EXPERIENCES OF USERS OF THE DATABASE

As stated above, the database has been supplied to 11 outside parties and the EU-JOULE project group 'VISCEL'. Universities, research institutes, consultants and industry are all represented in the group of users. In the beginning of 1999, an inventory was made of the experiences. At that moment the following conclusions were drawn on the use of the database.

It was remarkable to see that universities have spent much more effort on the database than research institutes or industrial parties. A possible explanation is the fact that the analysis of these data is very time consuming. Furthermore, the analysis of data is of a rather fundamental kind, which requires some academic freedom.

Generally speaking, the reply from the users was positive, but there was a wish for the addition of profile characteristics into the database. Both 2D as well as 3D profile characteristics are required. Users also wanted the addition of turbine characteristics to the database, and a more convenient procedure for selecting relevant data.

The NREL data have been used much more than the other data.

The expectations for the near future are that the database will be used more frequently, because many users received the database only recently.

The data will also be used for other topics than stall aerodynamics. The measurements deliver unique information about the load unbalance at yawed conditions. In the EU-JOULE project 'ROTOW' the data will be used to investigate the aerodynamic tower influence. The pressure measurements will be used as validation for free wake codes and Navier-Stokes codes at both stalled and non-stalled conditions.

Measurements other than those from NREL will also be used.

As a result of the inventory some activities have been undertaken. As stated above, profile and turbine characteristics are entered into the database and also some programs have been stored which can facilitate the selection of signals from the database. In August 1999 it has been attempted to make a new inventory of experiences. Since the reply was rather limited no new conclusions are drawn yet. Nevertheless, the participants who did reply were positive about the organization and reporting of the database and the auxiliary software.

Furthermore, the expectation that the measurements would be used for other topics than stall aerodynamics has to some extent come about. Some users performed investigations on the load unbalance at yawed conditions and the data have also been used in the EU-JOULE project 'ROTOW' to study the aerodynamic tower influence.

6.5 ACTIVITIES TO BE PERFORMED

The following tasks still have to be performed:

1. Maintenance of database, which implies the following.
 - a. The addition of some remaining turbine characteristics
 - b. The addition of some remaining 2D-profile characteristics
 - c. The addition of some remaining 3D-profile characteristics at different pitch angles
 - d. An update of the existing DUT-files.
2. A more convenient selection procedure. This implies the addition of some remaining FORTRAN programs to the database.
3. The addition of new measurements from Mie-University
4. The addition of new measurements from Delft University

5. The addition of DUT/ECN measurements with boundary layer manipulators.

6. The addition of three new RISØ measurement campaigns at yawed conditions

7. The addition of new measurements from CRES. The further development of an IEA Annex XVIII Internet-site. This implies a link to the final reporting and a link to the database.

8. The final report will be an extension of the Annex XIV final report [1], and it will, among other things, contain an updated description of the database and the facilities. Emphasis will be put on the usefulness and limitations of the database.

Reference: 1.

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

Author: LGJ Janssen, ECN, The Netherlands

CHAPTER 7

Overview

7.1 GOVERNMENT POLICIES

7.1.1 Aims and Objectives

All countries participating in IEA R&D Wind are evaluating wind energy technology and its potential contribution to their national energy supply, taking into account economic viability and environmental concerns. The reduction of greenhouse gas emissions is one of the main drivers in this policy. Diversity of energy supply and the development of a sustainable wind energy market to develop national industries and other commercial activities are also seen as advantageous for most countries.

7.1.2 Strategy

The strategies adopted by the countries to achieve their aims and objectives vary greatly. All have government-funded research, development and demonstration (R, D&D) programs aimed at assessing

the technical, environmental, and economic prospects for the technology but with widely different levels of funding and types of support. These programs are usually collaborative between industry and major utilities.

Many countries have introduced market stimulation to allow large-scale demonstration of the technology. The main market stimulation instruments used in participating countries are investment subsidies, tax incentives, payment of premium energy prices, and "green electricity" (specific tariffs which encourage investment in renewable energy). All countries also offer support for industrial development in some form or other. In some countries central government incentives are complemented by regional funds.

7.1.3 Market stimulation instruments

As shown in Table 7.1, the trend is away from investment subsidies and toward the payment of a premium price for energy

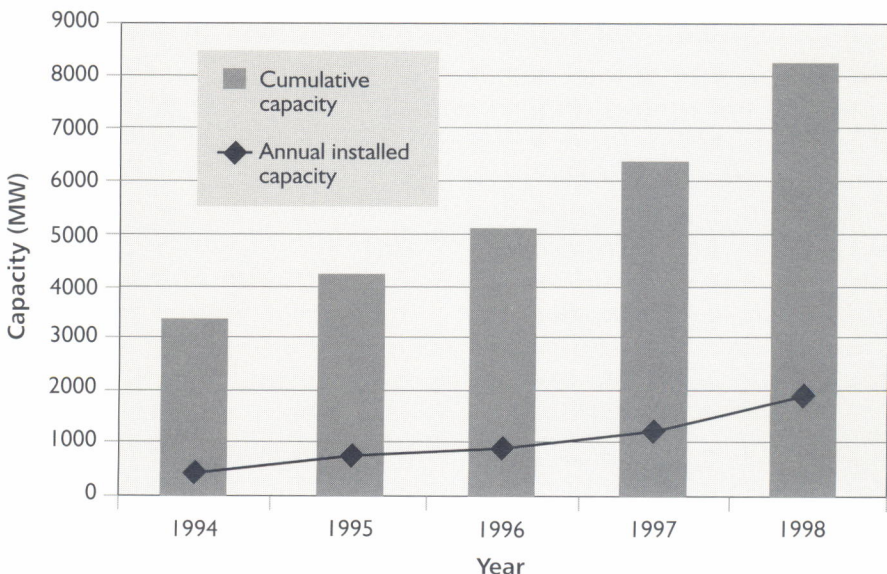


Figure 7.1 IEA countries wind capacity from 1994 to 1998

generated. The premium price is usually set in relation to the national electricity tariffs, except in the UK where a bid-in system is used and contracts are awarded to the lowest bidders. In a number of countries customers are being offered "green electricity" at slightly higher rates than electricity generated from conventional sources. Green electricity is usually offered by electricity suppliers in deregulated markets although often with initial government support when wind power is first established. This is providing another source of funding for wind energy projects.

7.2 MARKET DEVELOPMENT

The primary constraint on market development is the low cost of conventional generation arising from cheap fuel and surplus capacity. These low costs make wind energy economically unattractive where it has to compete on the open market (AU, CN, SF, JP, NZ, NO).

In countries where premium buy-back prices, and/or tax incentives, and/or capital investment subsidies make the generation of electricity by wind power economically viable, the main constraint on the rate of development is the difficulty of obtaining land use planning consent for projects. Objections to projects are often made because of environmental concern, in particular the visual impact of wind farms (DK, DE, IT, NL, SW, UK, US).

In the majority of countries, planning of land usage is a local matter taking account of broad national guidance. Hence planning consent decisions and imposed conditions on wind farm developments can be subjective and depend on how national guidance is interpreted at the local level.

Integration of large-scale wind generation into the electricity distribution system is seen as a potential, but not immediate, problem.

7.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

7.3.1 Installed capacity

The annual installed wind power capacity in the IEA R&D Wind participant countries increased in 1998 by nearly 2,000 MW compared to 1,230 MW in 1997. This brought the total installed capacity in the participating countries to 8,260 MW at the close of 1998. The number of new turbines was 3,200 as the trend toward machines of higher rated capacity continued. The average rating of the turbines installed during 1998 was around 625 kW.

Figure 7.1 shows the annual installation rate for each year from 1994 to 1998.

Germany, Denmark and Spain have seen major growth with Spain establishing itself as the second-largest European market. In the US, the restructuring of the electricity supply industry continued to delay some projects although 600 to 800 MW of new projects were either under construction or planned for construction in the next few years.

7.3.2 Type of development and ownership of installed plants

In most countries the new capacity was in the form of wind farms, typically consisting of 10 or more turbines. Ownership of new wind farms depends to a large extent on whether or not the electric utilities are government owned. In countries with government-owned utilities, the governments use the power generation and/or distribution companies as vehicles for demonstration. In countries with privately owned utilities, the spread of ownership has been much wider, including private companies as well as independent generators.

As turbine and project size increases, the resources of utilities and limited companies are more frequently used. However, private financing was used for a 100-MW

wind power plant in the United States. Small-scale developments have only become established on a significant scale in Denmark and Germany.

7.3.3 Performance of installed plants

Electricity Generation

The total amount of electricity generated from wind power in the participating countries was 12,000 GWh during 1998 compared to 10,800 GWh in 1997.

7.3.4 Operational experience

In general, the installed turbines performed well with few operational difficulties.

Lightning strikes and icing resulting from extreme weather conditions were the main operational problems in some locations. No major problem was reported on the integration of output into the electrical distribution systems. Large-scale electrical integration was identified by several countries as a potential constraint on development in sparsely populated areas although the benefits of embedded generation were also stressed.

7.4 ECONOMICS

The market price available to wind energy producers is a matter of national policy and varies among countries. In an attempt to compare market prices in different countries, Figure 7.2 shows the reported

range of wind energy market price compared to the price of electricity for industrial users in each country (source: IEA, Energy Prices and Taxes, 4th Quarter of 1996). These estimates are approximate and intended only as guidelines. The price charged to industrial users is shown as a dot while the range of the market price for wind-generated electricity is shown as a vertical line. Figure 6.6 shows that, for most countries, the market prices are close to the industrial tariffs.

7.5 MANUFACTURING INDUSTRY

7.5.1 Status of manufacturing industry

The status of the wind turbine manufacturing industry in the individual countries depends strongly on the internal program. Most countries see wind power as an opportunity to develop an industrial manufacturing capability and aim to use a high proportion of nationally produced machines. In several countries, wind manufacturing industries flourish (DE, IT, NL, ES, and US). The industry is even stronger in Denmark which, as well as having a national installation program, exports turbines to many countries, both in the IEA regions and elsewhere.

Table 7.1 summarizes the status of national manufacturing industries.

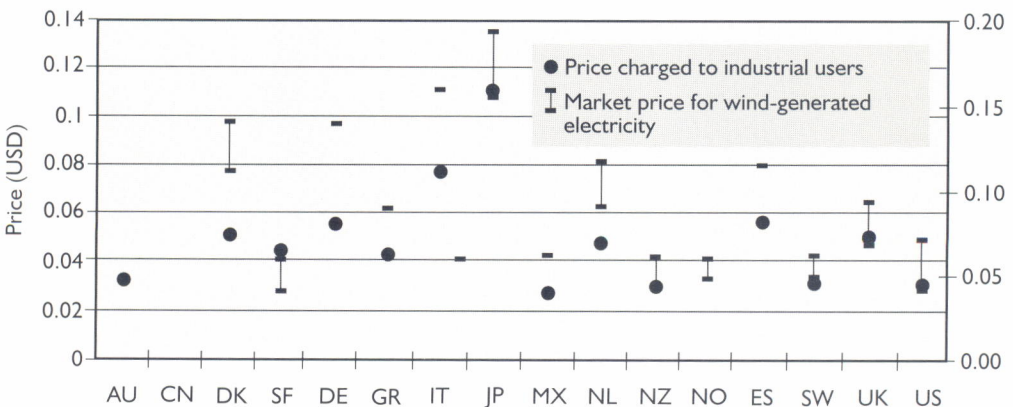


Figure 7.2 Wind energy market prices compared to industrial electricity prices

Table 7.1 Status of national manufacturing industries

	STATUS OF TURBINE MANUFACTURING INDUSTRY	NUMBER OF MANUFACTURERS OF COMMERCIAL SCALE TURBINES
Australia	None existent for large turbines.	2 small manufacturers of remote area systems.
Canada	Small/medium but growing. Blade manufacturing at all sizes	1 VAWT manufacturer (150 kW) 3 Joint Ventures with foreign manufacturers.
Denmark	Dominant turbine manufacture—founded on subsidies during formative years. Supported by large component industry including blades, generators control systems and brakes.	7–8 major manufacturers, more than 10 in total. Numbers steady.
Finland	None existent for large turbines.	0
Germany	Strong, initiated by 250 MW demonstration program. Major European gearbox supplier; also supplier of hubs and generators	Two large (dominating sales), several small.
Greece	None existent for large turbines, 2 small turbine manufacturers. some components including towers.	0
Italy	Medium—collaboration with government—sponsored programs.	2 indigenous 1 joint venture with Vestas
Japan	Strong through overseas sales.	2 indigenous manufacturers and a joint venture with Vestas
Mexico	None at present except for small turbine manufacturer.	0
Netherlands	Strong—founded on subsidies during formative years. Also two manufacturers of blades.	3 up to 1998, and 2 at the end of 1998.
New Zealand	At prototype stage.	0
Norway	Small components industry.	0
Spain	Strong—government support for industry and the planning system have resulted in the majority of installed machines being made in Spain. Little export activity as yet. Components manufactured include blades, generators, gearboxes, towers and sensors	4 Spanish companies and 3 joint ventures using foreign technology.
Sweden	Small—relies on government R,D&D support.	3
UK	At prototype stage, also components including blade and tower manufacture—can receive government R,D&D support.	1 UK owned. A Danish owned company has established a rotor manufacturing facility.
US	Consolidating as rate of commercial deployment is slowed by utility restructuring and low energy prices; Government R,D&D support focused on next generation technology. Numerous national components suppliers.	8

7.5.2 Technical and business developments

The trend of installing turbines with increased rated capacity for the commercial market continued during 1999. The 750-1000-kW machines were further refined and manufacturers began producing commercial machines rated at or over 1.5 MW.

7.5.3 Supporting industries

As the sales of wind turbines grow, the market has become more buoyant for component manufacturers, especially as the local sourcing of components is favored in some countries.

7.6 ENVIRONMENTAL IMPACT

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 have shown that these environmental advantages of wind power are recognized and, in general, the majority of the public are supportive of wind energy installations.

However the environmental impact of wind energy developments continued to be of concern during 1997 which has caused difficulties for developers trying to obtain construction consents from planning authorities. 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 other countries.

7.7 GOVERNMENT SPONSORED R, D&D PROGRAMS

7.7.1 R, D&D funding

There are government-sponsored programs in all the countries. These programs are funded either by the central

government through departments or agencies, or funded and managed by government-owned companies. The reported 1998 annual budgets for direct R&D work, excluding support for large-scale demonstration, range from less than USD 1 million (CN, MX, NZ, NO), through USD 1.0 to 15 million (AU, DK, DE, GR, IT, JP, NL, ES, SF, SW, UK) to USD 32 million for the US.

In Europe, overall R&D funding levels are actually higher than indicated because additional funding is available through the European Union which, of course, originates from the contributions of the individual national governments.

7.7.2 Priorities

The main R, D&D priorities reported by each country can be divided into two basic categories. The first covers concerns with national issues, such as the available resource and the impact of turbine siting, and the second includes concerns with the development of the technology.

National Issues

Resource evaluation (wind measurements, modeling); Planning consent (siting of turbines); Environmental impact (noise, visual intrusion); Electrical issues (integration, power quality); Standards and Certification.

Technology Development

Improved efficiency (aerodynamics, variable speed operation); Cost reductions (value engineering, component development); Advanced turbine development (new concepts); Noise reduction; Safety (structural loads); Reliability (lightning).

In general, work on national issues is directed by government departments or agencies while technology development is undertaken in collaboration with, and often partially funded by, industry.

7.7.3 New R, D&D developments

The main trends in turbine development continued to be towards lighter, more flexible turbines, the use of direct-drive generators, and variable speed operation. The development of turbines with higher rated capacity for the commercial market also continued. New concepts under development are described in the individual national reports.

7.7.4 Offshore siting

Interest in the offshore siting of turbines is mainly limited to those countries where there is a shortage of suitable sites on land (IT, SW) or where population density

precludes extensive on-land development because of environmental intrusion (DK, NL, UK). By the end of 1997, Denmark had two offshore wind farms of 5 MW in operation while the Netherlands (4 x 500 kW) and Sweden (1 x 220 kW, 5x500 kW planned) had mounted demonstration projects. Both Denmark and the Netherlands have announced sizeable targets for offshore deployment.

7.7.5 International collaboration

International collaboration takes place in the IEA R&D Wind activities called Tasks. These are described in Chapters 2–6 of this Annual Report.

Table 7.2 Exchange rates as of December 31, 1999

COUNTRY		USD*	EURO**
Australia	Australian Dollar	1.52439	1.53588
Austria	Austrian Schilling	13.66464	13.76030
Canada	Canadian Dollar	1.44400	1.45353
Denmark	Danish Kroner	7.39500	7.44004
Finland	Finnish Marka	5.90440	5.94573
Germany	German Marks	1.94223	1.95583
Greece	Greek Drachmas	327.90000	329.96500
Italy	Italian Lira	1922.81032	1936.27000
Japan	Japanese Yen	102.16000	102.86200
Mexico	Mexican New Pesos	9.48000	9.39095
the Netherlands	Netherlands Guilders	2.18839	2.20371
New Zealand	New Zealand Dollars	1.91058	1.93378
Norway	Norwegian Kroner	8.01000	8.06268
Spain	Spanish Pesetas	165.22939	166.38600
Sweden	Swedish Krona	8.50500	8.55541
United Kingdom	British Pounds	0.61919	0.62367
United States	US Dollars	1.00000	1.00712

* Data from the New York Federal Reserve Bank (<http://www.x-rates.com/>)

** Data from Xenon Currency Service (<http://www.xe.net/gen/about.htm>)

For R, D&D studies there is also strong multi-national collaboration in Europe through numerous JOULE and THERMIE projects which are partially funded by the European Commission. The United States, Denmark, Germany, Netherlands, Spain, and the European Commission have bilateral technical assistance agreements with several countries. In seeking to establish overseas trade, most countries are actively seeking collaboration with countries with large potential markets (e.g. India, China and South America).

Author: Ian Fletcher, ETSU, United Kingdom.

Table 7.3 Capacity and output data

COUNTRY	TARGET CAPACITY (MW)	TARGET DATE	TOTAL	TOTAL	ANNUAL INSTALLED CAPACITY (GW)					ANNUAL OUTPUT (GWH)				
			NUMBER OF TURBINES	INSTALLED CAPACITY (MW)	1994 (MW)	1995 (MW)	1996 (MW)	1997 (MW)	1998 (MW)	1994 (GWH)	1995 (GWH)	1996 (GWH)	1997 (GWH)	1998 (GWH)
Australia			36	9.7			0.025	1.05	5.78		6	7	8	20
Canada			130	73.5	18.9	0.6	0.2	3.0	48.0	35	55	61	64	
Denmark	5500	2030	5298	1448.0	52.0	98.0	169.0	300.1	308.0	1083	1175	1245	2000	2302
Finland	100	2005	40 ^{low}	17.4		1.8	0.90	4.6	5.6	7	10	11	16	24
Germany	2200	2010	6205	2874.0	309.0	505.0	428.0	534.0	792.0	1000	1450	2000	3150	2965
Greece	350	2005	178	39.0	0.7	0.7		3.0	11.5	37	33	37	38	71
Italy	3000	2010	403	180.0	10.2	0.6	48.4	28.5	79.7	11	11	30	150	231
Japan	300	2010	129	31.6	0.9	3.6	4.0	6.5	14.4		6			
Mexico			10	3.0	1.6		0.3	0.5	0.6	5	5	5	5	6
Netherlands	2750	2020	1195	364.0	22.0	100.0	47.0	44.0	39.0	251	317	430	451	640
New Zealand			8	3.7			3.5			1	1	8	13	14
Norway	1100	2010	18	9.3					5.4	10	11	10	11	16
Spain	8000	2010	2314	834.0	23.4	47.0	96.5	205.0	407.0	145	180	280	400	
Sweden	3800		421	174.0	7.0	28.8	38.0	17.0	52.0	75	105	142	205	300
United Kingdom			756	313.0	33.0	35.1	36.8	84.5	13.0	337	361	483	655	817
United States			17210	1890.0	42.0	41.6	7.2	11.0	147.0	3250	3400	3700	3700	3900

CHAPTER 8

8.1 INTRODUCTION

Australia contributes just over 1% of total worldwide greenhouse gas emissions, and the per capita emissions are among the highest in the world. Without action, growth in Australian 1990 emissions is projected to be 28% by 2010 with emissions from the energy sector alone increasing about 40%. Australia ratified the United Nations Framework Convention on Climate Change in December 1992 and signed on to the Kyoto Protocol in April 1998. If ratified, the Protocol commits Australia to a legally binding limit on future greenhouse gas emissions. Australia's Kyoto Protocol target is for an increase in emissions in 2010 that is limited to 8% above 1990 levels.

The largest single source of Australia's greenhouse gas emissions is the production and consumption of energy, which contributed 55% of emissions between 1990 and 1997. Between 1990 and 1996, greenhouse gas emissions from non-transport energy use increased by 13%, and further increases are projected with emissions linked to economic growth. Limiting the growth of greenhouse gas emissions particularly in the energy sector is thus an area of national priority. One of the primary vehicles for limiting emissions growth is the development of renewable energy.

Australia has an abundance of renewable energy resources. In particular, the wind resources of Australia are excellent for wind generation and more than comparable with other countries with significant wind energy industries. There are potential wind farm sites in all States of Australia. In the 1970s and 1980s, specialized wind monitoring of potential sites was commenced in most States. In the late 1980s, Australia saw the first installations of commercial 'wind farm' size machines to demonstrate the use of the new technology in the electricity supply industry.

Australia currently has over 38,000 MW of generation capacity that produces more than 160,000 GWh of electricity per annum. Currently 10% are from renewable sources, mostly hydro, and the remainder is from thermal sources, predominantly coal and natural gas. Wind energy currently forms less than 0.02% of total electricity generation in Australia.

8.2 NATIONAL POLICY

8.2.1 Policy

Current policies 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 entitled "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, though, that renewables require assistance to foster their development within an industry currently dominated by low priced coal thermal generated electricity within a de-regulated electricity market.

The strategies for the development of renewables in Australia currently are the following.

- Establishing a mandated target for the uptake of renewable energy by specifying a proportion of renewables in new generation requirements
- Support for Green electricity schemes and accreditation of green energy products
- Funding the development, commercialization and demonstration of renewable energy and greenhouse technologies
- Education and training standards
- Identifying and removing of barriers to the development of a renewables industry.

8.2.2 Progress towards national targets

Progress towards the development and growth of a renewable industry has been steady over the last five years. In the last couple of years, and particularly 1999, commitment towards the development of a renewable industry has been building with growing support for renewables as a means of limiting the increase in national greenhouse emissions.

In 1999, Australia has:

- Established a Ministerial Council on Greenhouse Gas Abatement measures;

- Established an explicit goal for increasing the contribution of renewable energy sources;
- Established a timetable for the provision of an efficient, open and competitive energy market that will enable the emergence of new technologies including the renewables;
- Increased funding for renewables R,D&D, training and education;
- Finalized the formation of a peak renewable energy industry body;
- Established the Emerging and Renewable Energy Action Agenda Leadership Group;
- Continued restructuring of the electricity industry to improve access to the market for renewables.

A Ministerial Council on Greenhouse has been established to oversee the implementation of the National Greenhouse Strategy. The Council consists of the Minister for the Environment and Heritage; Minister for Industry, Science and Resources and Minister for Agriculture, Fisheries and Forestry. This provides for a unified approach on greenhouse action from three key areas of Government. 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 two percent of their electricity from renewable energy sources by 2010. It was announced in November 1999, that legislation would be introduced in 2000 to ensure that the measure is phased in from January 2001. The measure will be implemented using a system of tradeable certificates.

Certainty for the renewable industry to plan for the measure has been provided by fixing the target at 9,500 GWh per annum at the start of 2010 and capping

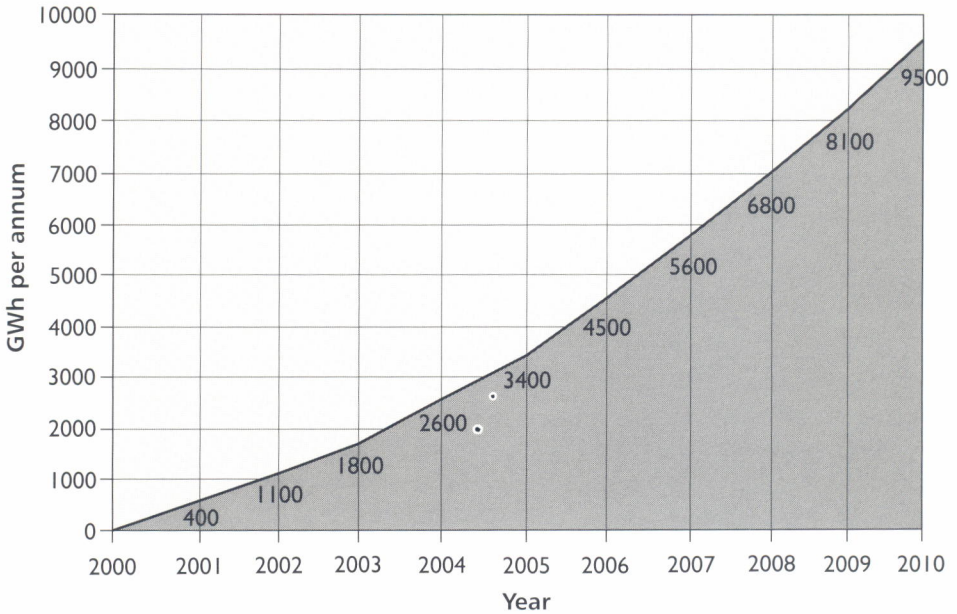


Figure 8.1 Target for new renewable electricity generation

penalties for liable parties who fail to meet their purchase obligation at AUD 40 per MWh. The measure is designed to allow the market to find the least cost response to meeting the target and develop innovative responses that would not be as likely to occur under a centrally administered scheme.

By specifying a number of interim yearly targets over the period 2001-2010 as shown in Figure 8.1, a timetable for the growth of the renewable energy market has been set. The interim targets will ensure that there would be consistent progress towards achieving the 9,500 GWh target by 2010 and that all investment does not occur in the final years of the scheme.

Estimated contribution from wind energy towards achieving the national target, as shown in Figure 8.2., 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.

Significant increases in funding have been announced to support the use of renewable

energy in remote power generation as part of the introduction of the new Goods and Services Tax package. Total funding of up to AUD 321 million is to be available over four years, commencing 1 July 2000. In areas not serviced by a main electricity grid, renewable energy is often a viable alternative to diesel-generated electricity in those areas of 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. The program will be funded from excise paid on diesel used to generate electricity by publicly owned public generators. States and territories will be allocated funding on the basis of the relevant diesel fuel excise paid in that state or territory. Many of the remote power stations will be transformed into wind-diesel and wind-diesel hybrid power systems.

In May 1999, the Ministerial Council on Greenhouse announced the formation of a peak renewable energy industry body, the

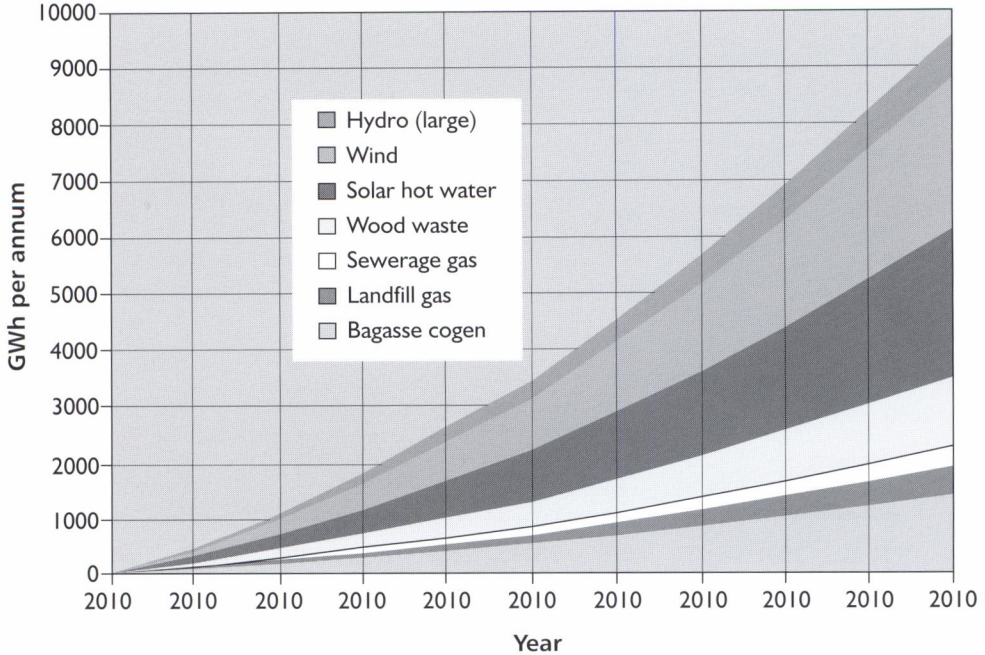


Figure 8.2 Possible contribution to renewable generation target by source

Sustainable Energy Industry Association of Australia (SEIA). The formation of a peak body was done to ensure a coherent and focused approach to the development of a sustainable energy industry in Australia.

An Emerging and Renewable Energy Action Agenda has been established as a major part of the Commonwealth Government’s strategy to assist the long-term development of Australian industry. The objective of this Action Agenda is to develop a policy framework underpinning growth in a commercially viable and internationally competitive Australian emerging and renewable energy industry. The Action Agenda is focused on strategic analysis of the industry’s competitive position, developing an agreed industry “Vision” to 2010, identifying opportunities and impediments to the industry’s sustainable growth and developing a set of actions and

clear roles for industry and government. A Leadership Group will facilitate high-level consultation between representatives of the emerging and renewable energy industry and the Government with the objective of delivering an Action Agenda for the industry.

Progressive restructuring of the electricity industries over the last decade has led to greater competition amongst generators, supply efficiency improvements, and innovative promotion of renewable energy. Continued energy market reform is a key element of Australia’s greenhouse response and of the National Greenhouse Strategy (NGS). Further reforms outlined in the NGS include the delivery of consistent and compatible national frameworks for electricity by 2002, and removal of barriers for grid connection of small-scale generation, such as from co-generation and renewable sources.

8.3 COMMERCIAL IMPLEMENTATION

8.3.1 Installed capacity

The Installed capacity of wind turbines (>25 kW in size) reached over 10 MW at end of 1999. Approximately 5 MW is grid connected and the remainder is in remote wind-diesel power systems. Increases in wind power capacity for 1999 have been modest with less than 0.6 MW added to the national total from two wind-diesel power systems.

The prospects for large grid-connected developments are good with announcements made on the planned completion of 55 MW in 2000 and 61 MW in 2001. The prospects for wind-diesel power systems are also excellent with the introduction of the Renewable Remote Power Generation Program in late 1999.

See Table 8.1 and Table 8.2 for further details on each installation and the planned installations respectively.

Four wind turbines were installed in 1999 by a remote community and a University in conjunction with ACRE and a State Government owned electricity utility. All installations were in Western Australia and the Northern Territory. ACRE has installed a 20-kW wind turbine at Murdoch University and research is being conducted into this innovative variable speed, permanent magnet machine. Testing of the blade pitching mechanism, tail fin arrangement, and turbine controller are being logged with further results expected in 2000. Initial indications are that the turbine is operating at or above design expectations. In the Northern Territory, an 80-kW Lagerwey wind turbine has been installed in a remote Aboriginal community hybrid power system. The turbine forms part of a wind/PV/diesel/battery hybrid. Commissioning trials have seen 60% to 100% wind penetration possible.

During 1999, two wind turbines were installed by Western Power at Denham in the World Heritage Area of Shark Bay 900 km North of Perth. The two Enercon E30 230-kW turbines on 50-m towers now compliment an existing E30 installed in 1998, and all feed into the local diesel based grid. The extra two machines have been funded in part through an Australian Greenhouse Office Showcase Grant, which in 2000 will also see the addition of an energy flywheel storage system. This should bring the average wind energy penetration into this system to about 65% including times of operation with the diesel generators switched off.

A number of wind farms are also in various stages of development at the end of 1999. Stanwell Corporation is developing a grid-connected wind farm at Windy Hill on the Atherton Tablelands in Queensland. Construction of the first 12 MW commenced in November 1999 with installation of the 20 Enercon E40 turbines



Figure 8.3 Showcase installation at Denham, Australia (0.69MW)

expected to be completed by June 2000. A further 13 MW at the site is currently being investigated and if it proceeds, completion is expected in 2000. An ex-SECV site of Toora is also being investigated by Stanwell. This 18 to 20-MW farm is at the feasibility stage with estimated completion by second quarter of 2001. Stanwell has plans to accelerate the installation of wind power generation from these levels to meet the growing demand for renewables.

Pacific Power has commenced site works on a grid-connected wind farm at Blayney in New South Wales. After a successful development application process, site work for the 10-MW wind farm commenced in January, 2000 and is planned to commence commercial operation in October, 2000. The wind farm, which comprises 15 Vestas 660 wind turbines, is being installed on private grazing land and will have no significant effect on the existing land use. The Blayney Wind Farm is being built, owned and operated by Pacific Power with the output being sold to the local electricity retailer Advance Energy for their SEDA approved green

power scheme. The Blayney Wind Farm is accredited by SEDA and was supported by the Authority's Renewable Investment Program.

EnergyAustralia's plans for future wind farm development are presently uncertain after completing the successful installation of a demonstration turbine at Kooragang Island in 1997. EnergyAustralia (in conjunction with University of Newcastle and Biomass Energy Services & Technology Pty Ltd) have received funding from the Australian Greenhouse Office to commercialize a 10-kW wind turbine, based on technology used in the 5-kW machines currently being manufactured in Australia and under license in China.

Western Power is developing a 21.6-MW grid-connected wind farm at Albany in the south of Western Australia. Following a Tender in August, Powercorp Pty Ltd from Darwin and Enercon GmbH was selected as the preferred Contractor with a tender of twelve E66 1800-kW wind turbines on 67-m towers. The design put forward includes the novel use of the

Table 8.1 Australian wind turbine installations at end of 1999 (over 20kW)

COMMISSIONING	LOCATION	NO./KW	TOTAL MW
1986	Malabar, NSW	1 x 150	0.150
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	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
		TOTAL	10.300

Table 8.2 Planned Australian wind turbine installations at the end of 1999

SITE	DEVELOPER	STATE	ESTIMATED CAPACITY-MW	PLANNED COMPLETION	STATUS
Blayney	Pacific Power Advanced Energy	NSW	10	2000	Site works commenced—planned operation late 2000
Codrington	Pacific Hydro	VIC	18	2000	Development application approved
Exmouth	Western Power Corporation	WA	0.06	2000	Awaiting funding application result
Lake Bonney	P. Hutchinson	SA	15	2000	Unknown
Windy Hill	Stanwell Corporation	QLD	12	2000	Under construction
Albany	Western Power Corporation	WA	21.6	2001	Environmental approval granted, tenders completed, and Development Application in preparation
Toora	Stanwell Corporation	VIC	20	2001	Feasibility investigation stage
Windy Hill	Stanwell Corporation	QLD	13	2001	Feasibility investigation stage
Woolnorth	Hydro Electric Corporation	TAS	10.5	2001	Environmental approval being sought. Construction to commence in 2000
Woolnorth	Hydro Electric Corporation	TAS	120	2002-2006	Environmental approval being sought
Cape Bridgewater	Energy Equity	VIC	20	Unknown	Lost planning appeal, current status unknown
Cape Jervis	ETSA Boral Energy	SA	5	Unknown	Planning commenced
TOTAL			265.16		

SUPPLIER	OWNERSHIP	OWNER	APPLICATION	1998 GWH*
WindMaster	Government Utility	Pacific Power	Grid Connected	0.00
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	Government Utility	Government	Wind Diesel	0.25
Vestas	Government Utility	Western Power	Wind diesel	3.90
—	Government Utility	Ergon Energy	Wind Diesel	0.04
—	Private	N/A	Wind Diesel	0.04
Westwind	Private	N/A	Grid Connected	0.03
Vestas	Government Utility	Energy Australia	Grid Connected	0.90
Vestas	Government Utility	Ergon Energy	Wind Diesel	1.40
Vestas	Government Utility	Pacific Power	Grid Connected	10.00
Nordex	Government Utility	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
TOTAL				20.30

turbine's inverters full-time to aid the local electrical network which, being 300 km from the nearest power station, is considered weak. The turbine choice was based on extensive community, visual and environmental analyses which indicated a larger machine would be more appropriate for the coastal site. The final steps in this project are a Development Application that will be lodged in early 2000 and the finalizing of negotiations with the Tenderer.

Western Power continued its wind-monitoring program with 65-m towers installed at three locations. The company also submitted an application for funding from the Australian Greenhouse Office for a "mini" wind farm consisting of three Australian made Westwind 20-kW turbines at Exmouth in the State's north. These turbines are the result of research and development through the Australian Cooperative Research Centre for Renewable Energy, and as they can be raised and lowered at will are suitable for the areas cyclonic weather.

Victoria's first commercial wind farm is to be Pacific Hydro's 18-MW wind farm at Codrington located near the south coast. It has received planning approval for 14 of the 65-m-high turbines, with a total capacity of 18 megawatts. Power will be distributed through underground cables. Construction is expected to commence in 2000.

The Hydro-Electric Corporation is going ahead with a 10.5-MW wind farm at the Woolnorth property on Tasmania's West Coast. This development, to be built and in service by January 2001, is the first stage of a proposed full-scale wind farm on the site rated at about 130 MW. The Hydro has monitored the wind resource on the site, undertaken comprehensive environmental studies and consulted widely with the local community and others interested in this project. This wind farm is seen as the first step in the Hydro's strategy for achieving business



Figure 8.4 Huxley Hill wind-diesel installation, Australia

growth through the development of new renewable energy sources.

8.3.2 Rates and trends in deployment

See Figure 8.6 for the yearly and cumulative total capacity of wind turbine installations over the last 13 years.

8.3.3 Contribution to national energy demand

Australian generation capacity totals over 38,000MW. Total electricity generated is more than 160,000 GWh. The States of New South Wales, Victoria and Queensland

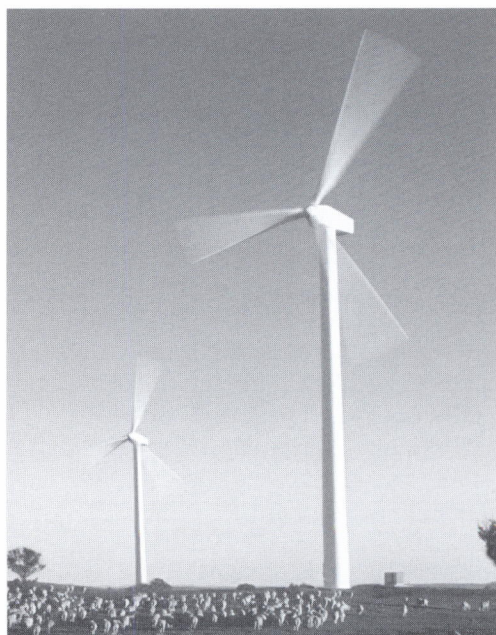


Figure 8.5 Crookwell Wind Farm, Australia

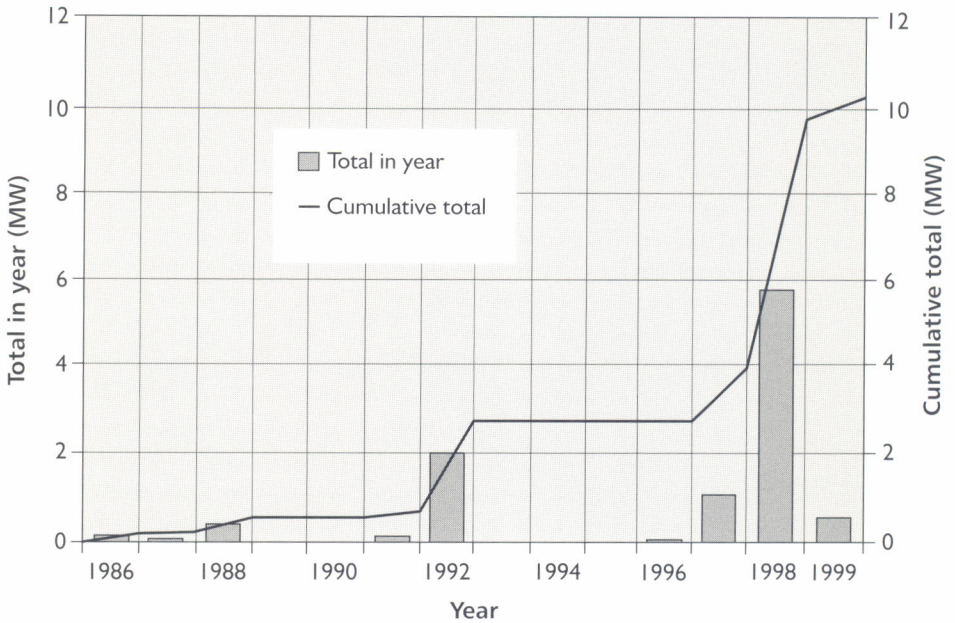


Figure 8.6 Yearly installed capacity of wind generation in Australia

account for almost 80% of Australian electricity consumption. Coal accounts for 93% of electricity generation capacity in NSW, 90% in Victoria and 98% in Queensland. Overall, coal-fired generation meets 82% of Australian electricity needs with the balance coming from hydro-electric power (9%) and natural gas (8%). Wind energy currently forms less than 0.02% of total electricity generation.

8.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

The most powerful market stimulant in Australia is the mandatory requirement for an increase of two percent in the use of electricity generated from renewable and specified waste sources by 2010. This is estimated to require investment of between AUD 2 billion and AUD 4 billion in renewable electricity generating capacity.

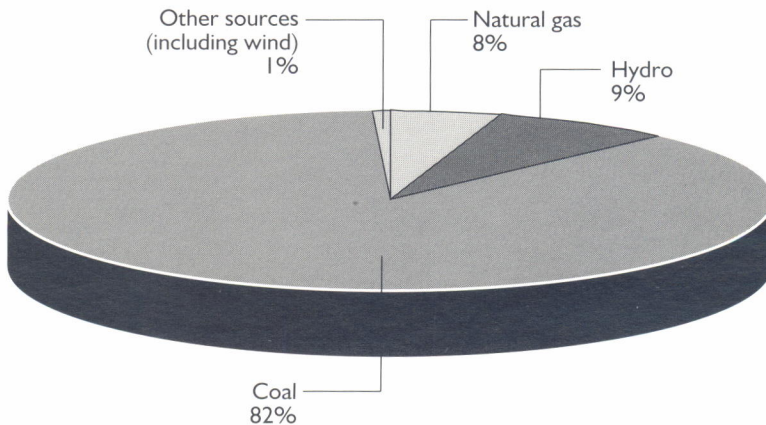


Figure 8.7 Contribution of wind to national energy demand

The Federal Government and State Governments are separately providing support for renewable energy industry development. The Federal Government support for the renewable energy industry includes the following:

- AUD 10 million Renewable Energy Showcase over three years commencing in 1998. This program consists of one-off competitive grants to demonstrate the very best of Australia's technologies.
- AUD 1 million has been allocated to the development of an innovative wind-diesel power system for large off grid communities.
- AUD 29.6 million for the Renewable Energy Commercialisation Program over four years commencing in 1999. These are grants to assist the commercialization of renewable technologies.
- AUD 300,000 for the development of a renewable energy Internet site which will promote the renewable energy industry, serve as a major education tool on various renewable technologies and provide information on government assistance.
- AUD 100,000 over two years for the Sustainable Energy Industry Association of Australia (SEIAA) to support a range of industry development activities including training and accreditation support for sustainable energy service providers and vendors.
- AUD 21 million in funding from the Government through REEF to provide specifically for the R&D and commercialization of renewable energy technologies. The value of the fund rises to approximately AUD 30 million when matched by private-sector capital. The fund would promote better access to venture capital funding for commercializing R&D. A fund manager, CVC-REEF has been appointed.
- AUD 321 million will be available over four years, commencing 1 July 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 AusIndustry's R¥Start program, the Cooperative Research Centre for Renewable Energy and the CSIRO. The 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 Federal Government agencies including the Australian Greenhouse Office (AGO), Australian Cooperative Research Centre for Renewable Energy (ACRE). A summary of these agencies is given below.

- The Australian Greenhouse Office (established in 1998) is the key Commonwealth agency on greenhouse matters. 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 industry. ACRE currently has 8 programs. Those programs that address the application of wind power cover Power Generation, Power Conditioners, System Integration and Demonstration projects.

State Governments and their agencies including Sustainable Energy Development Authority are also providing support for renewable energy industries in their states include the following.

- AUD 13 million per annum by the Sustainable Energy Development Authority (SEDA) to assist in the development, commercialization, promotion and use of sustainable energy technologies. SEDA was created to bring about a reduction in the levels of greenhouse gas emissions and other adverse by-products of the production and use of energy in 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 farms projects of Crookwell and Blayney off the ground.

In 1999, the State Government of Western Australia announced a state renewable energy policy, with the following.

- the introduction of a green energy tariff in March 2000 overseen by Western Power in which at least 50% of the energy required will be sourced through a competitive procurement process from independent power producers,
- the development of a sustainable energy development fund up to AUD 1 million per annum for 5 years which will be used to support the establishment of new renewable energy resources, administered by the Alternative Energy Development Board,
- the continuation of the Remote Area Power Systems scheme with an annual budget of AUD 500,000 under which isolated householders can receive a

subsidy for renewable systems up to AUD 8000,

- approval for private renewable energy producers to use Western Power's grid systems to sell directly to customers using more than 0.3 GWh of electricity per annum, and,
- approval for private renewable energy producers to sell up to 100 kW of renewable electricity "over the fence", without using Western Power's grid system.

8.5 DEPLOYMENT AND CONSTRAINTS

8.5.1 Wind turbines deployed

The majority of wind turbines that are less than 20 kW are owned by Government Utilities as shown in Table 8.3. The proportion in wind-diesel power systems is currently high but should decrease when construction of grid-connected wind farms accelerates as a result of the mandated 2% new renewables target.

Western Australia has been the most active in the installation of wind turbines over the last decade followed by New South Wales and Tasmania, as shown in Table 8.4.

8.5.2 Operational experience

An estimated 20.3 GWh of energy was produced by wind generation in 1999 and is approximately the same as produced in 1998. Estimates of the energy generated are shown in Table 8.1.

There are reports from only three of the current installations available at the time of this report.

Western Power's two wind farms at Esperance have had a mixed year. The older, Salmon Beach wind farm, which has been running for twelve years, is experiencing a higher frequency of faults and is becoming problematic. The larger, seven year old Ten Mile Lagoon wind farm has experienced problems with gear-

Table 8.3 Deployment by ownership and application

OWNERSHIP	TOTAL NUMBER	TOTAL MW	APPLICATION
Research	1	0.02	Research
Government utility	10	5.55	Grid connected
Government utility	26	4.53	Wind Diesel
Private	2	0.09	Grid connected
Private	2	0.08	Wind Diesel
TOTALS	41	10.3	

boxes on some of the Vestas V27 machines and this wind farm has been found responsible for system stability problems during grid fault situations. One of these V27s also lost a blade during a bad electrical storm, with the blade catching on fire and falling to the ground.

The installation of the three Nordex N29 250-kW machines on King Island was completed in early 1998. The wind farm has met performance expectations in its first year of operation. The wind turbines generated between a low of 14% and a high of 21% of the total energy demand for the island over the 12-month period. This equates to a saving of about AUD 400,000 in energy generation costs.

8.5.3 Main constraints on market development

Market development constraints are principally the following.

- Market price for electricity from renewable sources
- Access to the grid for export of power
- Planning approval
- Lack of general wind resource information

The market price for electricity from wind farms is to be set by a number of sources.

- spot price on the national or state electricity markets (varies as depends on market price)
- value of the renewable energy certificate (varies as depends on market price) and
- green power component (premium set by retailers who sell the electricity product to consumers).

Obviously, wind farm development will only take place at sites where the total market price justifies the development costs

Table 8.4 Deployment by State

STATE	TOTAL NO.	TOTAL MW
NT	1	0.080
SA	1	0.150
VIC	1	0.060
QLD	3	0.475
TAS	5	0.830
NSW	10	5.550
WA	20	3.125
TOTALS	41	10.300

over the financing period. The spot price for electricity continues to be depressed in the national electricity market, however, the indications are that it will rise in the long term as demand starts to reach the capacity to generate and distribute electricity. There is no precise data available on the contribution from the certificate or green power. Estimates of the value of certificates range from AUD 20/MWh up to the price cap of AUD 40/MWh. The value of embedded generators to the distribution network operator may increase the return to the wind farm.

The level of wind energy development to date has not been significantly constrained by grid connection cost or integration into the local grid. Wind turbine installations have typically been embedded in the distribution grid. Integration of wind turbines into either the grid or power system is being monitored. Some areas of Australia are making efforts to allow for future wind turbine developments in planning schemes and land management plans. Lack of Australian Standards relating to wind turbines (particularly noise) and Guidelines for wind farm development, is an issue.

Australia has no wind atlas. There are some atlases developed for some States and some regions. The data is either old, in an inappropriate format or produced for a developer and commercially confidential. There are currently plans for the development of a wind atlas for New South Wales. Of course, the wind resource is not the only factor governing the choice of a wind farm but it does give an indication of the magnitude of the wind resource, and likely areas of interest for Local Governments in managing planning schemes and for prospective wind farm developers.

8.6 ECONOMICS

8.6.1 Trends in investment

No trend information is available.

8.6.2 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.

8.7 INDUSTRY

8.7.1 Manufacturing

A 1995/96 survey found that the Australian renewable energy industry including wind:

- contributed about 6% of Australia's total primary energy demand;
- employed 6,400 persons of whom 4,000 were in manufacturing, sales and servicing of wood heaters; and 1,000 were in hydro-electricity generation;
- produced AUD 850 million of goods and services of which AUD 490 million was in hydro-electricity;
- exported AUD 100 million mainly of photovoltaics (AUD 27 million) and associated equipment (AUD 30 million).

The proportion of this market attributable to the wind industry would be less than 0.01% of the total renewable energy market at this stage. However there is no reliable data available at this time to confirm this figure.

Primergy, an Australian renewable energy company, in conjunction with Renewable Energy Australasia Pacific has secured the exclusive license for the manufacture, of the Lagerwey BV 750-kW wind turbine. Already the venture has an initial contract to provide 50 turbines to Japan from the Siemens Ltd facility in the Latrobe Valley with delivery expected in 1999/2000.

8.7.2 Industry development and structure

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

illustrate the stage at which the industry is developed:

- The Ministerial Council on Greenhouse has completed formation of a peak renewable energy industry body, Sustainable Energy Industry Association of Australia. The formation of peak body was done to ensure a coherent and focused approach to the development of a sustainable energy industry in Australia.
- An Emerging and Renewable Energy Action Agenda has been established as a major part of the Commonwealth Government's strategy to assist the long term development of Australian industry as previously indicated.

8.8 GOVERNMENT SPONSORED R,D&D

8.8.1 Priorities

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

- promise a significant contribution to increased local employment and shave export potential while contributing to a reduction in Australia's greenhouse emissions.

Other Government priorities include the development of viable wind turbine or component manufacturing capability, and improvement to the performance of wind diesel power or hybrid power systems.

These priorities are evident by the funding allocation as previously indicated, see Section 8.4.

8.8.2 New R,D&D developments

ACRE and Murdoch University are conducting research into an innovative variable speed 20-kW wind turbine. The turbine has a unique permanent magnet generator, blade pitching mechanism, tail fm arrangement, and turbine controller.

A wind/PV/diesel/battery hybrid power system is being tested in the Northern

Territory. The system uses an 80 kW Lagerwey wind turbine. Commissioning trials have seen 60% to 100% wind penetration possible.

Three Enercon E30 230-kW turbines on 50-m towers have been installed in a 1200-kW diesel based grid. A flywheel storage system has been incorporated to allow average wind energy penetration into this system to about 65% including times of operation with the diesel generators switched off. Testing is expected to commence in 2000.

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 and under license in China.

8.8.3 Offshore siting

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

Reference:

<http://www.greenhouse.gov.au>

Author: Robert Stewart, Hydro Electric Corporation, Australia

CHAPTER 9

9.1 INTRODUCTION

Canada has tremendous wind energy potential. The government 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.

9.2 NATIONAL POLICY

9.2.1 Strategy

The main elements of the Wind Energy R&D program are Technology Development, Resource Assessment, Test Facilities, and Information/Technology Transfer. Field trial projects are selected to evaluate the performance of the equipment under special environmental conditions or for specific applications.

9.2.2 Progress towards national targets

There are no national wind energy deployment targets in Canada at this time. However, the development and expansion of the wind energy industry and wind turbine deployment is supported by all levels of governments.

9.3 COMMERCIAL IMPLEMENTATION

9.3.1 Installed capacity

- Canadian Hydro Developers (Alberta), 18.9 MW (in Southern Alberta), Keneteck 350-kW turbines
- Vision Quest Windelectric (Alberta), 2.4 MW (in Southern Alberta), 600-kW Vestas turbines
- Le Nordais (Quebec), 100 MW (in Gaspé, Quebec), 750-kW NEG-Micon turbines
- Various other installations with a total capacity of 3.7 MW, for a total installed capacity at the end of 1999 of 125 MW.

9.3.2 Rates and trends in deployment

No specific rates or trends of wind energy deployment have been set at this time.

9.3.3 Contribution to national energy demand

The total conventional installed generation capacity in Canada at the end of 1997, the most recent year for which statistics are available, was 112,606 MW which includes coal, oil, natural gas, nuclear and hydro power plants. The energy produced in 1997 was 553,855 GWh. By comparison, the installed wind capacity at the end of 1999 was about 125 MW.

9.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

9.4.1 Main support initiatives and market stimulation incentives

Currently, Class 43.1 of the federal Income Tax Act provides an accelerated rate of write-off (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 one in which the first, exploratory well of a new oil field is being written off.

Natural Resources Canada and Environment Canada have jointly 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 these two federal government departments, at premiums negotiated through a competitive process.

As a result of these incentives and by creatively combining them, Vision Quest Windelectric Inc., a private wind power producer, has secured contracts with Enmax—Calgary's Electric System, Suncor Energy, West Kootenay Power, and a number of municipalities, businesses and private consumers. To supply the demand, Vision Quest installed two Vestas 600-kW wind turbines in 1997, and another two 600-kW units in 1998. Plans for 1999 are to install at least two more turbines of similar size. A key aspect to the success of Vision Quest is the sale of Emission Reductions to customers, who may use them, or trade them to other parties. Enmax, in Calgary, is re-selling wind energy purchased from Vision Quest to the federal departments of Natural Resources Canada and Environment Canada, as well as to over 1,000 residential consumers, at a premium price.

9.4.2 Unit cost reduction

We have no information to discuss this item.

9.5 DEPLOYMENT AND CONSTRAINTS

9.5.1 Wind turbines deployed

52 Kenetec 350-kW wind turbines;
133 NEG-Micon 750-kW wind turbines;
4 Vestas 600-kW wind turbines; 1 Tacke 600-kW and 1 Bonus 150-kW wind turbines.

9.5.2 Operational experience

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

In December 1999 the Tacke TW600 wind turbine, located near Tiverton, Ontario reached the production milestone of 5,000 MWh after operating for 4 years and 3 months. The 1999 production was 1,335 MWh, the highest yearly production figure since installation, with an availability factor of 98.5%, the highest yearly availability factor since start up.

9.5.3 Main constraints on market development

The main constraints for wind energy development in Canada are the relatively low cost and the surplus of generation capacity of conventional energy.

9.6 ECONOMICS

9.6.1 Trends in investment

The budget for the Wind Energy R&D (WERD) program of Natural Resources Canada is about CAD 600 K with contribution of about CAD 1.5 million from contractors, research institutions and provinces.

As well, the Canadian government has established the Technology Early Action Measures (TEAM) providing funds for activities falling under the Climate Change initiative. These include renewable energy deployments. TEAM's support is conditional upon 50% minimum participation

from the private sector and about 12% from the sponsoring renewable energy program (e.g. WERD). This results in an 8:1 leverage ratio for the wind energy program.

9.6.2 Trends in unit costs of generation and buy-back prices

The “net-billing” program in Ontario gives businesses and agro-businesses who operate wind turbines of up to 50 kW, for their own use, full retail price credit for the energy produced by the wind turbine. A similar program is to be implemented shortly in the Yukon. In all other Canadian jurisdictions, the buy-back price is, generally, set by the local utility at the wholesale value of electricity generated from conventional sources. Large wind farms, such as the Cowley Ridge and Le Nordais projects, have pre-negotiated special buy-back rates from the local utilities.

9.7 INDUSTRY

9.7.1 Manufacturing

- Dutch Industries (water pumps), Regina, Saskatchewan
- Koenders, (water pumpers and aerators) Englefield, Saskatchewan
- Wenvor-Vergnet of Guelph, Ontario is manufacturing 25-kW single and three-phase wind turbines for grid connected, remote communities and stand-alone applications.
- Polymarin Huron Composites Inc, Huron Park, Ontario is manufacturing blades for 25-kW to 750-kW wind turbines and is presently tooling up to manufacture blades for the 1 MW to 2 MW range.

9.7.2 Industry development and structure

Industries related to wind turbine manufacturing and deployment activities include control systems, inverters and tower manufacturers.

9.8 GOVERNMENT SPONSORED R,D&D

9.8.1 Priorities

The focus of the Canadian National Program continues to be on R&D to develop safe, reliable and economic wind turbine technology to exploit Canada’s large wind potential, as well as supporting Field Trials. As well, the program also supports a national test site—The Atlantic Wind Test Site (AWTS) at North Cape, PEI for testing electricity generating wind turbines and wind/diesel systems.

9.8.2 New R, D&D developments

The program supports new technology development activities related to:

- components for large wind turbines, in the 1 MW to 2 MW range;
- small to medium size wind turbines (10 kW to 60 kW) for use in agro-business, and to supplement diesel-electricity generation in remote communities;
- wind/diesel control systems for wind/diesel hybrids in remote communities.

9.8.3 Offshore siting

There is no information on this item for 1999.

Authors: Raj Rangi and Morel Oprisan, Natural Resources Canada, Canada

CHAPTER 10

10.1 INTRODUCTION

Denmark has a long tradition of implementing vigorous energy policies with broad political support and involving a broad range of actors, including energy companies, industry, municipalities, research institutions, non-governmental organizations (NGOs), and consumers.

A continuous effort since the beginning of the 80s has led to an installed wind energy capacity of approximately 1750 MW, a wind energy production covering 10% of Denmark’s electricity consumption, and a wind turbine manufacturing industry with a turn-over in 1999 of 11 billion DKK.

10.2 NATIONAL POLICY

10.2.1 Strategy

Denmark has had several energy strategies over the last 20-25 years, and the aims of these strategies have shifted from securing energy supplies after the crisis of 1973-74 to plans pursuing 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.

Energy 21 generally considers new large wind turbines as one of the cheapest technologies for reducing CO₂ 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.

The Energy 21 expects that a significant part of the expansion until 2005 will take place on land. The increase of wind turbine capacity on land after 2005 will have to be effected, among other things, by renovation of wind turbine areas as well as by removal or replacement of existing wind turbines in accordance with regional and municipal

Table 10.1 Policy instruments used in 1998 to promote wind turbine technology and installations

DEMAND PULL INSTRUMENTS	TECHNOLOGY PUSH INSTRUMENTS
<p>Incentives</p> <ul style="list-style-type: none"> • Taxation • Production subsidies • Programs for developing countries <p>Other regulation and policy instruments</p> <ul style="list-style-type: none"> • Resource assessment • Local ownership • Agreements with utilities • Regulation on grid connection • Buy-back arrangements • Information programs • Spatial planning procedures 	<p>Incentives</p> <ul style="list-style-type: none"> • R&D programs • Test station for wind turbines • International cooperation <p>Other regulation and policy instruments</p> <ul style="list-style-type: none"> • Approval and certification scheme • Standardization

planning. In the longer term the main part of new development will take place offshore.

In the spring of 1999, an electricity reform has been introduced and a number of new bills for the Danish electricity sector has been approved by the Parliament. The reform contributes to ensuring the fulfilment of the long-term, international environmental commitments in 2008-2012. The agreement covers the first four years from 2000 to 2003 and is a framework for CO₂ emissions from the electricity sector and for development of renewable energy.

For the period 2000-2003 a ceiling has been established for the total electricity sector's CO₂ emission of 23 million tons in 2000, 22 million tons in 2001, 21 million tons in 2002, and 20 million tons in 2003. The ceiling is to be expressed in CO₂ quotas, which will be split among the electricity production companies. The ceiling will make it possible to incorporate environmental commitments in the electricity companies planning of future investments and operational dispositions. If the annual quota is exceeded, the production companies must pay to the state the sum of 40 DKK/ton CO₂.

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

This means 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 (RE) quotas are to be announced by the Government and all consumers will be obliged to purchase an increasing share of electricity from renewable energy. In the first instance, a quota will be laid down meaning that 20% of the electricity

consumption should be covered by RE at the end of 2003. Since wind power is the most developed and one of the cheapest ways to save CO₂, a major part of the RE is going to be wind power.

The Government intends to continue its promotion of the employment and export opportunities by continued research and development.

10.2.2 Progress towards national targets

As 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 a wind turbine plans. The Danish Energy Agency has analyzed this local planning, and estimates from this the onshore wind energy potential to be between 1500 MW and 2600 MW.

Several investigations of the offshore wind resources have been prepared since 1977. As a result, two demonstration projects have been finalized. In July 1997, a Plan of action for offshore wind farms was submitted to the Minister of Environment and Energy. The plan was prepared by the two utility associations Elkraft and Elsam 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 meter are included. The wind speeds in the areas allow 3530 "net full load hours" per year at the North Sea (Horn's Reef) and between 3000 and 3300 hours in interior Danish waters. (Hub height of 55 m and rotor diameter of 64 m is anticipated). This should be compared to inland conditions of 2000-2500 hours. The total capacity for electricity production is estimated in Table 10.2.

Table 10.2 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%

In Energy 21 the targets for wind energy is 1500 MW of wind power by 2005 (12% of electricity consumption) and 5500 MW wind power by 2030 (40-50% of electricity consumption), out of which will be 4000 MW offshore. As shown later, the targets for on-shore wind power have already been surpassed, while the off-shore development is just beginning.

10.3 COMMERCIAL IMPLEMENTATION

10.3.1 Installed capacity

During 1999, approximately the same new capacity was added as in 1998. By the end of 1999, the total installed capacity of wind turbines was approximately 1750 MW. The contribution and the total capacity of wind power by the end of 1999 are shown in Table 10.3.

10.3.2 Rates and trends in deployment

The deployment rate in Denmark in numbers and electrical capacity are shown in Table 10.4. The deployment has been almost constant since 1996, adding approximate 300 MW of wind power

capacity onshore annually. The average size of the installed wind turbines has grown gradually, to 760 MW in 1999.

10.3.3 Contribution to national energy demand

The total electricity production in 1999 is estimated to approximately 3055 GWh, approximately 10% of the total electricity consumption in Denmark. The wind's energy index in 1999 was 91. Numbers are based on an estimate by E&M-Data.

10.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

10.4.1 Main support initiatives and market stimulation

A production subsidy of 0.10 + 0.17 DKK/kWh is paid to private wind turbine owners. There are limitations to the wind farm developments to which the above incentives apply. Private individuals, for example, are only allowed to grid-connect one turbine, and this must be placed on the owner's land. Similarly each shareholder in private co-operatives is limited to

Table 10.3 Status for wind turbines in Denmark by the end of 1999

OWNER TYPE	TURBINES ADDED	MW ADDED	TOTAL TURBINES	TOTAL MW
Private individuals	307	233.0	2511	1012.0
Private cooperations	50	37.0	2282	433.0
Power utilities	66	51.0	723	283.0
Municipalities, industries, others	3	2.0	114	24.0
Total	426	324.0	5630	1752.0

Table 10.4 Installed wind turbine capacity and development in size

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

owning shares equal to 30,000 kWh. The shareholders must live in the same municipality where the turbine is installed. The utilities receive 0.10 DKK/kWh in production subsidy.

The buy-back rates are related to the utilities' production costs (tariffs). A law obliges power utilities to pay wind turbine owners a kWh rate of 85% of the utility's production costs. The average buy-back rate in 1998 was 0.328 DKK/kWh. Since most Danish electricity production is based on coal, the wind energy buy-back rates are closely related to the coal prices on the world market.

Favorable taxation schemes have been used to stimulate private wind turbine installations. These taxation schemes have changed over time. Today, income from wind turbines, by and large, is taxed as 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 vindmøller i Danmark" (Technical Criteria for Type Approval and Certification of Wind Turbines in Denmark). 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.

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

international competition, and several foreign enterprises are active. See Table 10.5.

10.4.2 Unit cost reduction

The ex-factory price of wind turbines of one generation (1991, 150 kW - 225 kW) to another generation (1997, 600 kW) level has decreased by 20% (measured in DKK/kW). Other investment costs related to a wind farm (foundation, grid connection, roads, consulting, etc.) have decreased 50% (from 28% to 20% of total investment), and electricity production costs have decreased by approximately 30%.

Because technological development and manufacturing improvements have taken place together with an up-scaling of the machines and an increasing of the market volume, it is difficult to determine from which of the sources cost reduction comes. However, it has been generally acknowledged that the introduction of a new generation (or size) of turbines has reduced turbine prices significantly - especially for the 600-750 kW generation, see Figure 10.1.

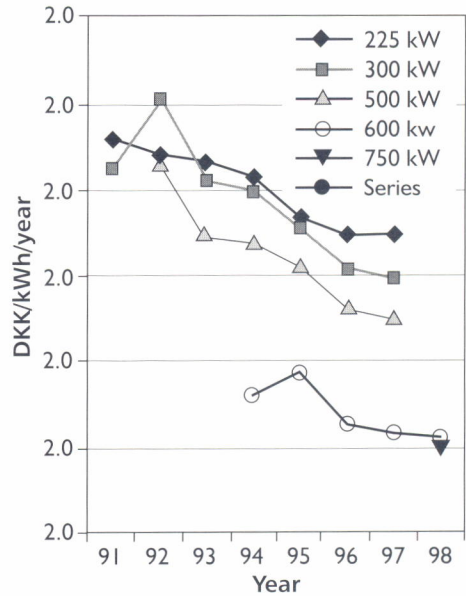


Figure 10.1 Development of specific investment defined as ex-works turbine price divided by annual production in roughness class 1. Price level 1999. Based on list prices of leading manufacturers.

Table 10.5 Bodies authorized by the Danish Energy Agency to provide services under the Danish scheme for certification and type-approvals for wind turbines (1999)

SERVICE	AUTHORIZED BODY
Production and installation certification	Germanischer Lloyds Certification GmbH Det Norske Veritas Certification of Mgt. Systems Bureau Veritas Quality Insurance Dansk Standard
Type approvals	Risø, Approval Office Det Norske Veritas Germanischer Lloyds
Basic tests	Tripod Consult Aps Risø, Test & Measurements
Power curve measurement	DEWI, Wilhemshafen WindTest, Kaiser-Wilhelms-Koog GmbH Tripod Consult Aps Risø, Test & Measurements
Noise measurement	DEWI, Wilhemshafen WindTest, Kaiser-Wilhelms-Koog GmbH Wind Consult GmbH DELTA Akustik & Vibration + bodies approved by DELTA

10.5 DEPLOYMENT AND CONSTRAINTS

10.5.1 Wind turbines deployed

Wind turbines are typically installed in clusters of 3 to 7 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 (in capacity) is Rejsby Hede with 42 600-kW machines.

Different groups own wind turbines, including 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. Especially co-operations spreading ownership of a wind turbine between 20 to 100 families in the vicinity of the wind turbine have been 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 interest rates have decreased, prices for wind power electricity have increased slightly, and laws for facilitating structural changes in the farming sector have unintentionally opened up new possibilities for farmers.

Approximately 400 wind turbines were installed during 1999, and the total number of turbines by the end of the year was 5630. Numbers are based on manufacturers' information. All turbines in Denmark are horizontal axis machines of the "Danish concept" type. There is no available overview of market shares on the Danish market.

10.5.2 Operational experience

Technical availability of new wind turbines in Denmark is usually in the range of 98% – 100%.

The Danish wind turbine owners' association is responsible for recording operational experiences. The results are published in the association's magazine "Naturlig Energi". They voluntarily report operational data to this database regularly on 2,830 turbines with a total installed capacity of 700 MW.

Technical life time 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 gearbox, braking clutches, etc. are often replaced with intervals of 1 to 3 years. Parts of the yaw system might be replaced in intervals of 5 years. Vital components exposed to fatigue loads such as main bearings and bearings in gearbox might be replaced halfway through the total design lifetime. This is dealt with as a re-investment.

Operation and maintenance costs include service, consumables, repair, insurance, administration, lease of site, etc. The Danish Energy Agency, E&M-Data, and Risø National Laboratory have developed a model for annual operation and maintenance costs. The model is based on statistical surveys and analyses in 1991, 1994, and 1997. The model includes a large re-investment after the 10th operational year on 20% of the cost of the wind turbine.

Table 10.6 Annual operational and maintenance costs in % of the investment in the wind turbine

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

This re-investment is distributed over the operational years 10 to 20. See Table 10.6.

10.5.3 Main constraints on market development

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

Up to 1999, two small (5-MW) offshore demonstration wind farms at Vindeby and Tunø have been built by the utilities and the permissions were granted by the Government based on existing regulations. Other applications have been refused with the argument that further investigations were needed in connection with the earlier mentioned large scale demonstration projects before any other permissions could be granted.

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

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

The bill lay down the procedures for approval of electricity production from water and wind and for 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 coasts.

10.6 ECONOMICS

10.6.1 Trends in investment

The ex-works cost of wind turbines has decreased significantly with the latest 600 kW and 750 kW generation (44-48 meter rotor diameter). For 600-kW machines installed in 1997 and 1998, the ex-works cost was, typically, DKK 3.1-3.5 million, and for 750-kW machines in 1998 it was

DKK 3.4-4.1 million depending on rotor diameter and tower high.

Additional costs depend on local circumstances, such as the condition of the soil, road conditions, proximity to electrical grid sub-stations, etc. Additional costs at typical sites can be estimated as 20% of total project costs for the 500 kW to 750 kW generation machines. The cost of land has however increased during recent years and has raised the percentage of additional costs.

The figures in Table 10.7 are the result of a statistical analysis of a number of projects of 600-kW wind turbine technology. The turbines in the analysis were sited individually or in clusters of up to 8 machines.

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.

In 1998, individually owned projects (farmers) typically finance projects over 10 years with an annual interest rate of 6% to 7%.

10.6.2 Trends in unit costs of generation and buy-back prices

The production costs for wind generated electricity per kWh have decreased rapidly over the last 18 years and today the costs are getting close to the cost of electricity production from a new coal fired power station based on condensation. The estimated cost is shown the Figure 10.2.

Average electricity price from power distribution utilities varies from 0.295 to 0.442 DKK/kWh. For private consumers (connected to the 400/230-Volt distribution grid) a number of taxes are added to this price. In addition, a 25% value added tax (VAT) is added. In 1998, the average consumer price for Danish low voltage customers was between 1.20 DKK/kWh and 1.35 DKK/kWh.

In 1998, the price of electricity from power distribution utilities has been approximately DKK 0.37 - 0.45/kWh.

For private consumers (connected to the 400/230-Volt distribution grid), a number of taxes are added to this price. The electricity tax was DKK 0.46/kWh in 1998. The CO₂ tax is DKK 0.10/kWh. The SO₂ tax is DKK 0.009/kWh. On top of this, 25% VAT is added. In 1998, the average

Table 10.7 Cost of a 750 wind turbine project. Based on a statistical analysis

COMPONENT	AVERAGE KDKK (000)
Turbine ex works	4100
Foundation	200
Grid connection	385
Electrical installations	26
Communication	20
Land	135
Roads	52
Consulting	47
Finance	25
Insurance	125
TOTAL	5115

consumer price for Danish low-voltage customers was DKK 1.28/kWh.

The utilities are obliged by law to connect private wind turbines to the grid. 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 obliged power utilities to pay wind turbine owners a kWh rate of 85% of the utility's production and distribution costs (85% of DKK 0.37-0.45/kWh in 1998). Up to now, the Government has reimbursed wind-turbine owners the DKK 0.10/kWh CO₂ tax and added DKK 0.17/kWh in direct subsidy. As a result, in 1998 the average selling price of electricity from private wind turbines was approximately DKK 0.6/kWh.

With the new regulation, from year 2000 the whole payment will come from the electricity consumers. The price the distribution companies pay after a transition period will be the actual market prices of conventional electricity. In addition, the producers of electricity from wind will receive green certificates, which all consumers are obliged 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 DDK/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 a well-functioning market for renewable energy has been established or for a fixed period of 10 years. In addition wind turbines will continue to get the so-called "CO₂ 10-Øre".

Also depending on the size and the age of the turbines, an additional price subsidy

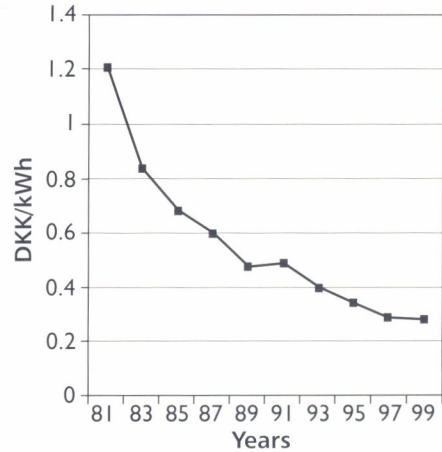


Figure 10.2 Estimated Costs of Wind-Generated Electricity in Denmark, Based on 20-Year Depreciation, 5% Interest Rates, and Siting Roughness Class 1

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 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 10-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.

10.7 INDUSTRY

10.7.1 Manufacturing

Danish based manufacturers of large commercial wind turbines in the 150 kW to 2.0 MW range are: Bonus Energy A/S, NEG Micon A/S (incl. Wind World), Nordex Energi A/S, Vestas Wind Systems A/S, af

1997 A/S, Wincon West Wind A/S. Gaia Wind Energy A/S makes machines for electricity to households in the range 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, FAG, etc. have developed businesses in the wind power industry.

The wind turbine manufacturers turnover in 1999 was more than 11 billion DKK.

Approximately 85% of the production is exported. Total wind turbine manufacturing in Denmark was over 1800-1900 MW out of which 324 MW was sold domestically. Increasingly more manufacturing takes place in foreign subsidiaries and joint-ventures and does not appear in the Danish export numbers.

10.7.2 Industry development and structure

Industrial development in 1999 focused on refining the MW generation of turbines. This includes among other things upgrading the turbines with larger generators and larger rotor diameters. The wind turbines types of the Danish market are shown in Table 10.8. For most of the types, a number of versions with different tower heights can be supplied. In addition to the machines in the table, Bonus introduced in 1998 a commercial 2.0-MW machine.

Table 10.8 Wind turbines (>100 kW) on the Danish market. Energi-og Miljødata (EMD), Dec. 1999

MANUFACTURER	TYPE	NOMINAL POWER (KW)	EXTRA GENERATOR (KW)	ROTOR DIAMETER (M)	POWER REGULATION
BONUS	600 MK IV	600	120	44.0	Stall
BONUS	1 MW	1,000	200	54.0	Ac stall
BONUS	1.3 MW	1,300	250	62.0	Ac stall
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 (2.gen)	660	200	47.0	Pitch
VESTAS	V47 (1.gen)	660	0	47.0	Pitch
VESTAS	V66	1,650	300	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

Service and maintenance of the more than 5000 wind turbines in Denmark is carried out by the manufacturers service departments, but also a handful of independent service companies have been established. These are companies such as DWP MNlleservice A/S and DanService A/S. Some of the electricity companies service their own turbines.

Other industrial service enterprises have created important businesses in servicing the wind power industry. For example, companies are specialized in providing cranes for installations of wind turbines; providing transport of turbines, towers and blades domestically and for export; insurance, etc. 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.

10.8 GOVERNMENT SPONSORED R,D&D

10.8.1 Priorities

The Danish government sponsors two programs. One is the Ministry of Environment and Energy's Energy Research Programme (EFP). During recent years a part of the research program is allocated to energy issues in Eastern Europe and the former Soviet Union. The Energy Agency administers 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 are normally run over two or three years and funding will be given by the end of each year. In almost all projects several partners participate, and industrial participation and co-financing is encouraged. The Danish Energy Agency typically finances 50% to 85% of the total

costs. In the 1999 round (processed in 1998) 4 projects were supported with total amount of 14.33 million DKK.

Another is the Ministry of Environment and Energy's program for development, demonstration and information of renewable energy (UVE). The Energy Agency administers the program. The program so far has been renewed every three years. In the present period, projects are initiated through a standing call for proposals. There is no deadline for project proposals, but they are debated on at the regular meetings in the Technical Advisory Committee. Projects are always shorter than three years. In 1999, projects were supported by the Danish Energy Agency with a total of 10.6 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 with 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 this program, the Danish Energy Agency operates test stations for different renewable energy technologies. One is the Test Station for Wind Turbines at Risø National Laboratory. The activities of the Test Station for Wind Turbines are negotiated each year. The budget for the Test Station task at Risø was 8.1 million DKK in 1999.

The total budget for the Danish Energy Agency's wind energy activities amounted to 33 million DKK. This is 14% less than in 1998.

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 industry participate in the European Union's RTD programmes. No quantitative data are available.

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

10.8.2 New R, D&D developments

The overall aims of the energy research program follow.

1. Contribute to realization of the goals of the energy policy through short-term research activities
2. Support long-term and strategic research, which significantly can improve the Danish energy situation in a long-term perspective and establish the basis for new political initiatives.
3. Contribute to achieving other political goals than those affiliated with energy issues, such as the country's economical development, environmental improvements, industrial development, employment, export, etc.
4. 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.

At least one third of the resources of the energy research program must be aiming at long-term perspectives (beyond year 2005). Project titles in the 1999 round of the research program for wind power were:

- Aeroelastic Research Programme 1999-2000
- Wind farm production predictor
- Large off-shore wind farms in the power system. Voltage quality and power

dynamics. Pre-project on measuring techniques

- Design regulations for offshore wind farms

Descriptions (in Danish) of the projects are available on the Danish Energy Agency's Web pages.

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

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

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

The Test Station for Wind Turbines activities for 1998 were more or less the same as the preceding years and include the following.

- 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-down of turbines
- International standardization

- Development of test methods for wind turbines
- Development of test methods for blades
- Participation on the IEA annex on Round Robin test of a wind turbine

10.9 OFF-SHORE SITING

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 4.95 MW and Tunø Knob 5 MW.

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

Several investigations of the offshore wind resources have been conducted since 1977 resulting in the finalization of the two demonstration projects. In July 1997, a plan of action for offshore wind farms was submitted to the Minister of Environment and Energy. The plan was drawn up by the two electricity utility associations, Elkraft and Elsam, together with the Danish Energy Agency and the National Forest and Nature Agency. The plan of action includes eight areas with water depths of up to 15 meters. The total theoretical installed capacity of these areas is 28,000 MW, and it was estimated that about 12,000 MW realistically could be utilized in four major areas. These are west of Horns Rev in the North Sea, south of the island of Laesoe in "Kattegat", south of the island of Omoe in "Smaalands Havet" and south of Lolland Falster ("Roedsand" and "Gedser" in "Oestersoen" (the Baltic Sea). The wind speeds in the areas allow 3530 "net-full load hours" in the North Sea (Horns Rev) and between 3000 and

3300 hours in interior Danish waters. (Hub height of 55 m and rotor diameter of 64 m are anticipated). This corresponds to an annual electricity production of 12 - 14 TWh. For comparison, the total Danish electricity consumption in 1997 was 32 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 on land installations. It was recommended that steps be taken for a first phase of development, meaning that a 150-MW demonstration offshore wind farm should be erected in each of the selected areas. After that, approximately 150 MW would have to be built each year over the next 25 years to fulfil the above mentioned offshore action plan.

In 1999, 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 5 large offshore farms shall be erected between 2001 and 2008. The turbines sizes used will be the newest commercial technology in the coming years. For the first one 2.0-MW turbines will be used.

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CHAPTER 11

11.1 GOVERNMENT PROGRAMS

The Ministry of Trade and Industry presented late in 1999 a new promotion program for renewable energy sources. The program is motivated by three things.

- the Kyoto protocol on the reduction of emissions of greenhouse gases of 1997
- the European Union (EU) White Paper, endorsed by the Commission in 1997 and the Council in 1998
- Finland’s Energy Strategy of 1997 announced by the Parliament.

The program presents targets for the year 2010 and a vision for 2025. The target is to increase the use of renewable energy sources by at least 50% (3 Mtoe/a) by 2010 from the level of 1995. It is expected that of this increase 90% will consist of bioenergy, 3% of wind power, 3% of hydro power, 4% of heat pumps, and less than 0.5% of solar power.

The share of renewable energy sources in power production would increase by 8.3 TWh (2010 MW) from the level in 1995.

The major part, 75%, would be generated from biofuels (6.2 TWh, 1050 MW). The share of wind power in additional power generation would be 1.1 TWh (500 MW), and that of hydro power 1.0 TWh (420 MW) by 2010. The hydro power target concerns small-scale hydro power plants of (less than 10 MW), and renovation and overhaul of old plants but not new large-scale hydro power plants. The percentage of solar energy would be less than 1%, i.e. 0.05 TWh (40 MW). The achievement of the targets would reduce greenhouse gas emissions by about 7.7 million tonnes of CO₂ equivalent.

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

11.2 TARGETS FOR WIND ENERGY DEPLOYMENT

New and updated targets are set for wind energy deployment. The previous target of 100 MW by 2005, that was presented in

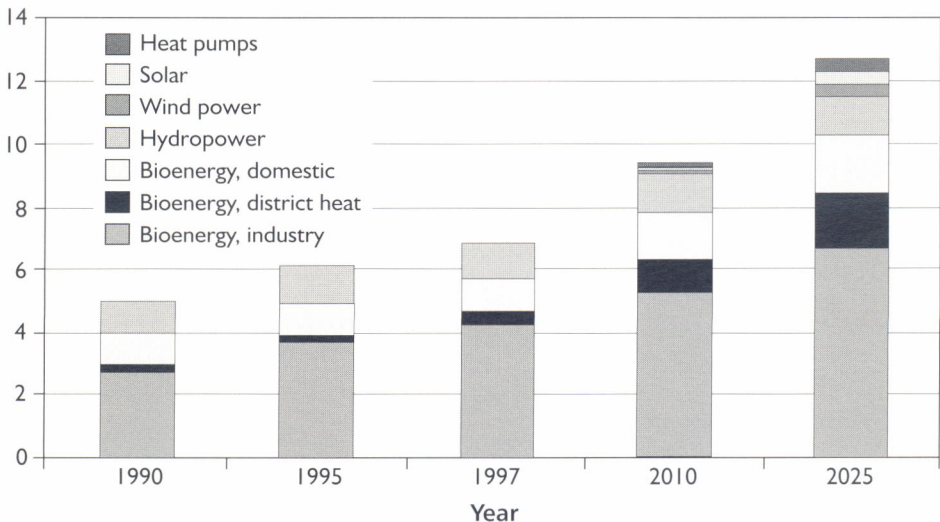
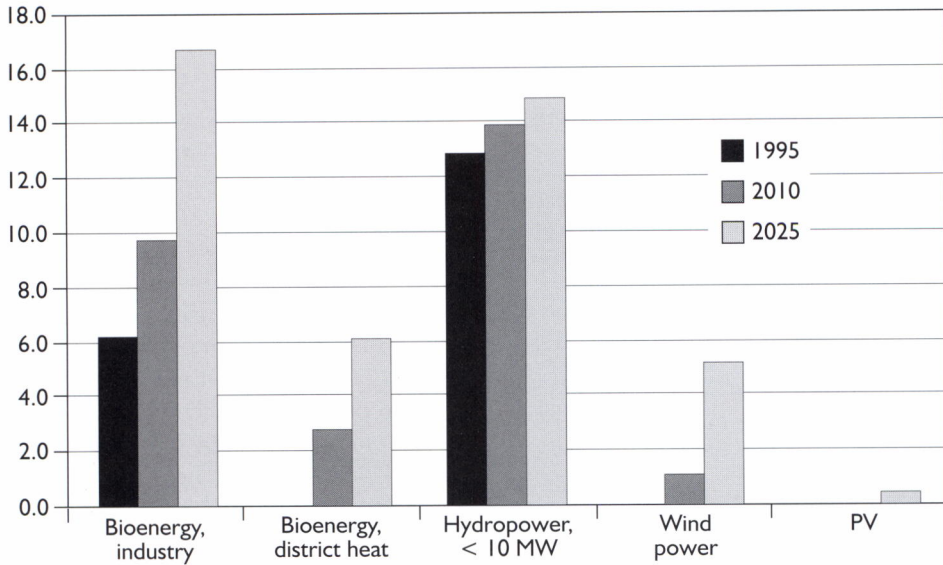


Figure 11.1 Targets for renewable energy sources in Finland (Mtoe)



Years 2010 and 2025 includes only small-scale hydro power < 10 MW and electricity cogeneration in district heat production includes industrial CHP

Figure 11.2 Targets for electricity production by RES (TWh)

1993, has been updated to 150 MW, and a new target of 500 MW is set for the year 2010.

In addition, the program presents a vision of 1000 MW in 2015 and 2000 MW in 2025. Thus wind energy production would reach 5 TWh/a in 2025, which is about 5% of the projected gross power consumption.

11.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

11.3.1 Installed wind capacity

In 1999, a total of 20 MW of new capacity was added, which doubled the total capacity in Finland. The largest wind park

of 8 MW was installed in western Finland during the summer. There is a clear trend towards larger turbines (Table 11.2) and already a majority of the turbines installed were 1 MW or 1.3 MW in size.

Turbines are either owned by co-operatives and specific wind energy companies or by power companies, utilities or companies partly/jointly owned by them. In 1999, especially utilities were seeking to add wind energy to the product range they offer their customers.

Wind energy activities are concentrated to the coastal areas of Finland, mainly the

Table 11.1 Installed capacity and production of wind energy in Finland

YEAR	NEW CAPACITY (MW)	TOTAL CAPACITY (MW)	PRODUCTION (GWh)
1992	-	1.6	2.4
1993	3.0	4.6	4.4
1994	-	4.6	7.2
1995	1.8	6.4	10.8
1996	0.9	7.2	11.0
1997	4.6	11.8	16.6
1998	5.6	17.4	23.5
1999	20.6	38.0	49.3

Wind turbines in Finland 1999

Total 38 MW, 63 turbines

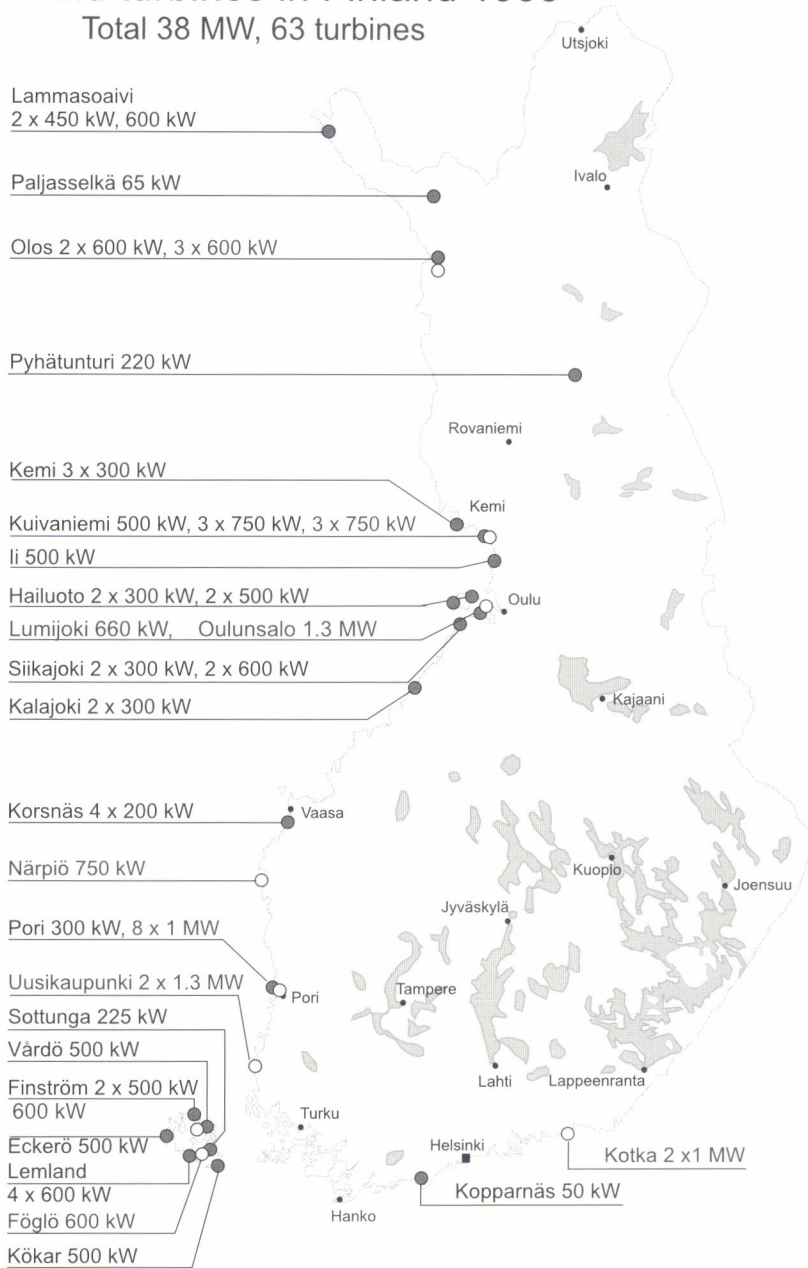


Figure 11.3 Location of installed wind turbines in Finland

northern part of the Gulf of Bothnia, the west coast and the Åland islands in the Southwest. There are, so far, fewer activities on the more heavily populated south coast. In addition, there is a significant interest in wind energy in Lapland in northern Finland, where, due to the

extreme climatic conditions, some special technical applications are needed.

11.3.2 Comparison with gross energy consumption

The annual gross power consumption in 1999 was about 78 TWh. The annual growth

Table 11.2 Number of new wind turbines in Finland installed each year

YEAR	< 100 kW	200–300 kW	450–600 kW	750–1000 kW	1300 kW AND ABOVE	TOTAL
1991	1	4				5
1992		1				6
1993		11				17
1994						17
1995			4			21
1996			2			23
1997			8			31
1998			6	3		40
1999			6	14	3	63

is expected to be about 2-4% for the next decades. The current power production capacity during years with normal rainfall amounts to about that 75 TWh/a. All in all wind energy will for the future years only supply very small shares of the national power balance.

11.3.3 Performance and operational experience

The 1999 wind year was not a very good one. Meteorological statistics show that, depending on region, the possible wind yield remained at only 80-90% of an average year. The storms that hit central Europe late in the year did not significantly affect the turbines. However, there were some incidents of heavy icing on turbines not normally experiencing this.

The turbines were generally operating well, except for some generator problems in individual turbines and some bigger problems in the harsh weather conditions of northern Finland.

11.4 MANUFACTURING INDUSTRY

11.4.1 Status of manufacturing industry

There are no wind turbine manufacturers in Finland. However, main components such as gearboxes and induction generators are produced and sold to the main wind turbine manufacturers. Also materials like steel plates and glass-fibre are sold to the wind industry. The total turnover of this

“sale of components” is estimated to be about FIM 500 million in 1999 and is expected to even double during the next two years.

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 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 will be exported. The first delivery to Sweden was made in 1998.

11.4.2 Support industries

Four Danish manufacturers have selling agents operating in Finland. Further, there are several consulting companies working in the field of wind energy. They carry out a wide range of activities, such as feasibility studies, engineering, environmental analyses, and potential studies. They are also offering full turnkey delivery and O&M services.

11.5 ECONOMICS

11.5.1 Power market

The Finnish electricity market was liberalized in 1995 and from the beginning

of 1997 also small consumers can participate in the market. Since September 1998, household customers can buy their power from any producer without hourly measurements. Basically, this means that power sales and distribution are separated and that anyone can buy power from anywhere and transfer the power through the common grid. Every producer has, however, a balance responsibility.

Specific co-operatives and wind energy producers have started activities to use the free energy market and to sell wind-generated renewable energy to dedicated customers. In response, the power companies and utilities have also taken measures to have some wind power in their product-line, in order to keep their customers. This was the prime motivator for utilities' activities in building wind turbines in 1999.

As a result, there is no fixed price at which wind power is rewarded by the utilities. Every producer has to find its own customers and work out an agreement on the retail price. Several utilities offer their customers a "green power tariff" with an extra charge of FIM 0.02-0.04/kWh that is allocated directly to the wind energy producer. E.g. the Society for Nature Protection Finland offers a "green energy certificate" for the production of renewable energy (including old hydro-power plants). The successes of these tariffs have, however, so far been modest.

11.5.2 Market stimulation instruments

The Ministry of Trade and Industry (MTI) can subsidize installations by up to 30% of the investment. The percentage is decided on a project-by-project basis, and handling time has been as long as one and one half years. Preference is given to projects that include some kind of technical innovation.

From the beginning of 1997, taxation was moved from energy production to energy consumption. Where the production tax

was CO₂-related, the consumption tax is a general electricity tax that does not consider fuel or any environmental impact. However, wind energy production is rewarded with an extra national support of 0.04 FIM/kWh, corresponding to the electricity tax for industrial consumers. For other small local energy production the support is 0.02 FIM/kWh.

11.5.3 Institutional factors

Regional Environmental Centres have authority regarding planning and environment issues in the respective regions. Some of them have a strong negative attitude towards wind energy. Local or regional councils have stopped several prospective projects.

A working group of the Ministry of Environment published in 1997 a draft report concerning how wind turbines should be considered in local and regional planning and which factors should be concerned in the handling of applications for planning permissions for wind turbines. The final report is expected soon and is directed towards local and regional planning authorities.

11.5.4 Impact of wind turbines on the environment

The visual impact on the landscape is the most difficult planning problem related to wind energy and after economics the most significant obstacle to development. The reason is simply that the most windy regions are also very picturesque and environmentally valuable. Especially the Finnish archipelago is significant in shaping the national identity. Further, many Finns have summer cottages in the countryside, especially in the archipelago and other coastal regions. At their summer cottages people want to have a close relation to the untouched nature. They do not approve of modern technology, like wind turbines, in close vicinity.



Figure 11.4 An overview of the 8-MW wind farm in Pori in the west of Finland

11.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

11.6.1 Funding levels

The national research program NEMO2 for Advanced Energy Systems and Technologies came to its end in 1998. Since then, there has been no dedicated program for wind energy R&D. Wind energy research projects are still funded by the National Technology Development Centre Tekes but decisions are made on a project by project basis. Wind energy research has in total received public funding of about FIM 5 million per year.

11.6.2 Priorities

Priority is given to projects that have an industrial benefit, i.e. projects leading to results that rapidly can be utilized by the industry. An indicator of this is usually the amount of direct financing by the industry itself.

Regarding wind energy, priority is given to projects that strengthen and maintain the current position of the component industry and projects that increase the added value of material supplies.

11.6.3 Offshore developments

R&D on offshore installations is focused on foundation technology. In addition to wave and wind loading, foundations have to withstand ice loads because the sea is covered with ice up to 100 days every year.

This whole ice field is moving and building ice ridges on the shorelines that can reach up to 30 m height. The possibilities for large-scale offshore installations are, however, present and the necessary foundation technology is used in other applications such as lighthouses.

The offshore potential is recognized and it is evident that one has to go offshore if significant amounts of wind energy are to be added to the national power balance. However, the general impression is to await results from programs like the Danish offshore program before deployment will start.

11.6.4 International collaboration

Most of the international collaboration in R&D is carried out within the European Union's research programs. Participation in the dissemination programs is also active.

R&D projects funded by the EU programs can be co-funded up to 20% by TEKES, if the projects fit in with the general targets for technical R&D, that are described above.

A national mirror committee was established in 1999 to follow the development of international standards on wind turbine technology within IEC and CENELEC.

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CHAPTER 12

12.1 GOVERNMENT PROGRAMS

12.1.1. Aims and objectives

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

The program continues to follow 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.

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 which allow the development of a sufficiently broad spectrum of technical options.

12.1.2 Strategy

The strategy of the R&D funding of the 4th Program follows three aims.

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 1. and 2. above.

In the short and medium term, an important contribution to decrease energy consumption

and to reduce CO₂ emissions is expected from the improvement of thermal power stations and a further use of rational energy.

In the medium or long term, renewable energies are expected to contribute significantly to the German energy supply and to reduce CO₂ emissions. Technically 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, photovoltaics).

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 are supported in photovoltaic energy (including the new 100,000 PV-roofs program), wind power (including the "250 MW-Wind"-Program), biomass, geothermal energy and other renewables. In addition it supports application systems for southern climatic conditions.

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

12.1.3 Targets

The "4th Program for Energy Research and Energy Technologies" was related to the political target of the German government to reduce the CO₂-emission by 25% from 1990 levels by the year 2005. Sustained implementation of the program will contribute to reaching 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

CO₂-emission by 20% compared to 1990 levels by the year 2005.

Governmental targets for wind energy in Germany are not specified. In governmental publications, an annual wind electricity production of up to several per cent of total electricity production are considered to be possible. Within the "250 MW Wind"-Program, a total rated power of actual 347 MW (250 MW refers of the WECS power at 10 m/s wind speed), corresponds to a yearly electricity production (including the early smaller WECS) of roughly $1800 \text{ h} \times 347 \text{ MW}$ plus or minus 10% = 0,6 multiplied by 109 kWh plus or minus 10%, or almost 0.13% of the total electricity actually produced.

Two German Federal States published specific Targets. Lower Saxony: 1000 MW by the year 2000 (status by 31. Dec. 1999 : 1204 MW) and Schleswig-Holstein: 1,200 MW by the year 2010 (status by 31. Dec. 1999 : 978 MW).

12.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

12.2.1 Installed wind capacity

By December 31, 1999, the number of installed wind turbines was 7879, with a total rated power of 4445 MW. In 1999, 1676 turbines with a total of 1568 MW were installed.

The total number of turbines in operation by December 31, 1999 within the "250 MW Wind"-Program was 1493 (19% of all WECS), corresponding to a total of 347 MW (8% of the total capacity). The development of wind power in Germany is shown in Table 12.1. The distribution of wind power for the 16 German states is given in Table 12.2.

The total rated power of wind turbines by the end of 1999 in the three coastal Federal States Lower Saxony, Schleswig-Holstein and Mecklenburg-Vorpommern was 2538 MW (57% [last year 62%] of the total installed

Table 12.1 Development of wind power in Germany; "250 MW Wind" and total by December 31, 1999

DATE	NUMBER OF WECs		RATED POWER (MW)		WIND ELECTRICITY PRODUCTION (10 ⁶ kWh)	
	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	255.5	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	1493.0	7879.0	347.0	4445.0	ca 0.7000	ca 7.40

Table 12.2 Regional distribution of wind energy utilization

FEDERAL STATE	NUMBER OF	INSTALLED CAPACITY
	WTGS	MW
Lower Saxony	2124.0	1204.18
Schleswig-Holstein	1899.0	978.25
North Rhine Westfalia	974.0	420.24
Brandenburg	531.0	362.58
Mecklenberg-Vorpommern	591.0	355.79
Saxony-Anhalt	392.0	303.96
Saxony	359.0	245.22
Hessia	308.0	166.55
Thüringia	190.0	147.46
Rheinland-Palatine	278.0	141.91
Bavaria	89.0	48.85
Baden-Württemberg	64.0	31.96
Hamburg	39.0	18.42
Bremen	25.0	10.85
Saar District	16.0	8.30
Berlin	.0	0.00

wind power) corresponding to 4614 WECS (59% of all WECS).

12.2.2 Comparison with conventional public electricity consumption

The total public electricity consumption in Germany for 1999 was 436 TWh. According to the data given in the Table 12.1, it follows that during 1999 wind power contributed about 1.7% to the German public electricity consumption (1998 : 1.0%). The contribution of all renewables, is nearly 6%. For 2000, the wind power contribution to electricity consumption in Germany will increase again due to the further establishment of wind power and could surpass the 2% mark, see also Section 12.5 discussion of EFL.

The wind power contribution compared to the net electricity consumption for the three German coastal states increased considerably to 18% for Schleswig-Holstein, to 5% for Lower Saxony and to 12% for Mecklenburg-Vorpommern (potential annual energy yield for a 100% wind year).

12.2.3 Numbers/type, make of turbines/ownership

The statistics of different WECS types are available for the WECS within the "250 MW Wind"-Program too, see Figure 12.1. The table represents the situation from the beginning of the program in about 1990 until today. In 1990 many smaller WECS—no longer on the market—came into operation. Due to the "250 MW Wind"-Program the statistics of ownership are

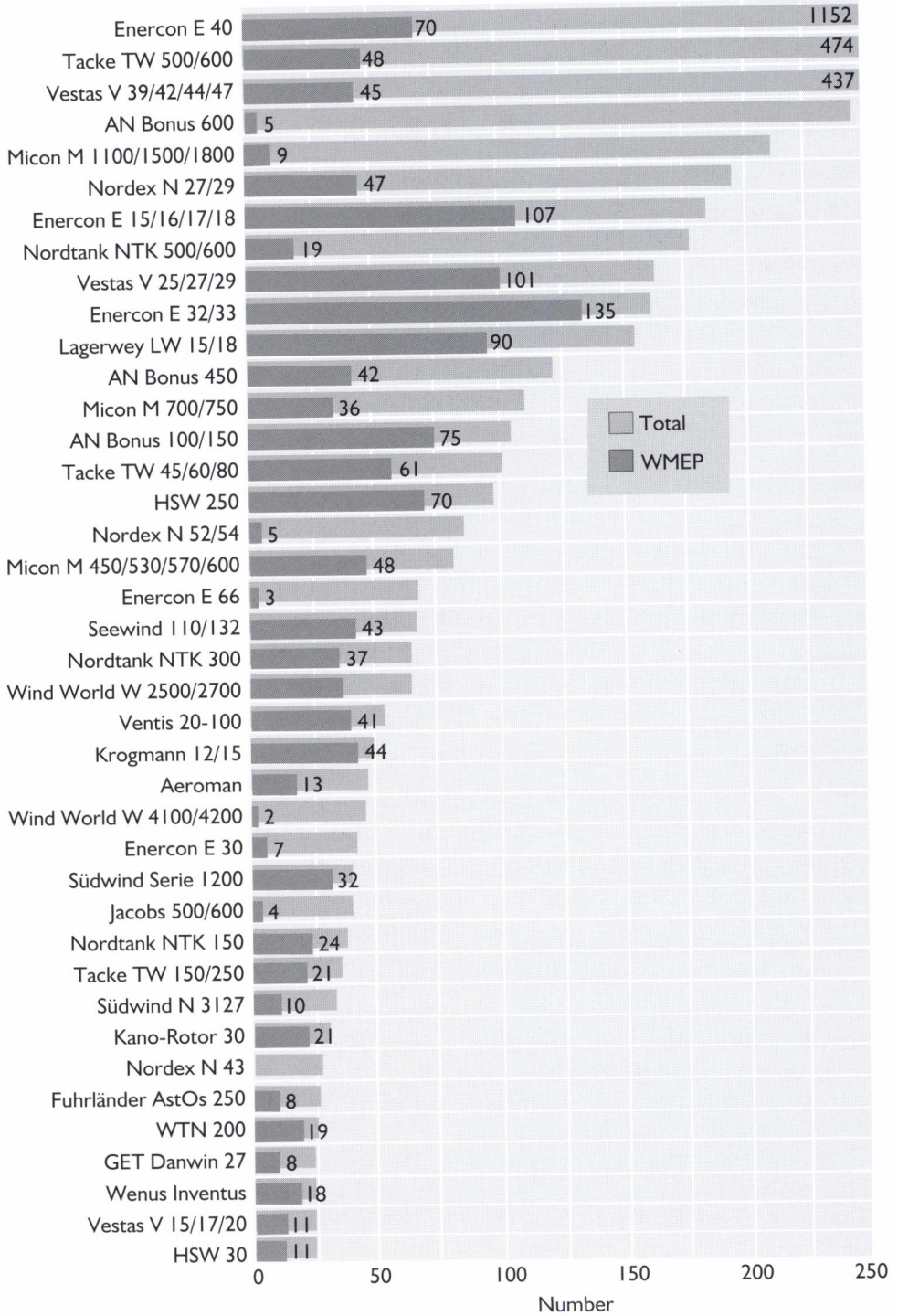


Figure 12.1 WECS types by December 31, 1999

Table 12.3 Ownership of WECS of “250 MW Wind” Program by January 1998

OWNERSHIP	PROJECTS	WECS	RATED POWER (MW)	AVERAGE POWER (kW)
Private individuals	594	678	121.6	179
Farmers	250	257	35.7	139
Trade and industry	237	452	165.3	366
Communities	51	57	7.41	130
Electricity companies	31	66	20.1	304

known, see Table 12.3. Private individuals and trade and industry (including the so called power-investors) erected by far the largest part of the total rated power, but trade and industry is leading with the average WECS size. For the number of turbines installed in 1999 and in total we refer to the previous section and Table 12.1.

These numbers again reflect the development of wind power in Germany since 1989/90: Farmers and private individuals bought the smaller WECS available at that time, whereas today trade and industry, mostly new firms, invested in projects with WECS of the commercial 500- to 600-kW class and MW-class WECS of European manufactures.

12.2.4 Performance and operational experience

The average technical availability of wind turbines for 1999 was nearly 99%. That means an average stand-still time of about 85 h per year per unit. This performance of wind turbines in Germany was recorded within the “250 MW Wind”-Program. For this purpose, ISET carries out a Scientific Measurement and Evaluation Program, WMEP, on behalf of BMWi.

Figure 12.2 shows examples of failure statistics and statistics of repaired and

exchanged parts. More than 50% of the causes of failure are identified with component failure or control systems of the WECS. About 25% of the causes are identified with external influences (high wind, grid failure, lightning, icing).

12.3 MANUFACTURING INDUSTRY

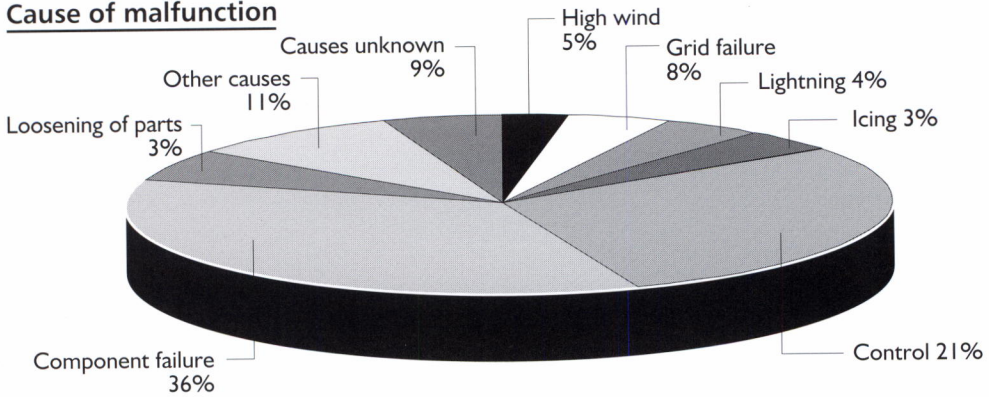
12.3.1 Market shares

Table 12.4 shows the shares of the suppliers on the German market in 1999. Table 12.5 shows new installations in October 99 according the Windkraft-Journal. This indicated that the MW-size turbines increasing popular. The table shows, that in October 1999, no small WECS were erected and that wind power development continues to grow in inland Federal States; 130 MW of wind power was installed in one month.

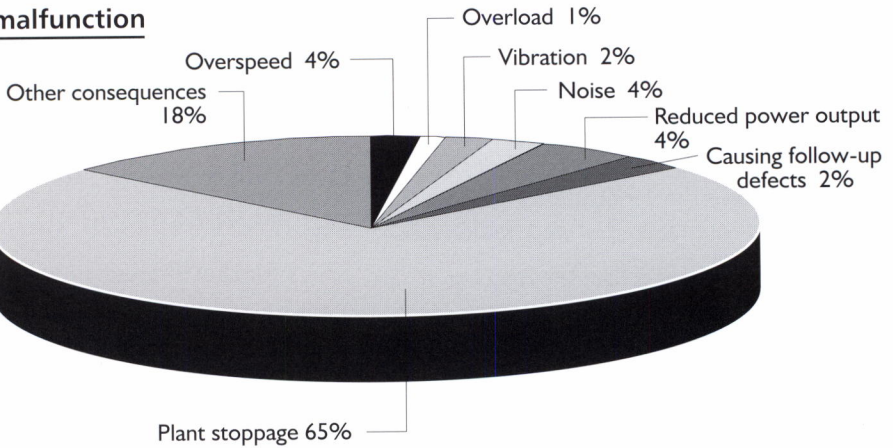
12.3.2 New products and technical developments

The excellent availability of the WECS-Installations in Germany, as well as the average installed power of 935.4 kW/turbine for new turbines in 1999, indicate a rapid technical development of wind power. This is not limited to German manufactures, as shown in Table 12.4 Market Shares, see also Section 12.4.

Cause of malfunction



Effect of malfunction



Repaired/exchanged parts

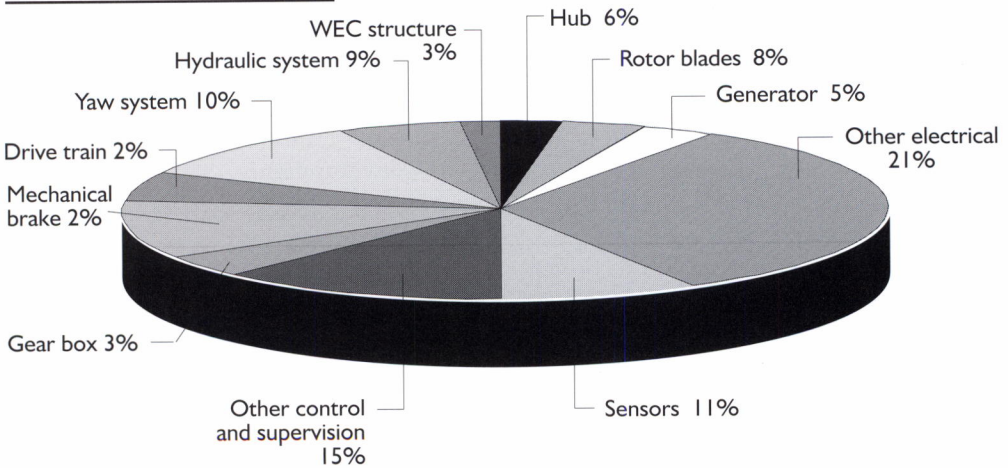


Figure 12.2 Failure and repair statistics for all WECs in the WMEP program

Table 12.4 Market shares in Germany (DEWI), 1999

MANUFACTURER	TOTAL POWER	WECS
	%	%
ENERCON	25.6	28.9
VESTAS	15.7	13.9
NORDEX	13.2	10.8
TACKE WIND	12.7	10.2
NEG MICON	10.5	11.5
AN WINDENERGIE	9.2	6.1
DEWIND	4.5	5.7
FRISIA	1.7	2.0
SUEDWIND	1.6	2.5
OTHERS	5.3	5.7
TOTAL	100.0	100.0

The number of direct and indirect employees in German wind power industry is at present more than 10,000. The total commerce connected with WECS in Germany in 1999 amounted to 3.4 billion DEM (DEWI). In addition, 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 most important to maintain the excellent availabilities (averaging 98%) obtained in Germany.

12.4 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 maximal power of 250 kW. Nevertheless, the majority of plants still had a rated nominal power of 100 kW or even 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 owing to the technical and economical development of WECS.

Most of the WECS erected in 1998 and 1999 have a rated power of 500 kW and more. In 1997, the introduction of the 1,500 kW class started very successfully. By the end of 1999, a first commercial 2-MW WEC Type N80 by Borsig Energy GmbH with a rotor diameter of 80 m was erected. Research and development for a 4-MW turbine is on the way, see Section 12.6.2.

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, where different users are often competing. Owing to the necessity of noise emission reduction, a distance of about at least 500 m to 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. On the other hand, the financing

Table 12.5 New installations in October 1999, total 130 MW

FEDERAL STATE	NUMBER	WEC MODEL (KW)
BRANDENBURG		
Dollenchen	2	Enercon E-40/600kW
Falkenhagen	2	E-66/1500 kW
Göllnitz	3	NEG Micon 600/48/70
Hallenbeck	14	NEG Micon 1000/60/70
HESSIA		
Heinerscheid	5	NEG Micon 1000/60/70
MECKLENBURG-VORPOMMERN		
Bergholz	2	TW600a (600 kW)
Friedland	1	Tacke TW600a
Kröpelin	5	Nordex N-54/1000 kW
LOWER SAXONY		
Debstedt	2	AN Bonus I MW/54
Dörpen	1	Tacke TW 600a
Elsfleth	2	E-66/1500 kW
Grobenkneten	2	E-66/1500 kW/98m Tower
Grob Mackenstedt	2	E-40/600 kW
Haselüne	4	Tacke TW1.5s/1.500 kW
Hoheneggelsen	1	AN Bonus 600 kW/44-3
Hoheneggelsen	1	AN bonus I MW/54 (70 m Hub height)
Lehe	6	Tacke TW600a
Wildeshausen	4	N-60/1300 kW (69 m Hub height)
NORTH RHINE WESTFALIA		
Ascheberg	1	E-40/600 kW
Exertal-Büdingfeld	2	E-40/600 kW
Haarbrück	1	E-40/600 kW
Kalletal	1	N-54/1000 kW (70 m Hub height)
Lichtenau	1	43/600 kW
RHINETAL PALATINE		
Habscheid-Hallert	5	E-40/600 kW
Lampaden	2	N-60/1300 kW (69 m Hub height)
SAXONY		
Ludwigsdorf	3	E-66/1500 kW
Wachau	3	E-40/600 kW
Glaubitz	3	NEG Micon 750/48/70
SAXONY ANHALT		
Nauendorf	3	E-66/1500 kW
Rottelsdorf	7	Tacke TW1.5s
SCHLESWIG-HOLSTEIN		
Ehlersdorf	3	E-66/1500 kW
Gremersdorf	2	E-66/1500 kW
Högel	5	AN Bonus I MW/54
Testdorf	4	E-40/600 kW
THURINGIA		
Eckolstädt	8	AN Bonus I.3 MW/62 (68 m Hub height)
Wangenheim	9	Tacke TW1.5s

conditions are considered to be favorable for wind power installations, see also next section.

12.5 ECONOMICS

The rapid market development between the late eighties and the nineties was driven by the favorable financing conditions in the 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 by January 1, 1991. Since then, the utilities have been obliged 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 amounts to 0.1679 DEM/kWh and 0.1652 DEM/kWh in 1999. EFL and "250 MW Wind"-Program are cumulative.

In April 1998, a modification of the EFL within the reformation the energy law 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 of a reconsideration. But in 1999 a complete new renewable energy law was prepared by the German government. The law with the name Gesetz für den Vorrang Erneuerbarer Energien (shortly Erneuerbare-Energien-Gesetz EEG) was passed by the parliament on February 25, 2000. It has to receive the approval of the Bundesrat and the EU Commission. General contents are.

- obligation on electricity grid operators to give priority access to all renewable energy
- 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)

Within the bill it is foreseen, that operators of wind turbines should receive

DEM 0.178/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 DEM 0.121/kWh. For wind turbines which 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 turbines output. An annual decrease in two tariff rates of 1.5% per year starting from January 1, 2002 is foreseen. The tariff for offshore plants more than about three miles from land, on-line by the end of 2006 will be DEM 0.178/kWh for nine years.

For wind turbines on-line before April 1, 2000, the maximum payment period is calculated as five years, minus half the number of years the turbine as been in operation. For turbines which—because of their age—are no longer qualified for the higher rate DEM 0.178/kWh are guaranteed for at least four years.

The defined standard turbine or "reference turbine" is in practice a series of turbine types operating at an average wind speed of 5.5m/s at 30 meters height with 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).

Over the last ten years, a market for wind turbines has been established in Germany which does not depend on direct funding. This market depends on: the conditions for reimbursement regulated in the EFL;

the development of key-turn prices of WECS; and the interest rate for loans and mortgages with a pay back time of 10 years was reached at about 10% by April 1991. This was followed by a fluctuating decrease to about 5% in 1999. Assuming a pay back time of 10 years, it can be calculated by established methods that a decrease of three percent corresponds to a price decrease of 25%.

The revenue from WECS is mainly determined by the electricity production, which can be expressed by hours of operation per year at nominal power. Under German meteorological and financial conditions, it is more or less generally accepted that for a WECS erected in 1999 the revenue will be higher than the expenses when 2,200 hours at nominal power are obtained. At good sites close to the German or to the Baltic Sea, where the mean wind velocity at a height of 10 m high is between 5.5 and 6 m/s, the majority of WECS have lower production costs than revenue per kWh according to the EFL. The inland situation, where typical wind velocities of 4 m/s dominate, might be different. The actual distribution of full

load hours for different site categories for WECS within the "250 MW Wind"-Program is shown in Figure 12.3. The broad distribution of full load hours is remarkably broad for three different site categories. This indicates that, besides the general wind regime, other factors like the size and type of the turbine and the local wind conditions may influence the full load hours considerably.

Financing of WECS is often managed with low equity. Even on inland sites, the projects are sometimes financed completely by loans. Here, the revenue from the WECS is needed in the first ten years to pay for the capital costs, the insurance, and operation and maintenance. But the investor may nevertheless make some profit. A depreciation time for WECS of ten years was possible until mid-1997. From July 1st, the depreciation time is 12 years. With a linear depreciation, investors can reduce their taxable income by about ten percent of the turn-key costs per year. This corresponds to approximately DEM 100,000 per annum. With an assumed tax rate of thirty percent, the taxes to be paid by the investor will be reduced by about

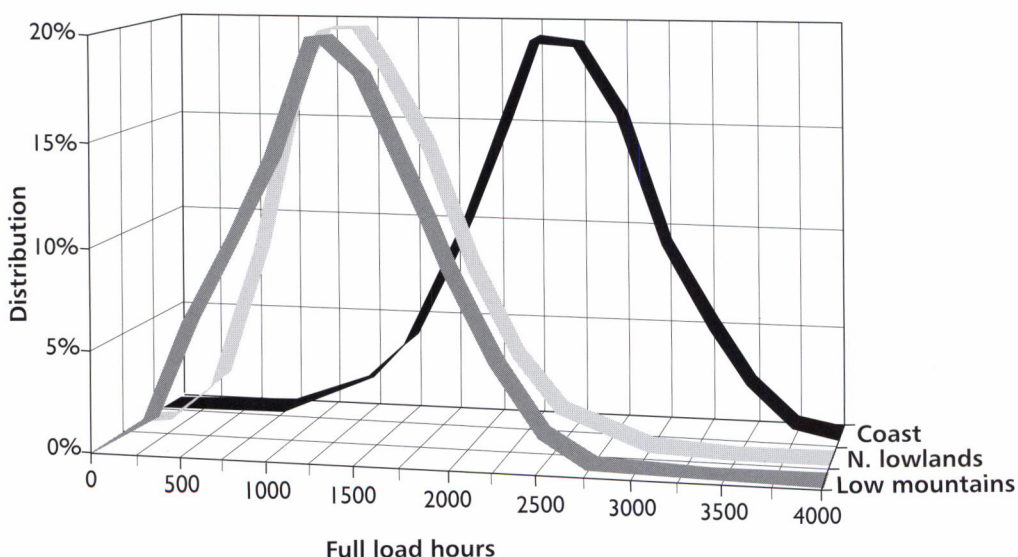


Figure 12.3 Full load hours "250 MW Wind"

DEM 30,000 per annum. Under the circumstances considered, almost no corporation taxes will have to be paid in the first ten years. Reducing the taxable income is one of the further driving forces of the German WECS market. On average, every investor is reducing his annual taxes considerably.

12.6 GOVERNMENT-SPONSORED PROGRAMS

12.6.1 Funding 1999

The BMWi 1999 funding levels of wind power were (1998 in brackets):

R & D	DEM	4.5 (5.5) million
"250 MW Wind"	DEM	37.2 (35.3) million
ELDORADO	DEM	6.3 (6.3) million
Total	DEM	47.0 (47.1) million

12.6.2 R&D/WMEP

Recent R&D-Projects by BMWi are shown in Table 12.6. The projects include the engineering of a 4 MW, 110 m (turbine, to be erected in about two years. The Scientific Measurement and Evaluation Program, Phase III (WMEP) involves a DEM 13,683 million contract for the period of July 1996 to June 2000.

In autumn 1998, experts reviewed the future of R&D for the wind energy technology on behalf of BMBF. Despite the fact that this technology has made a rapid technical development in the last 10 years and that a market for wind power has opened world-wide, there is still much work left to be done to fulfill the potential of wind power as key

Table 12.6 Recent energy R&D projects and the WMEP Phase III

SUBJECT	PERIOD	COSTS (DEM)	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	07/96-06/97	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 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

contributor of the renewable to the world-wide energy supply. Some recommendations are being realized by R&D-Projects.

12.6.3 "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 or wind farm receive grants for the successful operation of their installations.

The current subsidy for operators in the "250 MW Wind"-Program is either DEM 0.06 or DEM 0.08 per kWh, depending on whether the energy is fed into the grid or is being used by the owner of the WECS. The latter applies for instance to a farm, a factory, or a private household, and also to an utility as a WECS owner. The grants are limited now to a maximum of 25% of the total investment costs. In certain cases (private individuals and farmers) a subsidy of the investment, limited to DEM 90,000, was possible.

The interest in support of the "250 MW Wind"-Program was high. Until the closing date for proposals (December 31, 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 10 years of WMEP-participation of the MW-size turbines. It is expected that the total support will exceed DEM 350 million. The costs of the measuring program are not included in this sum and could reach an additional DEM 60-70 million for the period 1990 to around 2007.

12.6.4 "ELDORADO Wind"-Program

BMWi 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 (electricity, oil, gas and so forth). 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. By October 31, 1999, 29 projects were approved by BMWi, most of them with installations in operation. The total rated power is 30 MW.

References:

Home page of Project Management Organization Biology, Energy, Environment of BMBF und BMWi of the Forschungszentrum Jülich GmbH, Internet: <http://www.kfa-juelich.de/beo.htm>

Authors: Dr. N. Stump and Dr. R. Windheim, B.E.O., Germany

13.1 GOVERNMENT PROGRAMS

There has been no revision of the National Program of Greece during 1999. 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.

The legal framework governing the development of the renewable energy sources has been in effect since 1995 and is based on Law 2244/94 and relevant ministerial decrees. The main features of this framework regarding wind energy, are the opening of the market to the private sector and the precise definition of the tariffs for the energy produced. In addition, the Public Power Corporation of Greece (PPC) is obliged to buy the wind-produced electricity with contracts having a 10-year duration, with the possibility of a 10-year extension.

In 1995, the Ministry for Development set a target for 350 MW of installed wind energy capacity by the year 2005. Two national programs providing financial assistance to wind energy projects supported this policy.

- 1 The "Law for the Economical Development" Law 2601/98 of the Ministry for National Economy is implemented within a continuous program according to which wind projects may be subsidized by 40% of the cost or get up to 40% reduced soft loan.
2. The so-called "Operational Program for Energy (OPE)-Renewables within the Community Support Framework," for

the years 1994—1999, is implemented by the Ministry for Development. The total budget for renewables including private contribution is 50 billion drachmae. Financial support for wind energy is 40% considering maximum subsidized project costs of 350000 drachmae/kW.

Projects for a total of 128 MW of installed capacity have been granted support under OPE, the majority of which are currently under construction.

13.2 COMMERCIAL IMPLEMENTATION OF WIND ENERGY

In total, 129 WECS having an installed capacity of 67.5 MW in 9 projects have been connected to the electricity supply network in 1999, bringing up the total installed wind energy capacity to 107 MW (306 machines).

The development of wind energy within the last 10 years is shown in Figure 13.1, where the total installed capacity per year is depicted

13.2.1 Energy production

The energy produced from wind turbines during 1999 is approximately 160 GWh, while the energy produced in 1998, 1997, and 1996 was 71 GWh, 38 GWh, and 37.2 GWh respectively. Figure 13.2 shows the electricity produced from wind turbines for the last nine years and the corresponding capacity factor

13.2.2 Operational experience

The repair work at the two biggest wind farms of PPC, 5.1 MW each (17X300 kW Windmaster WTs) was completed and they returned to full operation. The experience, on the other hand, from the operation of the first private wind farm is very promising. The 10.2-MW ROKAS wind farm in Kriti, being commissioned

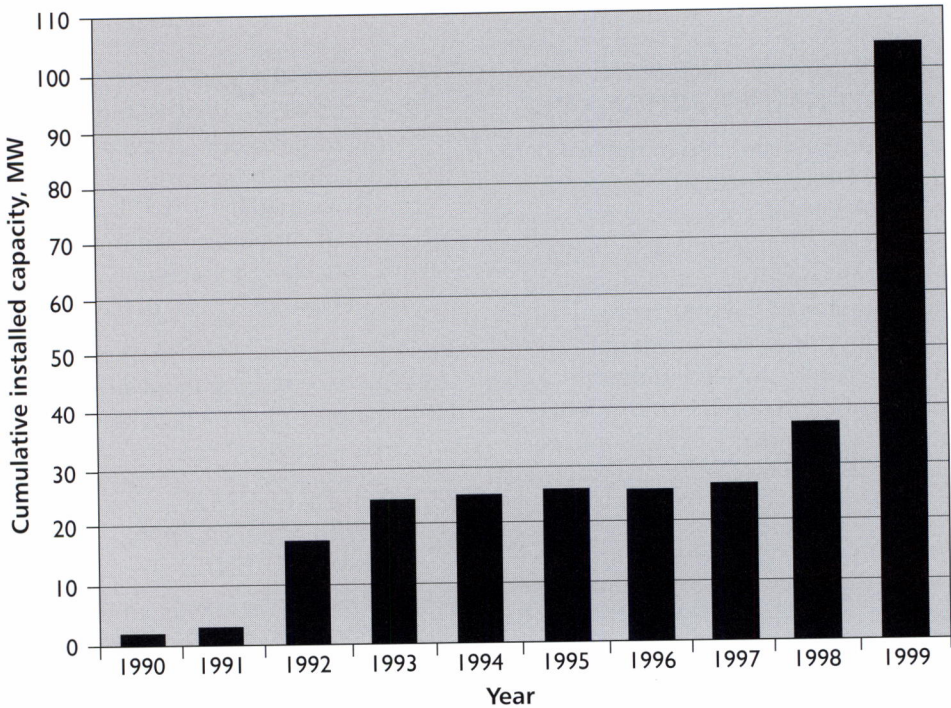


Figure 13.1 Total installed capacity in Greece by year

in 1998, had a capacity factor as high as 42.4%, during 1999.

13.3 MANUFACTURING INDUSTRY

Except for a couple of small wind turbine manufacturers (typical range 1.0-5.0 kW), there is no wind turbine manufacturing industry in Greece in a classic manner. However, the steel industry is quite developed in the country and could support wind turbine manufacturing. As a result, most of the tubular towers of the installed WTs have been constructed in Greece. Furthermore, a Greek company has been successfully involved in blade manufacturing. The company has produced blades up to 14 m, while a 19 m long blade is in construction. In the past, the Hellenic Aerospace Industry (HAI), was involved with the construction of wind turbines for PPC. But its activities were limited to a program of 50 machines based on imported Danish know-how.

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

13.4 ECONOMICS

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. PPC is still the only utility responsible for production, distribution and exploitation of electricity. Despite the different production costs in the two systems, a single charging price exists all over the country, depending on the identity

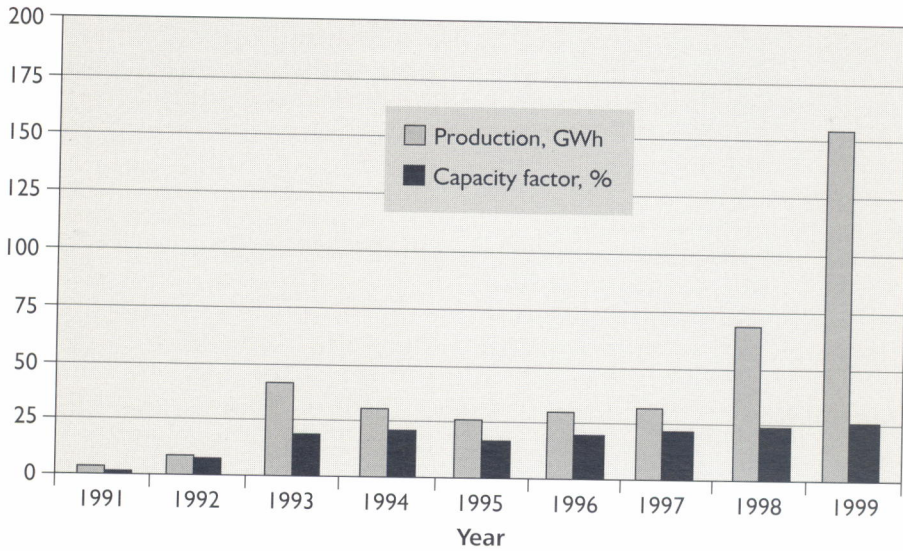


Figure 13.2 Electricity produced and capacity factor

of the consumer and the voltage class. The following tariffs are valid since 15 July 1998.

1. Low Voltage 26.60 Drs/kWh,
2. Medium Voltage 21.51 Drs/kWh and 994 Drs/kW (peak power value),

The prices paid by PPC for renewable energies are based on the actual selling price. For the autonomous island grids the prices are set at 90% of the low voltage tariff, i.e. 23.94 Drs/kWh. For the inter-connected 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. $497.0 \text{ Drs/kW} \times P$, where P is the maximum measured power production over the billing period. The aforementioned prices are effective since 15 July 1998.

The total cost of wind power projects depends on the type of WT, the size, and accessibility. The cost varies between 330.000 and 400.000 Drs/kW. The generated wind power cost could be assumed to be

between 9.0 and 16.0 Drs/kWh, depending on the site and project cost.

The typical interest rate for financing any project without subsidies is about 14%. However, many investments, including wind projects, may profit by reduced soft loans according to the so-called "Law for the Economical Development" 2601/98

13.5 MARKET DEVELOPMENT

Up to 1995, low selling prices in conjunction with the restriction of power generation from the private sector (with the exception of auto production), strongly affected wind energy development, although the first wind turbines have been operating since 1984. As a result, wind energy was limited on the activities of PPC and of some public organizations.

As soon as the new Law 2244/94 was issued in early 1995, a great interest has been shown by the private sector in developing wind power projects.

According to the Law, interested parties can 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.

13.5.1 Environmental impact

The major environmental impact being experienced in Lesvos Island in the PPC's 2.0-MW wind farm was finally overcome and the project was successfully completed. A strong protest against the installation of the wind turbines, due to the archaeological interest of the greater wind farm area, resulted in more than 5 years delay of the project. No other major environmental problem appeared

13.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

The Ministry of 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.

13.6.1 Research and development

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 deployment.

A project for the development of a 450-kW wind turbine was initiated within the framework of the EPET-II National Program, in 1995. The project is aimed 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, and its installation at the test site is planned to take place in early 2000.

The Center for Renewable Energy Sources (CRES) is the national organization for the promotion of the renewable energies in Greece and, by law, the certifying authority

for wind turbines. CRES is mainly involved in applied R&D and is active in the field of aerodynamics, structural loads, noise, power quality, variable speed, wind-desalination, standards and certification, wind assessment, and integration.

The development of a national certification system for wind turbines is considered 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 participating in the standardization work carried out by the Hellenic Organisation for Standardisation (ELOT) in the framework of European and International organizations, regarding Wind Energy matters. In 1999, an 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.

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

A number of research projects were running or initiated at CRES during 1999, co-funded by DGXII and GSRT (the Greek Secretariat for Research and Technology) aiming at:

1. Characterizing the main features of complex or mountainous sites, because most of the development sites favorable for wind energy are of such topography); and identifying the crucial parameters affecting both the

power performance and the loading of different types of wind turbines operating in such environments. In that direction, new techniques are under development for power-curve measurement of wind turbines operating in complex terrain,

2. Developing new techniques for power quality measurement and assessment,
3. Contributing know-how to Wind Turbine standardization procedures,
4. Developing blade testing techniques within the in-house experimental facility,
5. Understanding generic aerodynamic performance of WT blades through CFD (Computational Fluid Dynamics) techniques,
6. Developing cost-effective micro-siting techniques for complex terrain topographies,
7. Developing GIS (Geographic Information System) techniques for optimum wind-energy planning on a local level,

Basic R&D on wind energy is mainly performed at the country's technical universities. The Fluids Section of the Mechanical Engineering Department of the National Technical University of Athens (NTUA), is active in the field of wind modeling, rotor aerodynamics, load calculation, fatigue analysis, noise and wind farm design. The work conducted at NTUA during 1999 concerned mainly theoretical work related to numerical simulations.

The new viscous-in viscid interaction model for airfoils concluded in 1998 has been extended to include turbulent inflow and structural effects. The model predicts lift and drag with state-of-the-art accuracy even beyond maximum lift. Its extension to unsteady light stall situation has been also concluded.

The development of a Navier Stokes flow solver for rotating blades has been concluded based on multi-block architecture.

Testing on the NREL experiment has been concluded successfully

An aeroelastic code of the complete turbine has been concluded and successfully tested over several turbines. For the aerodynamic part, a second option based on free-wake modeling has been added.

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 19m GRP blades, verification of which was performed by full scale static, fatigue, and modal tests at CRES blade testing laboratory. During 1999, 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 and is currently under construction by a Greek industrial partner, Geobiologiki S.A.

In the frame of the JOULE-III program, UP is participating in projects contributing to the design of blades and failure characterization of composite materials using advanced numerical techniques for pattern recognition and analysis of NDT signals

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 and,
- (c) fatigue characterization of composite materials using non-destructive testing.

The Electrical Engineering Department of NTUA has been actively involved in the field of wind energy since the beginning of the 80s, participating in R&D projects sponsored by the EU and other institutions and co-operating with universities and research centers from many European countries.

In 1999, the Electric Power Division of NTUA has focused its research activities on issues relating to the power quality of wind turbines and wind parks and the technical constraints and problems in the integration of wind power into the electrical grids. It has also been concerned with the design of electrical components for variable speed machines and grounding systems for lightning protection.

The codes developed in collaboration with the Fluids Division of NTUA and CRES, for simulating the IEC electrical and control fault test, which will permit the accurate evaluation of the behavior of grid-connected WT's in case of electrical faults of any type, have been effectively applied.

NTUA was also active in evaluating the accuracy of power quality measurements according to the relevant IEC standards under development. Algorithms for evaluation of the slow voltage variations caused by wind parks have also been developed and applied.

The design of a 20-kW variable speed WT, equipped with a permanent magnet

synchronous generator and state-of-the-art electronic converters, is in progress. The contribution of the Electric Power Division mainly focuses on the design of the electrical generator, the converters, and the associated controls.

Other activities include the analysis and design of grounding systems used for the lightning protection of WT's. The developed GIS-based algorithms for the optimal site selection of wind parks and their integration in the distribution networks have been applied in selected areas.

There is also collaboration with CRES in the area of the safety and reliability analysis of the wind turbines control and protection systems.

13.6.2 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.

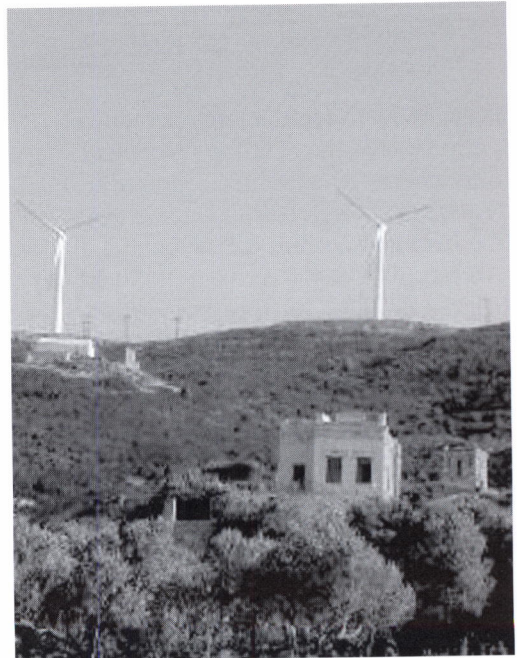


Figure 13.3 This 1.2-MW wind farm on Milos Island, consists of 2 Vestas V42 600-kW wind turbines.

The following demonstration projects were on-going in 1998.

1. The large advanced autonomous wind/diesel/battery power supply system in Kythnos (THERMIE program). The aim of this project is the demonstration of the technical feasibility of the integration of a very high penetration of wind energy in large supply systems. This large modular system for the island of Kythnos is designed for the combination of diesel generator sets, battery storage, rotating phase shifter, five small wind energy converters and one additional large wind energy converter. This large wind energy converter with a power output of 500 kW will supply a great portion of the power demand. It will be the first time that such a high proportion (more than 50%) of the energy demand is supplied by wind turbines. Due to this, the diesel generators can be totally stopped when the power output of the wind turbines is sufficient. Furthermore, the existing PV system with a nominal power of 100 kW as well as the existing five energy converters of type Aeroman (with 33 kW rated capacity each) will be integrated into the wind/diesel/battery system. The project will be carried out by PPC and SMA. The wind turbine was erected in mid 1998 but the commissioning was delayed due to the complexity of the system.
2. The 2.5-MW wind farm in Lesbos Island (THERMIE program) This project was abandoned, because of the considerably long and therefore expensive transmission line required to connect the wind farm to the electric network.
3. The Autonomous Wind-Desalination system in the island Therasia (APAS program) This project concerns the installation of an autonomous wind-powered small desalination system in Therasia. Therasia is a small island in the Aegean Sea, very close to the island of Santorini. The desalination system is based on Reverse Osmosis technology with a nominal water production capacity of 5m³ per day. The wind turbine has a rated power of 15 kW, manufactured by Vergnet SA. The purpose of the project was to demonstrate the feasibility of developing off-grid autonomous wind desalination units in remote areas. The monitoring phase of the project is currently ongoing.
4. The CRES 3.1-MW Wind Farm in complex terrain (National Operational Program of Energy) CRES' demonstration wind farm is located just near the WT 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 of the overall wind farm. It consists of five different medium-sized wind turbines with distinguished design aspects: a 500-kW gearless synchronous multipole WT generator, Enercon E40, a 750-kW stall-regulated induction WT NEG Micon 750/48, a 660-kW pitch-regulated induction WT Vestas V47, and two variable-speed stall AC/DC/AC WT generators of 500 kW and 600 kW each, both developed in Greece and manufactured by PYRKAL S/A. The wind farm is expected to start full operation within 2000.
5. A 300 induction WT connected to the desalination plant of Mykonos Island (THERMIE program) The aim is to couple a medium size WT with a desalination plant with the opportunity of operation as a standard grid connected machine, if necessary. During 1999, site preparation work has been completed. The NTK 300-kW wind turbine has been manufactured by NEG Micon and shipped to the site.

6. A 500-kW WT direct coupled to a desalination plant on Syros Island (Joule-Thermie program) 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 National Technical University of Athens, is to demonstrate the successful operation of a wind-desalination system. The wind turbine is directly coupled to a desalination plant of 900 m³/day capacity, while a grid connection alternative has also been foreseen. During 1999, the connecting line has been constructed but grid connection has not been completed yet.

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CHAPTER 14

14.1 INTRODUCTION

In 1999, Italy's overall wind capacity has grown by 58% over 1998 capacity, thus reaching 282 MW, not far from the 300 MW target once set by the 1988 National Energy Plan for the year 2000. Nevertheless, most of the projects that have, more recently, been admitted by the Ministry of Industry (MICA) into its nine classifications are still to be carried out (721 MW is the total capacity of projects in the first six classifications, which are entitled to premium energy buy-back prices, whilst another 1,498 MW is included in the last three classifications).

After the National Conference on Energy and the Environment, held in Rome in November 1998, some noteworthy developments have occurred in Italy's energy policy, concerning in particular renewable energy sources. Summing up, some new planning and legislative conditions have been set that could speed up the deployment of renewable energy plants, and wind power plants in particular, by electricity utilities and independent producers. This is, however, dependent upon the establishment of suitable commercial and permitting conditions. Some developments have been recorded in these areas, but the overall situation is still far from being fully satisfactory.

14.2 NATIONAL POLICY**14.2.1 Strategy**

The White Paper for the Exploitation of Renewable Energy Sources, which had been worked out by the National Agency for New Technology, Energy and the Environment (ENEA) with the contribution of several qualified operators, was definitively approved in August 1999 by the Interministerial Committee for Economic Planning (CIPE) as one of the main initiatives to be supported in order

to reduce CO₂ emissions in Italy (Kyoto protocol).

In particular, the Italian White Paper, in accordance with a previous deliberation of CIPE concerning guidelines for national policies and measures aimed at reducing greenhouse gas emissions, estimates a total target of avoided emissions of about 24 Mt/yr of CO₂ to be reached through exploitation of renewable energy sources by the years 2008-2012 (18 Mt/yr should be obtained from "green" electricity and 6 Mt/yr from "green" heat production).

More specifically, 3.4 Mt/yr of avoided CO₂ emissions should be contributed by wind power plants, corresponding to an overall installed capacity of about 2,500 MW by 2008-2010 (see also Table 14.1). Since the wind plant already on-line totals nearly 300 MW, this target means that an average new wind capacity of 200 MW per year should be installed in the next 10 years. Given the recent developments (see below) and the ongoing investment plans, it is likely that such a pace can be maintained at least for the first 2 years.

14.2.2 Progress towards national targets

A noteworthy event ensuing from the aforementioned energy conference in Rome was the stipulation, amongst central and local administrators, social parties, operators and users, of the General Agreement on Energy and the Environment. This agreement represents the starting point for the subscription of several voluntary agreements within specific sectors or territory areas, which are seen as one of the new instruments of energy policy.

In addition, pursuant Legislative Decree 112/98, new roles have been attributed to Regions, Provinces, and Communes as far as renewable energy sources are concerned.

Table 14.1 Deployment goals set by the Italian White Paper for renewable energy sources in the electricity sector

TECHNOLOGY	1997		2002			2006			2008-2012		
	MWe	Mtoe	MWe	Mtoe	D Mtoe	MWe	Mtoe	D Mtoe	MWe	Mtoe	D Mtoe
Hydro > 10 MW	13,942	7.365	14,200	7.435	0.071	14,500	7.592	0.228	15,000	7.854	0.490
Hydro < 10 MW	2,187	1.787	2,300	2.075	0.287	2,600	2.345	0.558	3,000	2.706	0.919
Geothermal	559	0.859	620	1.003	0.143	700	1.132	0.273	800	1.294	0.435
Wind	119*	0.026	700	0.308	0.282	1,500	0.660	0.634	2,500	1.100	1.074
Photovoltaic ²	16	0.003	25	0.006	0.003	50	0.012	0.009	300	0.073	0.069
Biomass & Biogas	192	0.125	500	0.660	0.535	900	1.188	1.063	2,300	3.036	2.911
Urban solid wastes	89	0.055	350	0.385	0.330	600	0.660	0.605	800	0.880	0.825
Total	17,104	10.221	18,695	11.871	1.651	20,850	13.589	3.369	24,700	16.942	6.722

*282 MW at the end of 1999

Primary electric energy is converted in Mtoe using the substitution principle, with the equivalence 2200 Mcal/MWh and remembering that 1 Mtoe = 10 10Mcal. The criterion has been also used for biomass and wastes. This criterion is more useful in order to evaluate the achieved greenhouse gases emission reduction. Experimental production data are for the year 1997. For the subsequent years the following production data have been assumed: hydro > 10 MW: 2380 kWh/kW; hydro < 10 MW: 4100 kWh/kW; geothermal: 7350 kWh/kW; wind: 2000 kWh/kW; photovoltaics: 1100 kWh/kW; biomass and biogas: 6000 kWh/kW; wastes: 5000 kWh/kW.

² The value of 300 MW in the period 2008-2012 rises from a 25% per year market growing estimation. If technology state of the art will improve faster, a correspondent larger diffusion can be expected.

These new roles will be better covered if proper technical structures and tools are made available. To this aim, ENEA will furnish technical support to drafting and actuating Regional White Papers, coherently with the provisions of Law 10/91 and Legislative Decree 36/99. Moreover, the Government will aid the creation and strengthening of local energy agencies, in order to facilitate co-operation between local institutions and social and productive operators and to foster citizens' consensus.

After quite some debate, in late 1998 and early 1999, on its draft set forth by the Minister of Industry, Legislative Decree No. 79 actually came into force on 16 March 1999. Stemming from the need to implement the European Union's Directive 96/92/EC concerning common rules on internal electricity markets, this Decree has eventually brought about a thorough restructuring of the whole domestic electricity sector.

The main principles of Decree 79/99 are that no company should generate or import more than 50% of Italy's electric energy demand, an independent body should act as the national transmission system operator, "eligible" customers (exceeding a fixed annual consumption threshold) can choose their suppliers on the market, and distribution should be streamlined in such a way as to have, among others, a single integrated system in each area.

The large utility company Enel S.p.A., (formerly the National Electricity Board) which formerly held nearly a monopoly in electricity production, transmission and distribution all over Italy, has thus been turned into a holding company controlling several companies concerned with different business fields, both inside and outside the core electricity business. Among these, Enel Produzione has been obliged to hand over more than 15 GW of generating

capacity to three new companies that are going to be sold shortly. A new company (ERGA) has been set up to do business in the renewable energy sector. Finally, a significant part of the Enel stock (about 35% of shares) has been sold by the Ministry of Treasury, thus actually starting the long-awaited privatization.

It should also be stressed that Article 11 of the same Decree has provided explicitly for recourse to renewable sources, setting minimum quotas of renewable-generated electricity and requiring the transmission system operator to give priority to renewable energy plants in dispatching. In addition, Article 15 specifies transient regulations, setting deadlines for those who qualified for incentives to their renewable energy projects in previous years.

14.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

14.3.1 Installed capacity

During 1999, 183 wind turbines were installed in Italy at ten sites, all located in the Apennines range in Southern Italy (in the territory of the Apulia and Campania Regions), totaling an additional capacity of 104 MW. The average size of the turbines installed in 1999 was 569 kW.

At the end of 1999, the overall wind turbine number has thus risen to 583, bringing total wind capacity to 282 MW, with an average rated power of 484 kW.

14.3.2 Rates and trends in deployment

The 1999 installed wind capacity grew nearly 58% over the total capacity on line at the end of 1998. For the overall trend of installed wind capacity over past years, see Figure 14.1. As already said above, an even better growth rate, at least in terms of added capacity (around 200 MW/yr), can be expected in the next 2 years.

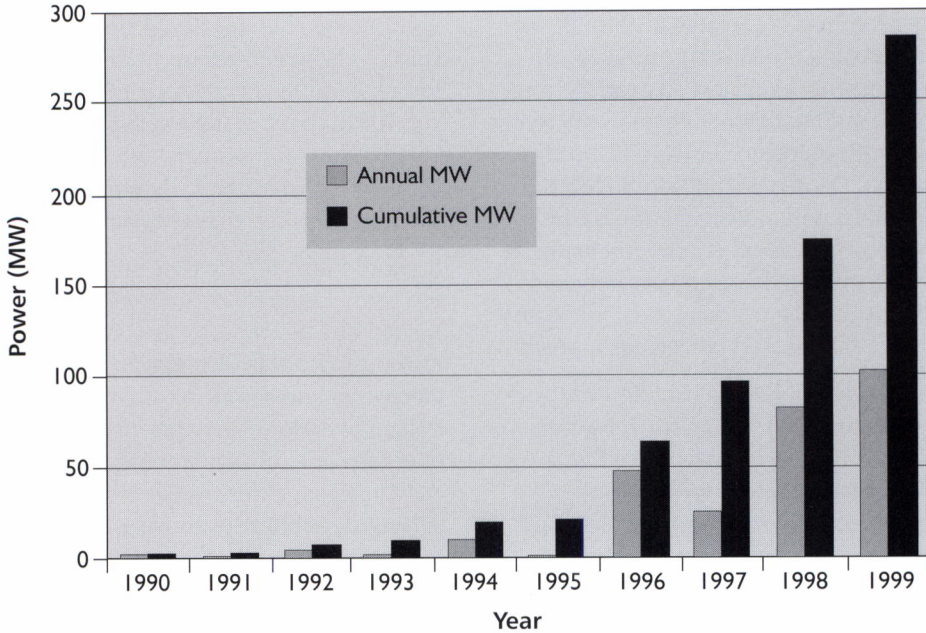


Figure 14.1 Trend of Italy's installed wind capacity

14.3.3 Contribution to national energy demand

For Italy's whole electricity sector, the latest comprehensive set of statistics relates to 1998. In 1998, Italy's overall electricity demand was 279 TWh (including transmission and distribution losses). Of this, 41 TWh was imported from neighboring countries. The net electric energy produced in Italy was 247 TWh (Enel produced about 72.5% of this). The energy supplied to end users totaled 261 TWh (Enel distributed 83.5%).

It is worth adding that Italy's net production from renewable sources in 1998, including large and small hydro, geothermal, wind and photovoltaic plants, was as much as 20.6% of total net production (for Enel alone, this percentage was 21.5%).

Installed net capacity totaled about 72.5 GW (of which about 20 GW were hydro and 51.5 GW were thermal plants) as of the end of 1998. Of this, 57 GW (of which about 16.5 GW were hydro and 40 GW

were thermal plants) belonged to Enel (as said above, at present this capacity belongs mostly to Enel Produzione and, to a lesser extent, to other subsidiaries of the Enel Group).

From the above figures, it can be inferred that the contribution of wind plants still remains very small in terms of both energy production (less than 0.2%) and capacity (nearly 0.4%).

14.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

14.4.1 Main support initiatives and market stimulation incentives

For the moment, and at least for another two years, the main measures for developing renewables are those ensuing from CIP Directive 6/92, the Structural Funds 2000-2006 and Legislative Decree 79/99. In particular, the last Decree brings in new instruments in order to attain the goals set by the recent national White Paper on renewables.

In addition to what has already been said above, it should be pointed out that Article 11 of Legislative Decree 79/99 changes completely the system previously implemented by CIP Directive 6/92, which was based on premium energy buy-back prices.

First, according to Article 11, the transmission system operator must assure priority in dispatching to plants fed by renewable energy sources and CHP (Combined Heat and Power) production. In addition, from 2002 onwards, all subjects who have produced or imported more than 100 GWh/yr of electricity from non-renewable sources, must feed into the public grid an amount of energy from new or repowered renewable energy plants that equals at least 2% of the non-renewable electricity, in excess of 100 GWh, they have produced or imported in the previous year. As to repowered plants, only the energy provided by added capacity will be taken into account. CHP production, auxiliary consumption and exported energy are excluded from the aforesaid computation.

Furthermore, CIPE will define targets for each type of renewable technology and will distribute economic resources for market stimulation amongst Regions and autonomous Provinces. Later on, these decentralized bodies will encourage the involvement of local communities by adding supplementary resources and will see, through tender procedures, to actual exploitation of renewables.

To carry these provisions into effect, on 11th November 1999 the Ministry of Industry issued a Decree that set up a system of Green Certificates. Every owner of renewable energy plants that have been put in operation or modified, after 1st April 1999 will be awarded these Certificates by the transmission system operator on the basis of the electricity produced in the previous year for a maximum period of eight years. Plant

owners can then get additional income from the sale of these certificates, at free market prices, to other subjects that are bound to keep to the 2% green energy quota as per Decree 79/99. This could, in principle, bring them a reward for the extra costs they may have borne for their renewable energy plants.

The transient rules set forth in Article 15 of Decree 79/99 refer to the renewable energy projects entitled to obtain the premium prices granted by CIP 6/92 (see previous reports for more details). In this case, the incentives are assured for eight years from the start of operation of the plant. For projects not yet carried out, the Ministry of Industry, in case of a justified delay, can grant a respite of two years, if a new coherent plan of construction is submitted, otherwise the project will be canceled.

Lastly, it should be mentioned that small isolated electrical systems have been the object of another, specific Decree of the Ministry of Industry, whereby the following criteria must be observed—security, efficiency and economical service; development, where possible, of the interconnection to the national grid; priority use of renewable energy sources.

14.4.2 Unit cost reduction

It has not been possible to gather enough data from the producers to be able to quantify the energy unit cost reduction that, in all likelihood, has occurred in the last few years as a result of reduction of machine cost, progress of machine technology, and increased experience of plant exploitation and maintenance.

14.5 DEPLOYMENT AND CONSTRAINTS

14.5.1 Wind turbines deployed

Of the 183 new machines installed in 1999, more than 90 were made in Italy by IWT and 24 by RWT. The remainder were

imported from Denmark (Bonus and Vestas machines). Up to now, the largest quantity of imported turbines has come from Denmark. In a short time, however, more than 100 MW of 600-kW German-made machines (Enercon) are likely to be installed in Southern Italy (see below). The market shares held by the various manufacturers, with reference to all the wind turbines on line at the end of 1999, are given in Figure 14.2.

As of the end of 1999, the total contribution to capacity by electricity producers from wind are given in Figure 14.3. The main producers are: IVPC with around 170 MW total capacity, FilippoSanseverino with 30 MW, Edison Energie Speciali (formerly RWP) with 27 MW, ERGA (a subsidiary of the Enel Group) with 23 MW and other small producers totaling 32 MW. These are often Communes (municipalities) or local consortia. No new entry is expected to the producer sector in the next few years.

IVPC is a big private developer, whose first installations were carried out in spring 1996. Now IVPC is the owner of 60% of Italian wind capacity, with Vestas V42 and V44 machines mostly built in Italy by IWT. In 1999, IVPC completed installations at Molinara and San Marco

dei Cavoti in the Val Fortore area (Campania), at Rocca San Felice (Campania), and at Alberona (Apulia)—at the last site, another 33 MW was added. In the same period, IVPC also began siting activities in Sardinia with the aim of building a wind farm on this island, too. About 50 technicians and employees are directly working with this company and additional people are involved as consultants or in local civil-engineering work regarding wind farms and electrical substations.

FilippoSanseverino, in 1999, completed a 30-MW wind farm (Fig. 4), installing 28 Bonus MK4 and 2 Vestas V42 turbines, each of 600 kW, at Castelfranco in Miscano (Campania). The largest shareholder of this company is API—Anonima Petroli Italiana S.p.A., an important energy Group involved in the oil sector in Italy and Europe. The location of this wind farm is very close to that of other IVPC and Edison Energie Speciali plants, thus making this mountain area one of the most wind turbine populated in the world.

Edison Energie Speciali, belonging to the Edison Group, has been set up very recently, acquiring both the past and (partly) the future business of RWP (Riva Wind Power, a subsidiary of Riva

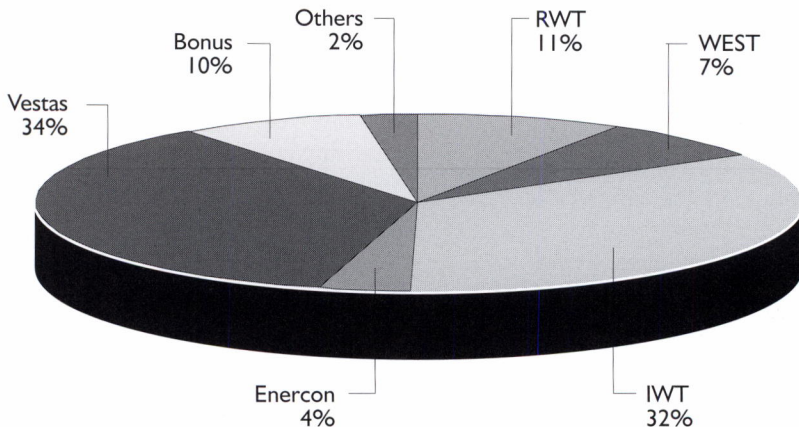


Figure 14.2 Market shares of wind turbine manufacturers at the end of 1999 (as a percentage of total on-line capacity)

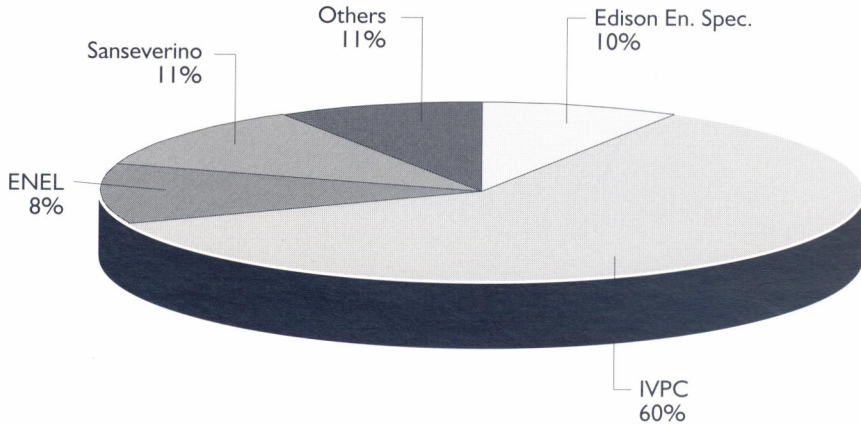


Figure 14.3 Contribution by electricity producers from wind at the end of 1999 (as a percentage of total on-line capacity)

Calzoni). Edison is the only group in Italy involved in the integrated generation, distribution and selling of both electricity and natural gas. At the moment, the rated wind capacity of this company is about 27 MW, but, according to the agreement recently signed with Enercon, an additional capacity of about 120 MW should be installed in Apulia and Campania within the next two years.

ERGA has been established inside the Enel Group since mid-1999. It has been endowed with 310 plants scattered all over Italy, including small hydro power plants, geothermal plants, wind power plants and photovoltaic plants, for an overall capacity of 1,560 MW. Its current wind (23 MW) and PV (3.5 MW) plants had formerly been developed by Enel's Research Department SRI. The company's mission is to exploit plants with a view to



Figure 14.4 Machine erection at the wind farm built by Filippo Sanseverino near Castelfranco in Miscano (Campania) with 50 units totaling 30 MW

economic profit (many of them are entitled to CIP 6/92 premium energy prices). The development plan up to 2002 provides for construction of a further 305 MW, of which there will be 150 MW geothermal, 135 MW wind, and 20 MW small hydropower plants. In particular, the design of three wind farms totaling 20 MW in Sicily is well along and tenders for turbine supply are being evaluated. These plants are expected to be completed by the end of 2000.

14.5.2 Operational experience

Italy's electric energy production from wind plants totaled nearly 400 GWh in 1999. In the Apulia and Campania area, where more than 80% of Italian wind farms are located, machine availability was around 97% and the average load factor was around 0.25 (up to 0.28 at some plants).

Apart from minor accidents, the only serious damage happened to a blade counterweight on one of the single-bladed machines equipping a wind farm near Foiano (Campania), where the wind presents the highest turbulence in the area. Technicians are investigating to find out the cause; for the moment, the whole plant is out of operation.

14.5.3 Main constraints on market development

Some difficulties have been encountered locally by plant developers during the permitting process due to bureaucracy and also due to opposition of part of the population against new wind installations in some Communes of the Apulia and Campania Regions.

Visual impact represents the main problem. This must be overcome through proper planning and lay-out, taking into account the fact that wind farms in Italy are generally located on the top of hills or mountains, so that it is very easy to perceive their influence on the landscape.

Young people, generally students, are generally in favor of wind plants, but, in some cases, it is more difficult for older inhabitants to accept this new technological presence.

Sometimes minor problems are connected to noise. This aspect has, however, come out only in a few circumstances, generally where a turbine on a wind farm has been installed too close to a rural house.

Another critical aspect is the connection of wind plants to the electrical system, especially in areas where developers are concentrating larger and larger wind capacities, as has been happening in the Apennines between Campania and Apulia. As already explained in previous reports, Enel has designed a power collection scheme dedicated to wind farms only. All wind farms in the area will eventually feed their power into seven dedicated sub-stations, from which 150-kV dedicated lines will carry this power up to the high-voltage (380 kV) transmission grid. Construction work on this scheme is now well along, although opposition of local people has recently caused a stop to work on one of the new lines.

14.6 ECONOMICS

14.6.1 Trends in investment

In this report, currency conversion has been made setting 1 USD = 1900 ITL. Assuming a plant cost of USD 1,000 per installed kilowatt, the total invested capital on wind energy in Italy at the end of 1999 could be estimated around USD 280 million. With the same assumption, the invested capital during 1999 was around USD 100 million.

The selling price of electric energy to typical domestic consumers ranges from ITL 100 to ITL 300/kWh (USD 0.053 to 0.158/kWh), whilst, for industrial consumers, the price ranges from ITL 90 to ITL 180/kWh (USD 0.047 to

0.094/kWh). These are all net prices without taxes.

No change has occurred since 1998 concerning wind energy buy-back prices under CIP Directive 6/92. The 1998 prices fixed by CIP 6/92 are: ITL 202.4/kWh (USD 0.106/kWh) for the first eight years of plant operation; ITL 102.8/kWh (USD 0.054/kWh) for the remaining lifetime.

14.6.2 Trends in unit costs of generation and buy-back prices

The energy buy-back prices made available by CIP Directive 6/92 have been the strongest factor boosting wind plant deployment in Italy. As to these prices, it now has to be reported that their 1998 level was subsequently questioned by the Italian Authority for Electric Power and Gas. On 8 June 1999, this body passed Resolution No. 81/99 stating that CIP 6/92 prices should, since 1 January 2000 onwards, be reduced to some extent depending on plant type and operation starting date, to take into account decreased costs due to progress of the various renewable energy technologies.

This meant that wind plants put in operation after 1 January 1997 should, in their first eight years, suffer price reductions ranging between ITL 56 and 102/kWh (the higher cuts applied to plants to be put in operation in 2001-2002). This resolution, which could heavily affect most existing and prospective investment plans, gave rise to much concern and opposition among investors. However, the State Council, which was called upon to solve the controversy in the first days of January 2000, made a decision in favor of independent power producers, confirming the former CIP 6/92 prices but with the exclusion of companies that are both producers and distributors.

14.7 INDUSTRY

14.7.1 Manufacturing

At the end of 1999, despite the good growth rate of overall wind capacity, the situation for the Italian manufacturing industry is not satisfactory. In fact the WEST and RWT companies are no longer developing new models of wind turbines.

For the time being, only IWT (a joint venture between WEST and Vestas) is advancing well in manufacturing work. In August 1999, in addition to production of blades and assembling of V42 and V44 nacelles (see below), another line for the construction of the Vestas V47 model of 660 kW was set up at the IWT factory.

14.7.2 Industry development and structure

In 1999, RWT (a subsidiary of Riva Calzoni) manufactured 24 single-bladed machines of the 350-kW M30-S2 model, but no further installations of the same wind turbine are currently foreseen, so that the only forthcoming activity of the company is likely to consist in the maintenance of the about 100 wind turbines that have been installed till now.

WEST did not install any machines in 1999, except for the substitution of 320-kW Medit units with their new version Lambda. The same activity can be anticipated for the year 2000. So far, the medium-sized turbines installed by WEST total about 70, plus one large prototype of 1.5 MW and 16 small-sized units.

IWT (a joint venture between WEST and Vestas) sold 91 turbines of the V42 and V44 Vestas model on the Italian market in 1999, nearly entirely to IVPC.

Several small industrial companies have been working as component suppliers to IWT and RWT as well as to the developers IVPC and FilippoSanseverino. Lattice and tubular towers are built by Monsud in

Avellino. For the single-bladed RWT M30-S2 machines, tubular towers have been built by Leucci in Brindisi, generators by Società Macchine Elettriche, gearboxes by Flender and blades by ATV. Another firm working on construction of tubular towers is Pugliese, located in Atessa. The list of the sub-suppliers of IWT includes Colombo Giuseppe (hub, house bearing), Metallurgica Sestese (main shaft), Brook Hansen (gearbox), Trademark Italia (brake system), Vickers Systems (hydraulic power unit), Hexcel Composite (pre-preg for blades), Bonfiglioli Riduttori S.p.A. (yaw system) and C.E.B. (generator).

14.8 GOVERNMENT SPONSORED R, D&D

14.8.1 Priorities

As to Government sponsored R,D&D programs, reference has, for several years now, been made to programs carried out by ENEA (the National Agency for New Technology, Energy and the Environment) and the electricity utility Enel S.p.A. (formerly the National Electricity Board). Most of the programs launched by these bodies in the past have been completed. Both organizations are now in the process of focusing on new objects and priorities in wind energy research, in light of the legislative and planning developments that have been described above, but it is too early to give a general view of new trends and priorities. Some noteworthy 1999 facts are reported hereunder for each organization.

14.8.2 New R, D&D developments

14.8.2.1 ENEA

Within the framework of an Italian-French co-operation in Antarctica, aimed at carrying out research in the field of glaciology, geophysics, atmosphere sciences, and astronomy, the importance of having autonomous wind-power plants for electricity supply to remote installations became evident. For this reason, taking

into account the very low temperatures of Antarctic sites, a special 5-kW wind turbine has been developed starting from a commercial 5-kW model manufactured by the French firm Vergnet. After several tests carried out at the ENEA Casaccia centre, the turbine was sent to Antarctica.

Within the framework of siting activities, the wind characterization of the Teramo Province was completed last autumn and the same work is now starting on the other provinces of the Abruzzo Region.

In summer 1999, a Program Agreement was signed between ENEA and the Ministry of the Environment with the main aim to link the ENEA R, D&D activities to the priority goals set by the Government's environment policy. The duration of the program was established as three years (1999-2001).

Among the 27 projects included in this Program, one is entitled Sustainable Environment in the Minor Islands. The actions of this project will be addressed to land protection and reduction of the environmental impact partly related to the massive presence of tourists. Within this framework, renewable sources, and in particular wind energy, will play an important role in meeting the growing energy demand, substituting in part for the oil used to supply diesel generating sets.

14.8.2.2 The Enel Group

Within the framework of the R, D&D programs launched by the former National Electricity Board, all activities were carried out or co-ordinated by Enel's Research and Development Department (SRI). In 1999, most of these activities had been, or were being, completed, whilst the Enel company underwent the restructuring that turned it into a holding company (the Enel Group) as explained in the foregoing.

In the wind energy sector, the Group's new company ERGA has now taken over all SRI plants, such as the Alta Nurra and

Acqua Spruzza test sites and the Collarmente (9 MW) and Monte Arci (11 MW) wind farms. About 15 wind farm sites, ready for exploitation and totaling 170 MW potential, have also been made available for ERGA by SRI.

SRI is now merging in CESI S.p.A., a research and testing company controlled by the Enel Group. Within this framework, some wind energy activity is planned to continue in 2000 and beyond, in support of ERGA and other possible customers inside and outside the Enel Group, as well as on behalf of the national Authority for Electric Power and Gas.

The latter branch of activity will be carried out in the interest of Italy's whole electricity sector. Its topics and funding sources are currently being defined with the Authority. Likely topics include further assessment of wind potential in both on-shore and off-shore areas, monitoring of wind turbine technology, in-depth investigation of problems related to wind farms in particular environments, gathering of data for evaluating prospective energy costs, review of renewable energy promotion mechanisms, etc.

14.8.3 Offshore siting

Considering that the technology of offshore wind turbines is evolving rapidly, since 1994 ENEA and ATENA (Italian Association of Naval Engineering) have been involved in the organization of international offshore seminars with the aim of making a specific and up-to-date review of ongoing activities and programs. Another aim is also to promote information and collaboration among European and Mediterranean countries in this field of wind energy application.

In 1999, activities were carried out to organize the seminar OWEMES 2000 (Offshore Wind Energy in the Mediterranean and Other European Seas) planned in Sicily on April 13-14th 2000. OWEMES 2000 will be the third edition of

the seminar; the first edition was in Rome (1994), the second at La Maddalena island near Sardinia (1997) with participation of qualified experts from all over Europe, the USA and some other countries. In December 1999, around 50 abstracts had been received, doubling the number of the previous meeting.

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CHAPTER 15

15.1 INTRODUCTION

During 1999, the introduction of wind plants was accelerated. A private wind farm of 20 MW scale was constructed in December 1999, and the cumulative wind power capacity in Japan reached 75 MW. The Government started a new research program on wind energy in order to develop wind turbine generator systems that are suitable for Japanese environmental conditions.

15.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

15.2.1 Strategy

At the UN Climate Change Conference in Kyoto in December 1997, the Japanese Government agreed to reduce the output of greenhouse gases by 6% compared to 1990 levels by 2008–2012. In September 1998, the Government decided on a new energy supply plan to stabilize CO₂ emissions by

2010 from 1990 levels as shown in Table 15.1. In a simulated case, the ratio of petroleum could be reduced from 55.2% (1996 level) to 47.2% (2010), while that of new energy could be increased from 1.1% to 3.1%. Wind energy is included in the new energy.

15.2.2 Progress towards national targets

Japan’s national wind energy target is 300 MW, declared in the latest Primary Energy Supply Plan. The government started a new subsidy system, the “Field Test Program,” to stimulate the introduction of wind energy plants in 1995. This program played a remarkable role in introducing wind energy to the Japanese people. In June 1997, the Law on Special Measures for Promotion of Utilization of New Energy (New Energy Law) was enacted, which initiated wind energy businesses into Japan resulting in the recent increase of wind power capacity.

Table 15.1 The new primary energy supply plan by 2010

	1996		2010 (CONTINUOUS CASE)		2010 (STIMULATED CASE)	
		Ratio(%)		Ratio(%)		Ratio(%)
Total Supply	597.00 GI*		693.0 GI		616.0 GI	
Petroleum	329.00 GI	55.2	358.0 GI	51.6	291.0 GI	47.2
Coal	329.60 Mt*	16.4	145.0 Mt	15.4	124.0 Mt	14.9
Natural Gas	329.20 Mt	11.4	145.9 Mt	12.3	1.1 Mt	13.0
Nuclear	302.00 TWh	12.3	480.0 TWh	15.4	480.0 TWh	17.4
Hydro	82.00 TWh	3.4	105.0 TWh	3.4	105.0 TWh	3.8
Geothermal	82.10 GI	0.2	105.8 GI	0.5	105.8 GI	0.6
New Energy	6.85 GI	1.1	9.4 GI	1.3	19.1 GI	3.1

*gl = giga-liters in petroleum equivalent, Mt = Million ton in coal equivalent

15.3 COMMERCIAL IMPLEMENTATION

15.3.1 Installed capacity

During 1999, 40 units with 43.4 MW of total capacity were installed, resulting in 75.1 MW cumulative installed capacity. If other plants in the planning stages or under construction are included, the cumulative capacity is approximately 100 MW. Table 15.2 and Figure 15.1 show the history of capacity increases of wind turbines in Japan.

15.3.2 Rates and trends in deployment

The installed wind power capacity increased from 32 MW at the end of 1998 to 75 MW at the end of 1999—a 234% increase. The average unit size also increased from 263 kW in 1998 to 469 kW in 1999.

15.3.3 Contribution to national energy demand

The contribution of wind power to national energy demand is very small and not much wind turbine operation statistical data has been systematically collected.

15.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

15.4.1 Main support initiatives and market stimulation incentives

Aiming at developing 300 MW of capacity by 2010, NEDO's Field Test Program, started in 1995, offers incentives to developing wind markets in Japan. This program has actually raised interest in wind energy among developers, local authorities, private companies/persons, etc. To realize the target CO₂ emission reduction after the Kyoto protocol, the Government settled on two schemes in 1998 additional to the Field Test Program. One is the New Energy Local Introduction Supporting Program, which supports new energy projects by leading developers or in the public sector with a rate of subsidy up to 1/2 of the initial cost for a plant capacity above 1200 kW. The second program, the New Energy Business Supporting Program, subsidizes private sector wind businesses. The rate of subsidy is up to 1/3 for a capacity above 1500 kW. As a result, large-scale projects

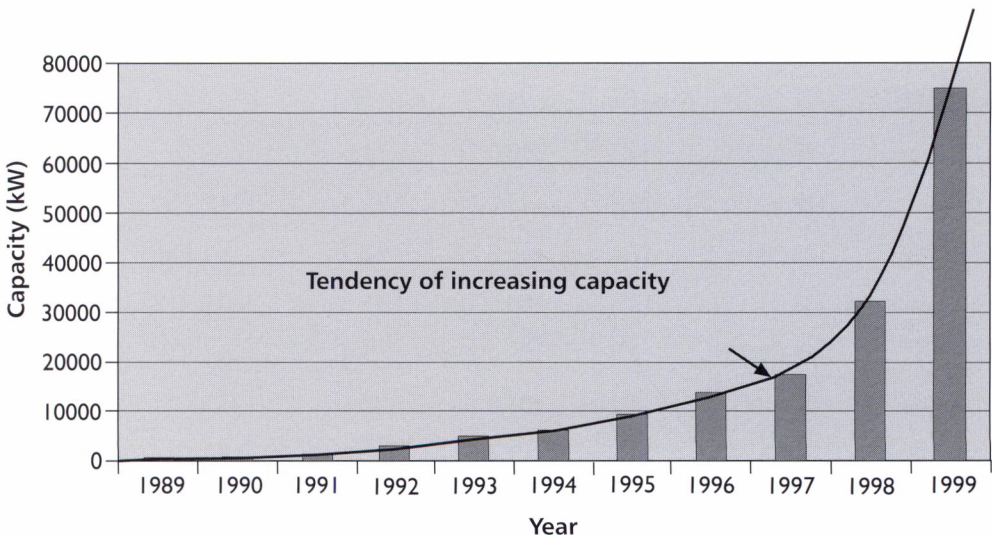


Figure 15.1 History of wind turbine capacity in Japan

are being planned, such as Tomen's Tomamae 20-MW wind farm, developed in December 1999.

15.4.2 Unit cost reduction

As the capacity of a commercial wind plant increases, it can achieve more cost reduction. However unit cost is still high and subsidies are quite necessary to operate a commercial plant.

15.5 DEPLOYMENT AND CONSTRAINTS

15.5.1 Wind turbines deployed

As shown in Table 15.2, both the cumulative number and the average capacity of wind turbines in Japan have increased rapidly. In the last two years, the number of turbines has increased by 200%, and average capacity has increased by 218%.

15.5.2 Operational experience

Figure 15.2 shows the operational technical performance of Tohoku Electric Power Company's Tappi Wind Park, which has an excellent annual mean wind speed around 9 m/s. The average capacity factor in the past three years has been 25%.

Among the technical problems, it should be noted that a middle-scale WTGS on Koshiki Island was hit by a typhoon and fell down last year. A few WTGSs at other sites have been destroyed by lightning, although not very often.

15.5.3 Main constraints on market development

Generally there are no severe concerns about bird issues, noise, or the visual impact of wind turbines or farms. In Japan, quality of electricity is one of the key issues, because most promising wind sites distribute electricity in weak grid

Table 15.2 Installation of WTGS in Japan

YEAR	TOTAL NUMBER OF UNITS	INSTALLED GENERATION (MW)	AVERAGE POWER IN KW PER UNIT
1989	9	0.358	39.8
1990	13	0.891	68.5
1991	14	0.991	70.8
1992	23	2.899	126.0
1993	35	4.982	142.3
1994	41	5.856	142.8
1995	54	9.496	175.9
1996	67	13.495	201.4
1997	80	17.198	215.0
1998	120	31.568	263.1
1999	160	75.063	469.1

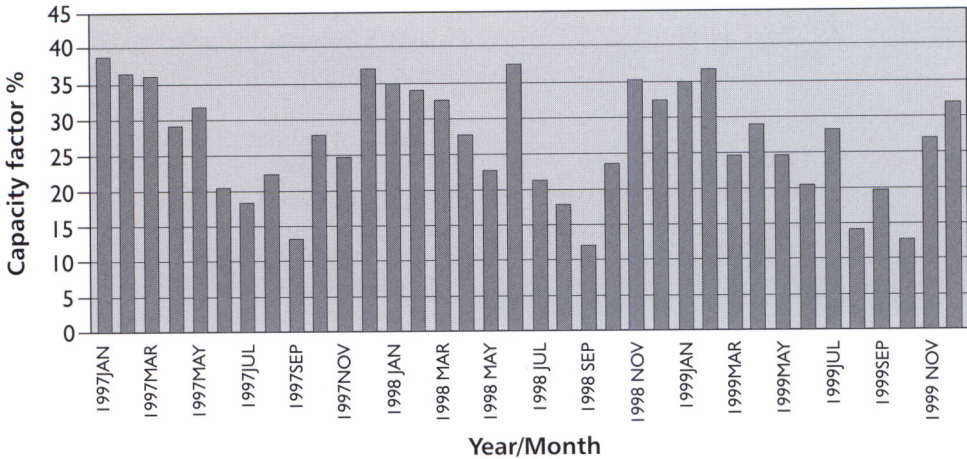


Figure 15.2 Operational technical performance of Tappi Wind Park

regions. Therefore, further technical developments are needed. Complex terrain and gusty and turbulent wind also affect the mechanical strength of the turbines, as well as the quality of the electricity produced. These problems increase the cost of transportation, erection, and grid-connection.

15.6 ECONOMICS

Because Japan is in the initial stage of commercial development of wind generation, a statistical evaluation of economics has not been done. In general, wind energy generation is considered approximately two times more expensive than conventional energy. However, the experience of a commercial wind farm development of 20 MW capacity showed some improvement in economics.

15.6.1 Trends in investment

The unit cost of a wind power plant is 300,000—650,000 Yen/kW for capacity below 500 kW, 250,000—300,000 Yen/kW for capacity between 750 kW and 3,000 kW, and 200,000 Yen/kW for capacity above 20,000 kW (1). All of these plants are supported by NEDO’s subsidy program. The plant cost slightly decreases as the capacity increases.

15.6.2 Trends in unit costs of generation and buy-back prices

According to NEDO’s investigation (1), the unit cost of generation varies from 9 Yen/kWh to 37 Yen/kWh, depending on plant capacity and wind speed. If plant capacity is larger than 1000 kW, the unit cost is from 9 to 14 Yen/kWh. If the wind speed is higher than 6 m/s, the cost is from 9 to 16 Yen/kWh. Electric power companies develop their own purchase price menus. They purchase wind electricity at the price of 11.5 yen/kWh on average for the contract period of 17 years. At the moment, the balance is subsidized by one of the NEDO’s projects—the Field Test Program, the New Energy Local Introduction Supporting Program, or the New Energy Business Supporting Program.

15.7 INDUSTRY

15.7.1 Manufacturing

There are many types of wind turbines supplied by many manufacturers in Japan. There are a few national wind turbine manufacturers, but only Mitsubishi Heavy Industries, Ltd. supplies middle to large wind turbines. Figure 15.3 shows a Shukutsu Wind Power Generation System in front of the



Figure 15.3 Shukutsu Wind Power Generation System, Muroran City in Hokkaido

Hakucho (Swan) Bridge, in Muroran City in Hokkaido. The WTGSs are a 500 kW and a 1000 MW Mitsubishi turbines.

500 kW, Mitsubishi 500 kW, 1000 kW, Jacobs 500 kW, DeWind 490 kW, NEG-Micon 600 kW, NORDEX 600 kW, Vestas 600 kW, Lagerway 600 kW, 750 kW and Bonus 1000 kW. The shares among the manufacturers are shown in Figure 15.4.

15.7.2 Industry development and structure

The introduced large WTGSs are Enercon

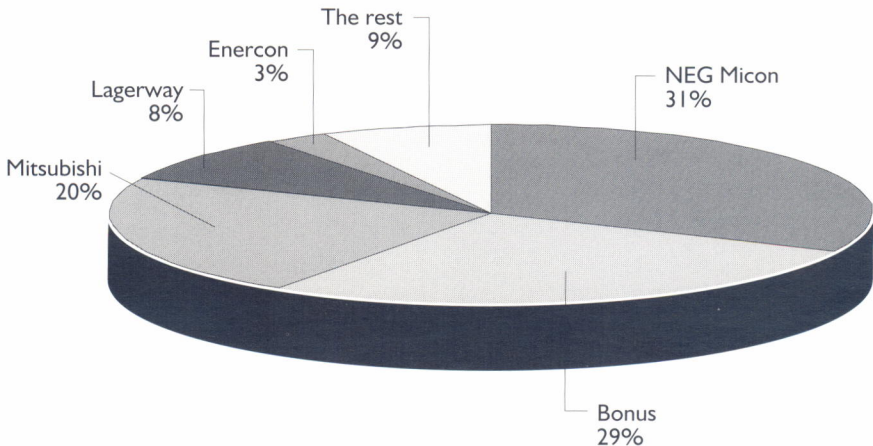


Figure 15.4 Shares among manufacturers in WTGS capacity (%)

15.7.3 Export potential

Mitsubishi Heavy Industries, Ltd. exports their turbines all over the world.

15.8 GOVERNMENT SPONSORED R, D&D

15.8.1 Priorities

Since 1978 after the oil crises, the Government has directed its wind energy R&D program to providing energy security. This is part of the general R&D Program for renewable energy called the "New Sunshine Project" and is directed by the New Sunshine Program Promotion Headquarters (NSS H.Q.) in the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI). After Global Warming was discovered, 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 15.3.

(a) New Sunshine Project: Research & Development, Demonstration

Since 1978, the Government has directed wind energy R&D development under the

"New Sunshine Project". In 1999, Japan started several new R, D&D programs as described in the next section.

(b) Promotion of Introduction with Subsidies

NEDO's Field Test Program, the New Energy Local Introduction Supporting Program, and New Energy Business Supporting Program promoted by MITI have played and are playing an important role in promoting the introduction of wind turbines in the private sector as well as among local governments, as mentioned above.

(c) IEC Standard and JIS Standard

These national programs include cooperation in IEC Standard activities in the wind energy category. MITI is also promoting policies to maintain international consistency in standards. Therefore, national JIS standards for wind turbine generator systems are also on the table for future publication.

(d) Funding Levels

Table 15.4 shows the history of the budget of MITI for wind energy R&D in the NSS Project and Field Test /New Energy Business Supporting Programs.

Table 15.3 Recent and future national wind energy activities in Japan

NATIONAL ACTIVITIES	PERIOD	ORGANIZATION/INSTITUTE
New Sunshine Project (R&D)	1978-	NSS-H.Q.
1. Wind resource measurement	1990/1994	NEDO
2. R&D of LS-WTGS (500 kw)	1990/1997	NEDO/MHI/Tohoku EPC
3. Demonstration of a MW-class wind farm	1991/1998	NEDO/Okinawa EPC
4. Generic, innovative R&D	1978-	MEL
5. Advanced WTGSs for remote islands	1999/2004	NEDO/MEL
6. Local area wind energy prediction model	1999/2003	NEDO
New Promotion Project	1992-	MITI/NEDO
Field Test Program/ New energy local introduction support New energy business support		
Standard	1988	MITI/JEMA/MEL/ Industries/etc.
IEC, ISO, JIS		

Table 15.4 Budget for national wind energy projects in MJPY

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999
NSS project	540	981	978	744	634	606	554	477	414
Field test/new energy business supporting programs	–	–	–	–	80	320	460	1529	1739
Total	540	981	978	744	714	926	1014	2006	2153

15.8.2 New R, D&D developments

NSS/NEDO started new Wind Energy R, D&D programs in 1999 for wider propagation of WTGSs that are suitable for the natural and social conditions of Japan. These programs include:

1. Development of Advanced Wind Turbine Systems for Remote Islands

To establish technology suitable for particular local and natural conditions on small and medium-sized remote islands currently relying on expensive diesel generation, R&D of 100-kW class WTGS was started. The research explores new technology applicable for sites under harsh environmental conditions, such as typhoons, complex terrain, weak grids, hilly sites, island sites, difficult accessibility, etc. Reliability of WTGS and power quality are the main issues.

2. Development of Local Area Wind Energy Prediction Model

This goal of this research is to develop a new powerful CFD code that is available for complex terrain in Japan. The model is required to predict the wind conditions with high accuracy, so that very reliable siting, WTGS arrangement, and prediction of generation may be performed.

15.8.3 Offshore siting

Just recently, some discussions of offshore siting have begun. Because oceans surround Japan, it is clear that offshore wind farms have huge wind generation potential. However, the level of the sea bottoms is deeper than those in Europe.

In the next few years, basic policy may be determined.

References:

(1) Yoshioka, Wind Energy Development in Japan, Proc. 21st Symposium of Wind Energy Utilization, Nov.1999

Author: Hikaru Matsumiya, MITI, Japan

CHAPTER 16

16.1 INTRODUCTION

Promoters of wind energy have pointed out that the exploitation of the main wind resource in Mexico could lead to installation of 3000—5000 MW of wind power plants. The main deployment of wind energy in Mexico could take place at the south of the Tehuantepec Isthmus, in a 3000 km² region known as “La Ventosa” (See Figure 16.1). Average annual wind speeds from 7 to 10 m/s, at 30 meters above ground, have been measured in this region. It is estimated that up to 2000 MW of wind power plants could be installed there with technical and economic advantages.

16.2 NATIONAL POLICY

The Mexican energy policy on electricity is aimed at securing enough supply to allow expected economic development. According to official projections, from 1998 to 2007 Mexico will require around 22 GW of new generation capacity. From this, around 7 GW are already committed, and the rest has been pointed out as an opportunity for private investment. It has

been stated that part of this non-committed capacity could be satisfied from suitable renewable energy projects (1).

Simultaneously, a strong national environmental policy cares about sustainable development and global warming. Up to now, reduction of emissions from power plants has been achieved using natural gas. There is an increasing interest in diversifying electricity generation using renewable energy, but specific plans for integrating a meaningful capacity of wind power into the national electric system have not been released yet.

16.2.1 Strategy

In November 1999, an “International Seminar on Implementation of Wind Power” was held at the initiative of the IEA Wind R&D Executive Committee and the Electrical Research Institute of Mexico (IIE). About 80 people attended the Seminar, including officials from the Ministry of Energy, the National Commission for Energy Conservation, the Federal Electricity Commission, the Federal Mexican Congress,

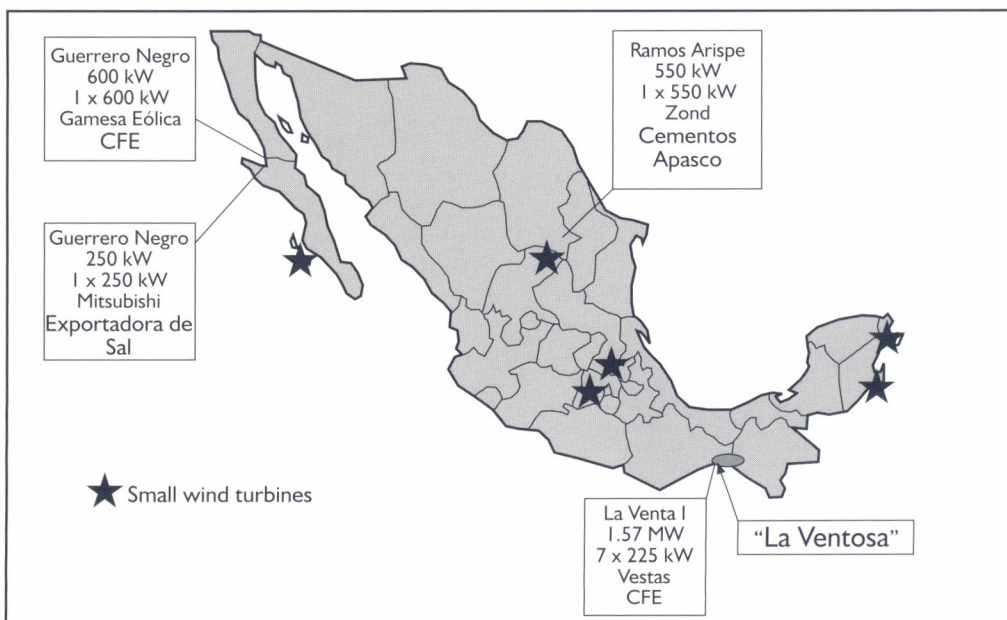


Figure 16.1 Distribution of wind turbine installations in Mexico

the Energy Regulatory Commission, the Electrical Research Institute, the National Solar Energy Association, universities, and private companies. International lecturers were delegates from The Netherlands, Spain, Germany, Denmark, the United States of America, and Greece, all members of the IEA Wind R&D Committee. The most important topics on Wind Energy were addressed, providing current and valuable information. Mexican speakers addressed the experience in demonstrative wind power installations and implications of wind power implementation. The main conclusion of the Seminar was that a first draft of a Mexican program on wind power implementation would be issued by mid-2000.

16.2.2 Progress towards national targets

In order to start actions, a project aimed at building a Wind Turbine Evaluation Station (WTES) is being carried out by the Electrical Research Institute, under the auspices of the Ministry of Energy. This station will be similar to a wind power plant rated at 6 MW, but wind turbines of different technological options will be installed there. Wind turbines will be evaluated from the operational point of view in order to find out which of them offer suitable performance. In addition, the project will develop local understanding of turbine operation, maintenance, and required technical support. The project will be built at La Ventosa, Oaxaca (see Figure 16.1), and will be aimed at becoming

the technological base of wind energy development in this region, using modern wind turbines rated from 600 to 750 kW.

The first phase of the WTES project is aimed at land acquisition, procurement of permits, specifications of infrastructure and wind turbines, negotiation of power purchase agreement, outline of the executive project, and procurement of international financial support. It is expected that wind turbine manufacturers interested in participating in the development of wind energy in Mexico will support this project.

16.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

16.3.1 Installed capacity

During 1999, additional wind power capacity was not connected to the Mexican Electrical System. The total installed capacity of wind turbines in Mexico remains around 3 MW. See Table 16.1 and Figure 16.1.

16.3.2 Rates and trends in development

The rate of increase in wind power development is negligible. Construction of the 54-MW wind power station proposed by the Federal Electricity Commission since 1996 was postponed again. Another five projects, led by private companies, continue in the negotiation phase (see Table 16.2). The Energy Regulatory Commission has already issued permits to build four of these projects; nevertheless, all these have been postponed again.

Table 16.1 Wind turbine installations in Mexico by the end of 1999

LOCATION	MANUFACTURER	WIND TURBINES CAPACITY		COMMISSIONING DATE	OWNER*
		(kW)	(MW)		
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)

Table 16.2 Wind power plants in 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
6	Energía Renovable	La Ventosa, Oax.	240.0
		Total	441.5

Project 6 is still in the promotion phase (permits have not been requested), but it is interesting to note that the corresponding proposal includes the construction of a wind turbine assembling facility in Mexico.

16.3.3 Contribution to national energy demand

Contribution from wind power generation to national energy demand is negligible. In 1997, total electricity sales accumulated 130.2 TWh; meanwhile wind power production was less than 10 GWh.

16.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

At present, there are no formal initiatives in this direction. However, proposals are being evaluated and it is expected that in the first half of the year 2000 a formal proposal will come forth.

16.5 DEPLOYMENT AND CONSTRAINTS

16.5.1 Wind turbines deployed

Additional wind turbines were not deployed during 1999. The number of wind turbines installed in Mexico remains at 10 (see Table 16.1).

16.5.2 Operational experience

During 1999, energy production from "La Venta" wind power station was 5.2 GWh. The facility operated with an annual capacity factor of 37.9%. The overall availability was only 84.8% due to the

failure of one of the wind turbines that remained out of operation most of the year. The technical performance of the other six wind turbines was very good, with average availability exceeding 98% and average capacity factor around 44% (2). Annual average wind speed, measured at the wind turbine's anemometers, was 9.07 m/s.

From December 1998 to August 1999, average capacity factor from the 600-kW wind turbine installed at Guerrero Negro was 24% (3). This means that energy production was around 1.3 GWh. Annual average wind speed at this site is around 8 m/s at 50 meters above ground.

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

16.5.3 Main constraints on market development

Main constraints on wind-power market development in Mexico are:

- Low cost of conventional electricity for the industrial sector
- Large availability of fossil fuels
- Lack of a national program on wind power for sustainable development

Preliminary accounts indicate that by the end of 1999 the total installed capacity in Mexico for electricity generation was 35.7 GW. It was mixed as follows: thermoelectric (59.8%), hydro (27.1%),

coal (7.3%), nuclear (3.7%), geothermal (2.1%), wind (negligible).

16.6 ECONOMICS

Electricity prices to consumers vary depending on the region, time of day, and voltage. For electricity billing purposes, the country is divided into eight regions. Each region has its own timetable for electric tariffs throughout the day. Table 16.3 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.

16.7 INDUSTRY

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

16.8 GOVERNMENT SPONSORED R, D&D

"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. During 1999, additional wind power installations were not deployed. It is expected that the next demonstrative project will be built by 2001 (see section 16.2.2). In addition, it is expected that during the year 2000 important decisions will be made regarding the implementation of a formal wind energy R, D&D program that would include goals for the short, intermediate, and long terms.

References:

- 1.Documento de Prospectiva del Sector Eléctrico 1998-2007. Ministry of Energy
- 2.Reported by Eng. Carlos Garcia Aguilar, General Manager of "La Venta" Wind Power Station.
- 3.Hiriart Le Bert, Gerardo. México: Experiencia de la Comisión Federal de Electricidad en la Generación Eoloetrica. Presented during the "International Seminar on the Implementation of Wind Power", México, D.F., November 1999.

Author: Marco A. Borja, Electrical Research Institute, Mexico

Table 16.3 Average electricity prices in Mexico during 1999

SECTOR	AVERAGE PRICE (MEXICAN PESOS)
Industrial	0.4210
Agriculture	0.2605
Domestic	0.5076
Commercial	1.2177
Public service	0.9471

NOTES: a. Preliminary data

b. 1 USD = 9.57985 Pesos (January 2000)

CHAPTER 17

17.1 NATIONAL POLICY

17.1.1 Aims and objectives

In the *Third Energy Memorandum* of 1995, the Dutch government sets down its CO₂-emission targets for the year 2020, aiming at an overall stabilization of CO₂ emission and fossil fuel use at the level of 1990. For renewable energy the target is set to a 3% contribution in 2000 and a 10% contribution in 2020. The targets have been set in annual saving of fossil fuels, expressed in petajoules (PJ) (Table 17.1). At present, about 1.1% of Dutch energy consumption is met by renewable sources such as biomass, solar, wind and water. The total national energy consumption is currently about 3010 PJ.

In its progress report *Renewable Energy in Execution* of July 1999, the government redefines what is considered renewable energy. Heat pumps using water from industrial processes and about half the energy from waste are no longer considered as renewable. As a consequence, the calculated contribution of heat pumps and bio-energy has decreased significantly. However, the government has not changed

its renewable energy targets, which in effect implies an increase of efforts needed to reach the targets.

In 1999, the *Monitoring Protocol Renewable Energy* was published. It gives guidelines to register and calculate the contribution of renewable energy options enabling calculation of national statistics on this issue. Compared to earlier methods, the monitoring protocol is straightforward and makes a clearly defined distinction between renewable and sustainable.

17.1.2 Strategy

The strategy to reach the targets of the *Third Energy Memorandum* is set down in the action plan *Renewable Energy on the March* of March 1997. This plan emphasizes the need to accelerate efforts of concerned parties and lists the measures required before 2000. The actions concern improvement of the price-performance ratio, removal of administrative bottlenecks and stimulation of market penetration

The measures for wind energy take shape by means of the execution of the

Table 17.1 Renewable energy targets in annual avoided fossil primary energy (PJ)

SOURCE	2000	2007	2020
Bio energy	54	85	120
Heat pumps	7	50	65
Wind energy	16	33	45
Cold en heat storage	2	8	15
Solar energy–PV	1	2	10
Solar energy–thermal	2	5	10
Hydro power	1	3	3
Geothermal	0	0	2
TOTAL (PJ)	83	186	270

TWIN-program, with support of R, D&D activities (Section 17.6.1) and the campaign *Room for Wind Energy* (Section 17.5.4). To stimulate the industry to develop innovative renewable energy options, the government made more money available for the program Economy, Ecology and Technology (EET). For stimulation of market penetration, several tax advantages were introduced (Section 17.5.1).

In *Renewable Energy in Execution*, the Dutch Government evaluates the progress made. It is concluded that additional action is needed in order to reach the objectives. That is why the Minister of Economic Affairs decided to introduce the following measures:

- Additional financial support for the development and application of renewable energy.
- Special arrangements for renewable energy in the Electricity Law.
- Increase of the Eco tax.

Especially the latter two measures will have an effect on the market introduction of wind energy. Also, the Ministry of Economic Affairs announced a plan to speed up the liberalization of the electricity market. This will be presented in more detail in Section 17.5.1.

17.1.3 Targets for wind energy

To reach the target for wind energy, in the year 2000 a total installed capacity of about 750 MW, and in the year 2020 a total of 2750 MW should be reached (Table 17.2) of which about 1250 MW will be installed offshore. For a country like the Netherlands—with a population density of more than 380 people per km²—the first part of this scheme appears to be unrealistic. At the end of 1999, the installed capacity was only 416 MW. That is why the Dutch government announced in the report *Renewable Energy in Execution* specific initiatives in order to increase the implementation rate of wind turbines (see Section 17.5.4).

Table 17.2 Rough estimate of installed capacity to meet the targets for wind energy

YEAR	CAPACITY MW	SAVED PRIMARY FUEL, PJ
1990	50	0.6
1995	250	4.0
2000	750	12.0
2007	2000	33.0
2020	2750	45.0

17.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

17.2.1 Installed Wind Capacity

In 1999, 79 wind turbines with a total capacity of more than 53 MW were installed whereas five small wind turbines with a total capacity of less than 395 kW were removed. This brings the total operational capacity by the end of 1999 to 416 MW with 1,319 wind turbines and 1,002,636 m² swept area (Figure 17.1).

17.2.2 Performance

The electricity generated by wind turbines in 1999 was approximately 688 GWh. The Windex, which compares the annual wind speed in a certain year with the 30-year average wind speed set at 100%, is estimated at 83%. The average specific production was 787 kWh/m² and corrected for the Windex it was calculated at 792 kWh/m². The load factor was calculated at 1816 hours, and the capacity factor at 0.21.

17.2.3 Installed conventional capacity and electricity consumption

The installed conventional capacity has decreased further in 1999 to approximately 13 GW. A number of installations closed down as part of a plan to reduce the excess capacity. It should be noted however, that since the eighties the importation of electricity has increased and fulfils

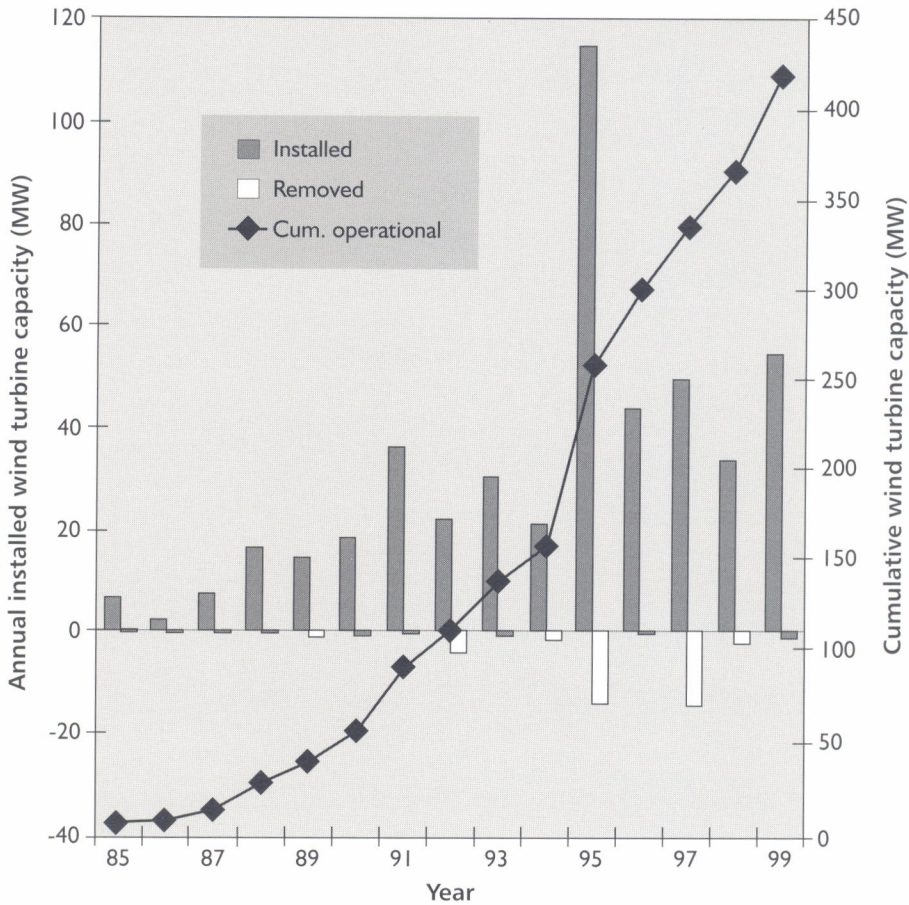


Figure 17.1 Installed, removed, and operational wind capacity

currently about 16% of the total electricity demand.

The calculated primary energy savings due to wind energy are 5.7 PJ, and is approximately 0.2% of the national energy consumption of 3010 PJ. The generated electricity is 1% of the national electricity consumption of 70 TWh.

17.2.4 Type and make of turbines

The average installed capacity per wind turbine in 1999 was nearly 675 kW, the average ratio between swept area and capacity was 2.63 m²/kW and the average hub height was 48 m.

Danish manufacturers manufactured more than 90% of the newly installed wind turbines (Table 17.4).

Removed were four Lagerwey wind turbines of 80 kW (LW18/80) and one of 75 kW (LW15/75).

17.2.5 Plant types and form of plant ownership

In 1999, one large wind farm (Figure 17.3) was installed consisting of 19 NEG-Micon 600-kW wind turbines (21% of the capacity). Three wind farms of 7-8 wind turbines (43% of the capacity) and three small wind farms of 2-4 wind turbines (6% of the capacity) were installed. The other 28 wind turbines (30% of the capacity) are solitary (Table 17.5). The wind farm in Dronten is unique with its 7 Vestas wind turbines of 1.65 MW (22% of the capacity), as it is the first wind farm in the Netherlands with wind turbines of this size. Both wind

Table 17.3 Electricity production, avoided fuel and emissions

Year	ESTIMATED ELECTRICITY GENERATED GWh	WINDEX %	PRIMARY ENERGY SAVINGS PJ	AVOIDED EMISSIONS	
				CO ₂ kton	NO _x and SO ₂ kton
1985	6		0.06	4	0.12
1986	7		0.07	4	0.14
1987	14	95	0.13	8	0.29
1988	32	100	0.29	20	0.65
1989	40	83	0.36	24	0.82
1990	56	98	0.50	35	1.14
1991	88	80	0.79	55	1.80
1992	147	93	1.32	91	3.00
1993	174	87	1.57	108	3.55
1994	238	94	2.15	145	4.86
1995	317	88	2.86	195	6.47
1996	437	68	3.79	254	8.91
1997	475	68	3.93	267	9.69
1998	640	93	5.30	360	13.06
1999*	688	83	5.70	387	14.03

*1999 numbers are estimates

farms with the largest capacities are owned and exploited by private companies in which several farmers hold the shares and have the turbines on their land. Of the installed wind turbines, only one 750-kW turbine is owned by a utility; all the other wind turbines are privately owned. This is remarkable, because until last year most of the newly installed wind turbines were utility owned.

17.2.6 Operational experience

There were no major accidents or incidents in 1999.

17.3 MANUFACTURING INDUSTRY

17.3.1 Business developments and sales

NEG Micon Holland, formerly NedWind, was completely reorganized. The company consists of an independent production unit, which produces parts for the product range of NEG Micon, and a design and engineering unit, which executes projects for NEG Micon worldwide. Maintenance of installed NedWind turbines is being executed by a separate company, Newinco bv.

Lagerwey the Windmaster produces wind turbines with a capacity of 80 kW, 250 kW, 600 kW and 750 kW. Although sales in the Netherlands have dropped significantly, the sales abroad are promising. Lagerwey

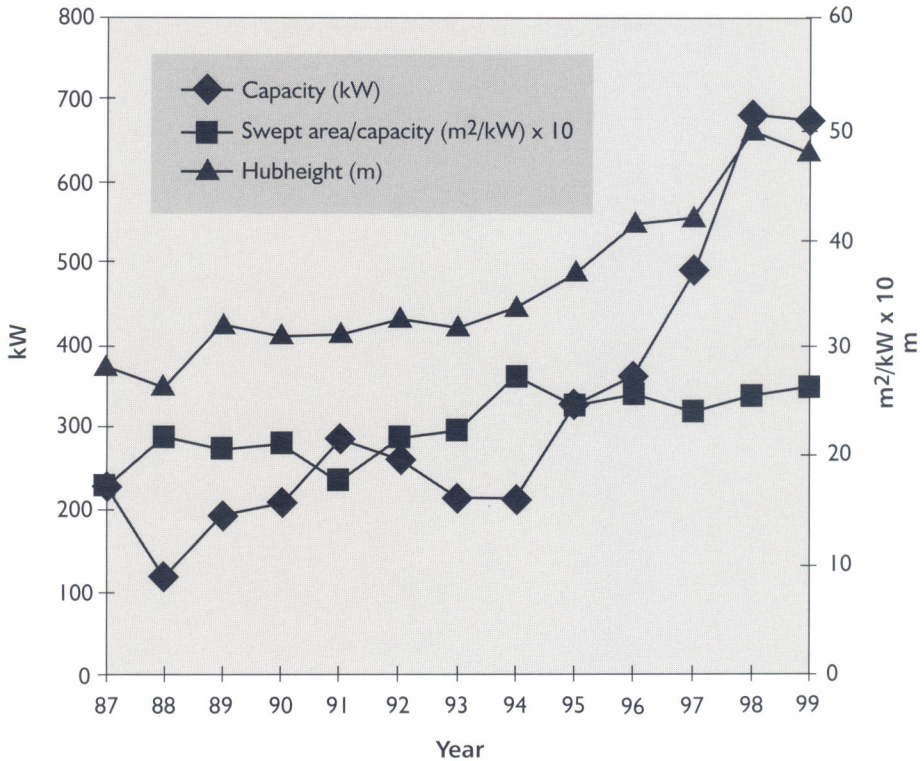


Figure 17.2 Average capacity, area/power and hub height of installed turbines in the period 1987-1999

acquired orders for its 750-kW wind turbine, a.o. from Japan and Germany.

In April 1999, LM Glasfiber from Denmark took over Rotorline. The name of the new Dutch affiliation is LM Glasfiber Holland.

In addition to existing production facilities in Heerhugowaard, LM opened a new production facility in Den Helder. A harbor location was chosen so they could transport large rotor blades by ship. LM Glasfiber Holland produces LM blades

Table 17.4 Distribution of new wind turbines by manufacturer

MANUFACTURER	TURBINES (Number)	INSTALLED		ROTOR AREA m ²
		MW	%	
Vestas	31	24.4	46	63,735
NEG-Micon	36	23.7	45	60,403
Lagerwey	6	1.8	3	5,947
Bonus	4	1.8	3	5,554
NedWind	1	1.0	2	3,019
Enercon	1	0.5	1	1,288
TOTAL	79	53.2	100	139,947

Table 17.5 Size of wind farms installed in 1999

NAME OF WIND FARM	MANUFACTURER	NUMBER OF TURBINES	HEIGHT (m)	DIAMETER (m)	CAPACITY (MW)	SWEPT AREA (m ²)
Lutjewinkel	NEG-Micon	19	45.0	43.0	11.400	27,952
Vlissingen	NEG-Micon	8	60.0	48.0	6.000	14,476
Tuitjenhorn	Vestas	8	47.0	55.0	5.280	19,007
Dronten	Vestas	7	66.0	67.0	11.550	24,680
St. Philipsland	Vestas	4	31.0	27.0	1.000	2,290
Hoorn	Vestas	3	36.0	27.0	0.670	1,718
Zeewolde	Vestas	2	55.0	47.0	1.320	3,470
Maasvlakte	NedWind	1	60.5	62.0	1.000	3,019
Various solitary turbines	Danish/Dutch/German	27	—	—	14.980	43,696
TOTAL		79			53.200	139,947

formerly Rotorline blades. It has an engineering department that designs large blades.

Aerpac, the largest manufacturer of wind turbine components in the Netherlands, produces blades for wind turbines with a rotor diameter of 25 to 70 m. The company expanded rapidly in 1999 and the number of employees increased from 300 to approximately 600 worldwide.

Polymerin with a low profile in the field of wind energy during the last couple of years, in 1999 supplied the design and tooling for rotor blades of 750-1500 kW through a subsidiary in Canada. It also produces blades for the 250-kW turbine of Lagerwey.

The total number of people employed directly by wind turbine and blade manufacturers in 1999 in the Netherlands is about 550.

17.3.2 Technical developments and new products

NEG-Micon Holland, Aerpac, LM Glasfiber Holland, TU Delft, Van Oord, and the Netherlands Energy Research Foundation (ECN) started a concept study for offshore wind turbines. These turbines should be able to withstand the severe wind and wave conditions on the North Sea. As a follow-up, a 3-MW R&D wind turbine will be designed, especially for conditions more than 20 km from the coast. Later on, this effort will result in a prototype of an offshore wind turbine of 5-6 MW. The diameter of this turbine will be well over 100 m. This work is carried out in the Dutch Offshore Wind Energy Converter (DOWEC) project which is funded through the program Ecology, Economy, and Technology.

In 1995, the Dutch energy distribution company EDON opened one of the largest wind farms in Europe consisting of 94 KVS 33 m wind turbines. Ever since its operation, problems with the blades have occurred. In order to solve these problems, NLR investigated the blade failures and

ECN determined specifications for new blades. The studies showed that the blades were not manufactured according to their design. In 1998, the Dutch blade manufacturer Aerpac developed a new blade for the wind turbine and got the assignment to produce all 282 blades. Nearly all blades were replaced in 1999.

Manufacturers of wind turbine blades are increasingly obliged to take back old wind turbine blades. Therefore they seek economic and environmentally friendly processing techniques to discard wind turbine blades. A study executed by Kema, Aerpac and Hanze Milieu showed that cutting, followed by shredding gives the best reduction results. Processing the blade material in the Belgium cement industry seems the best option, both from a cost perspective (250 NLG/ton = 114 Euro/ton) and an environmental perspective, because the ashes can be put to good use.

17.3.3 Support industries

Due to the intensification of the campaign *Room for Wind Energy*, especially the workload of consultants who execute the so-called Quick scans increased (see Section 17.5.4). Because of activities related to wind energy near shore and offshore, new companies are entering the wind energy market, especially the offshore industry.

17.4 ECONOMICS

17.4.1 Electricity prices

For the more windy part of the Netherlands, wind energy can be exploited economically. The price paid by the electricity companies to producers of wind electricity is currently about 0.16-0.17 NLG/kWh (0.07-0.08 Euro/kWh).

The price that utilities charge for their electricity to customers depends on the variable costs of fuel, coal, and natural gas, but also on the fixed costs of the electricity plant and transport (grid). For industrial purposes, prices vary between 0.11 and

0.13 NLG/kWh (0.05–0.06 Euro/kWh). For domestic purposes, with an annual use of approximately 3000 kWh the price varies between 0.25 and 0.30 NLG/kWh (0.11–0.13 Euro/kWh), including VAT and Eco tax (see Section 17.5.1).

17.4.2 Turbine and project costs

In Table 17.6 the investments costs per kW, per m² and the cumulative invested capital are given for the years 1989-1999. It shows a decrease of costs per m², whereas the costs per kW has not decreased significantly in the last three years.

17.4.3 Invested capital

The cumulative invested capital in wind energy in the period 1987-1999 is given in Table 17.6.

17.5 MARKET DEVELOPMENT

17.5.1 Market stimulation instruments

In order to stimulate market penetration of renewable energy, the Dutch government has introduced different market stimulation instruments.

17.5.1.1 The Regulating Energy Tax, a kind of Eco tax, is a tax on energy carriers like natural gas and electricity. The consumer pays this tax via the energy bill to the energy company that pays it to the Ministry of Finance. Each household has a tax-free contingent of 800 kWh. The tax rate is set anew by the Dutch government every year (see Table 17.7). The total revenue from this tax in 1999 is in the order of a billion guilders. Most of this revenue is fed back to the taxpayer through a lower income tax. Part of it however is fed back through fiscal measures to stimulate energy conservation and the use of renewable energy. On the average, it is budgetary neutral for the taxpayer, but it has the regulating effect of increasing the price of energy, thus stimulating energy conservation and narrowing the price gap between grey and green electricity. The Eco tax can also be seen as the attribution of a value to the external costs of energy.

17.5.1.2 The following tax incentives are used in order to reduce the capital costs of renewable energy installations.

Table 17.6 Investment cost per kW, m² and cumulative invested capital

YEAR	SPECIFIC INVESTMENT COSTS (NLG/KW) (NLG/M ²)		CUMULATIVE (MNLG)
1989	1894	806	66
1990	2318	1223	98
1991	2322	861	175
1992	2500	1124	217
1993	2483	1114	299
1994	2322	811	348
1995	2262	909	564
1996	2280	791	671
1997	1905	769	726
1998	2089	794	807
1999	2000	780	913

- **Green Funds** invest in green projects like wind turbine installations. Revenues such as dividends or interest are exempted from income tax. This allows Green Funds to offer a lower interest rate of about 1.5 percentage points.
- **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 investment. With company tax currently at 35%, this implies a 14% reduction on invested capital.
- **Accelerated Depreciation** on Environmental Investment Scheme allows free depreciation of renewable energy installations. The deferral of tax payments is of benefit to companies' cash and interest position.

17.5.1.3 The effect of these tax incentives is that they lower the production costs of a kilowatt hour of electricity for the owner of a wind plant. The total effect for a typical wind farm can be between 2 ct/kWh and 4 ct/kWh.

The following measures have been implemented to create a reasonable pay back rate for renewable generators. The Ministry of Economic Affairs and the association of Dutch energy utilities EnergieNed agreed that utilities pay for the avoided costs. They also took on the obligation that the remaining costs, to reach a reasonable pay back rate, are split equally between the utilities and the government.

- The basic reimbursement is computed by taking into account the avoided fuel costs and a tiny fraction for the capacity credit. For wind power this is currently 0.081 NLG/kWh (0.037 Euro/kWh).
- The government has obliged the utilities to Feed Back of Eco Tax. For each renewable kWh fed in they have to pay to the generators the Feed Back

Eco tax rate (Table 17.7). The utilities are exempted from paying this part to the Ministry of Finance. This fulfills the government's part of the obligation.

- Each utility committed itself to supply a 3.2% share of renewable electricity in its total output in the year 2000. To facilitate the acquisition of renewable electricity, EnergieNed in 1998 set up a trading system in Green Labels, administered by KEMA. Green Labels are issued to renewable energy producers—one label for 10,000 kWh. Operators of wind turbines can freely trade these labels, but also, utilities can freely sell the labels. Currently Green Labels are trading at about 0.052 NLG/kWh (0.023 Euro/kWh). The total commitment for the year 2000 is 1700 GWh. In 1999, the level reached about 1000 GWh. The costs of the labels are financed from a fund fed from a small environmental levy on the electricity price.

Table 17.7 Tax rate

YEAR	CONSUMER ECO TAX (ct/kWh)	FEED BACK ECO TAX (ct/kWh)
1998	2.95	2.95
1999	4.95	3.23
2000	8.20	3.54
2001	12.11	To be decided

17.5.1.4 To stimulate market demand, the energy distribution companies offer their customers green-, nature-, or eco-electricity. Customers can voluntarily buy all or a share of their annual electricity consumption as green electricity at 0.04-0.08 NLG/kWh (0.02-0.04 Euro/kWh) higher than the normal price. Green pricing has proved to be very successful after clever and intensive marketing campaigns. In 1999, about 300 GWh were sold. To stimulate the demand for green electricity the government decided that consumers that buy

green electricity do not have to pay the Eco tax. With the further increase of the Eco tax in the coming years, the consumer price for green electricity might fall below the price of electricity from fossil fuels.

In the *Energie Rapport*, the Ministry of Economic Affairs announced that it will not use the instrument in the Electricity Law of a mandatory share of renewable energy. To stimulate market demand further, the Ministry wants to

- introduce as of 1 January 2001 Green certificates, a government certified trading system for green electricity following the idea of the Greenlabels.
- delete the regulation in the Electricity law that a licence is needed for the generation of renewable electricity
- allow small consumers to shop freely for their green electricity among the different electricity companies from 1 January 2001, although full liberalization will only come about after 2003.

17.5.2 Financing

Due to Green Funds (see Section 17.5.1), there seems to be an abundance of available capital for renewable energy projects, like wind turbines. Currently, five Dutch banks have a so-called Green Fund, with a total capital of 3 billion NLG (1.36 billion Euro). The typical interest rate is approximately 1.5 percent point lower than the general interest rate, resulting in about 3.5%.

17.5.3 Grid connection and certification

Because of the current liberalization of the electricity market in the Netherlands, activities of utilities have been split up into production, distribution, and grid management. The Minister of Economic Affairs has appointed the Netherlands Electricity Regulatory Service (DTe) to watch over the electricity sector. In 1999, the service issued the system code, measuring

code, network code, and rate code. The network manager is obliged to connect electricity generators to the grid, including renewable electricity generators. Also it is the manager's duty to make in-depth investments to expand the network capacity.

In April 1999, a preliminary standard for wind turbines was issued—the NVN 11400-0: 1st edition. *Wind turbines - Part 0: Criteria for type-certification - Technical criteria*. Because a European or international standard is preferred, the document is considered a transition document. Essentially it is the same as the previous preliminary standard NEN 6096/2, but it has as its basis the international standard IEC 61400-1. However, the Dutch standard also considers labor safety, material codes, noise, energy production, type certification, and criteria for modifications, incidents and practical experience.

17.5.4 Institutional factors

Institutional factors hamper the implementation of wind energy in the Netherlands. The development of sites with building permits for wind turbines is increasingly difficult. Also the number of windy sites is decreasing as these are already in use by earlier installed wind turbines. To address the problem of the availability of sites, Novem started a national campaign *Room for Wind Energy*. The backbone of the campaign is a series of products and services that can be used to assist local authorities to create room for wind energy. Some of the products are described below.

- A quick scan of wind energy to get an estimate of local wind energy potential. More than 100 municipalities, out of a total of 500, applied for a quick scan of which 45 were executed in 1999. The results show a potential of more than 800 MW.
- Excursions to wind farms. More than 60 local councils visited wind farms in 1999

- Support to organize information meetings for the public about wind energy
- Public support interviews, of which ten were carried out
- Process management support, which in 1999 was given to three clusters of municipalities
- A detailed guideline for planning officials to help them incorporate wind energy in their physical planning schemes.

In order to reach a higher implementation rate of wind turbines, the Dutch government announced the following actions.

- To extend the campaign to less windy provinces
- To relieve the conditions under which an environmental effect report (MER) for a wind energy project is required from 10 to 20 MW
- To instruct local authorities to allocate space for large wind farms
- To prepare legislation to force local authorities to allocate space for small wind energy installations
- To prepare legislation which eliminates administrative constraints for offshore wind farms.

In 1999, a special *Task Force Wind Energy* was established to remove barriers for a few large projects that have run into serious institutional difficulties.

17.5.5 Impact of wind turbines on the environment

In order to develop wind farms near shore and offshore (see Sections 17.1.3 and 17.6.5), studies into the possible impact of wind turbines offshore on birds and the maritime environment started in 1999. With the use of military radar systems, bird migration at a distance of 13 km from the coast of IJmuiden, is being monitored. The sensitivity of the radar systems allows registration of

the number of birds that migrate, as well as the mass of the birds and the frequency of their wing movements. Based on these data it is possible to determine the birds' species.

To illustrate that wind turbines can also add a new dimension to the landscape, the *Atlas of Wind Energy in the Netherlands* was published with pictures of existing wind farms, feasible plans and ideas.

17.6 GOVERNMENT-SPONSORED R,D&D PROGRAMS

17.6.1 Funding levels

In the beginning of 1999, Novem contracted its wind energy program for 1999-2000 with the Ministry of Economic Affairs with a budget of about 30 million NLG (13.6 million Euro). It shifts manpower and budget from technology development to implementation, compared to the program of 1997-1998. Key issues are the campaign *Room for Wind Energy* (Section 17.5.4) and preparation for wind farms offshore (Section 17.6.5).

Industrial support for wind turbine and blade manufacturers ended in 1999, whereas R&D for design tools and development of offshore wind energy systems has slightly increased. The R&D budgets of ECN from the Ministry of Economic Affairs have also slightly increased over the years. Through the Ecology, Economy and Technology (E.E.T.) program of the Ministry of Economic Affairs and the Ministry of Science, two wind energy projects are funded. One researches the possibilities of producing large blades from ecologically friendly materials. The other is the DOWEC project (see Section 17.3.2)

17.6.2 Priorities

The *Netherlands R&D-Strategy Wind Energy 1999-2003 (NRW)* is the basis for the research programs of Netherlands Energy Research Foundation (ECN), the Faculty of Civil Engineering and Geo-sciences of the Delft University of Technology (TU Delft) and Novem in 1999 and 2000. Priority subjects are the following.



Figure 17.3 Wind farm of 11.4 MW consisting of 19 NEG-Micon 600-kW, 48m diameter turbines in typical farming country. This is the largest wind farm built in 1999 on the land of farmers. It is owned and exploited by a private company in which five or six farmers hold the shares.

- New developments—Offshore, innovative materials and recycling
- Testing and measuring—Condition-monitoring systems and wind turbine test facilities
- Databases—Failures of wind turbines and components
- Design tools—Reliability, Wind turbines, Control, Aerodynamics

In the discussion about the NRW, the Dutch wind turbine industry emphasized the need for technology transfer from the research institutes to wind turbine designers. In order to fulfil this need, the TU Delft in co-operation with ECN organized a one-day workshop dedicated to design tools for wind turbines and blades.

17.6.3 New concepts and developments

Since January 1999, ECN and TU Delft have intensified their co-operation in the field of wind energy. ECN and TU Delft now jointly tender for large, often international R&D projects, and make use of each other's test fields and other research facilities. The co-operation focuses on development of wind turbines for offshore applications (3-5 MW), new turbine

concepts leading to cost price reductions, and improved aerodynamic rotor models.

ECN developed a special technique to visualize the stall behavior of rotor blades. The technique is based on so-called stall flags. Stall flags are small reflecting sheets, covered with a hinged non-reflection sheet. This device is glued to a blade. When stall occurs, the non-reflecting sheet opens and the reflecting part is visible. In night time, the traces of reflecting parts can be recorded with a video camera if the turbine is lit with a light source. With this technique it is possible to optimize the location of stall strips and vortex generators on the rotor blades of stall regulated machines, to gain insight into the problem of multiple stalls and to analyze in plane vibrations.

ECN developed several design tools for the prediction of buckling loads of double curved orthotropic panels under various load conditions (see also Section 17.6.6). The buckling loads predicted with these tools appear to be a good approximation for the actual buckling load. Within the STARION project, buckling loads analysis programs are evaluated and implemented in tools for application to rotor blade design. The buckling load analysis tools are validated and appear to be correct.

Table 17.8 Levels of R,D&D funding in The Netherlands 1991–1999 in NLG million

	1991	1992	1993	1994	1995	1996	1997	1998	1999
TWIN (subtotals)									
Short term implementation	1.5	1.7	1.1	1.1	0.7	0.9	2.5	2.5	6.4
Long term implementation	0.1	0.2	0.4	0.3	0.2	1.8	2.2	2.2	
Industrial development	4.0	3.6	3.5	3.5	3.3	3.3	6.1	6.1	4.0
Technological development	3.0	3.4	3.0	3.0	2.4	2.4	3.3	3.3	5.3
Dissemination of know-how	0.4	0.5	0.3	0.3	0.5	0.7	0.7	0.7	1.2
TWIN R,D&d total	9.0	9.4	8.3	8.1	7.0	9.0	14.8	14.8	16.9
Applied R&D (ECN)	2.5	2.5	3.0	3.0	3.0	3.0	3.5	3.5	3.5
R&D Universities (est.)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
R&D Utilities	0.6	0.6	0.6	0.4	0.0	0.0	0.0	0.0	0.0
E.E.T. program	14.1	14.5	13.9	13.5	12.0	14.0	25.2	20.2	10.0
TOTAL									32.4

The project resulted in an evaluation of the tools for buckling analysis, which is based on tests of three rotor blade sections.

The Institute of Wind Energy of the Delft University of Technology, developed the method NewGust to quickly generate extreme turbulence gusts for load calculations. Incorporation of the method in a wind filled simulator makes it possible to calculate a more accurate prediction of extreme loads, which enables manufactures to design more reliable wind turbines.

17.6.4 MW-rated turbines

A demonstration project has started with a prototype of the 1-MW NedWind wind turbine. It is a 3-bladed wind turbine with active stall control and a rotor diameter of 62 m. It is a unique wind turbine with a rotor area-power ratio of 3m²/kW. The Dutch wind turbine manufacturer NedWind, which was taken over by NEG-Micon last year (see Section 17.3.1), developed the wind turbine.

17.6.5 Offshore developments

In 1999, preparatory activities for the legal and administrative procedures of a 100-MW near shore demonstration wind farm were completed, as well as the Location Environmental Effect Report. From three alternatives, the location near Egmond aan Zee is most advantageous. The plan will be discussed in the Ministerial council early in 2000, whereas the parliament will probably decide on the final location before July 2001.

In 1999, the Deployment Plan Wind Energy Offshore was drawn up based on a preliminary feasibility study into the possibilities of offshore wind farms. The underlying studies focused on market development of renewable energy, investment costs of offshore wind farms, environmental benefits; ecological effects; legal and administrative framework of selecting locations outside the territorial waters; public support; technological development of turbines, and support

structures; electrical infrastructure and logistics. The study indicates that large offshore wind farms are feasible, provided that the Dutch policy for renewable energy is continued, national and local environmental groups are actively involved in site selection to obtain public support, and technological development of offshore wind turbines is continued. Especially administrative and legal procedures seem a bottleneck as legislation for offshore wind farms is lacking.

It is estimated that a wind farm of 3 times 650 MW at a distance of about 100 km from the coast in 30-50 m deep water could deliver electricity for 0.131 NLG/kWh (0.06 Euro/kWh). In December, a workshop took place to gain insight into the activities needed to implement these large offshore wind farms. All parties involved attended the workshop. The lack of legal framework for the North Sea was seen as the biggest constraint. The attendees emphasized the need for a stable financial climate and clear regulations for renewable energy, preferably on a European level, as well as a quick start of the near shore demonstration wind farm of 100 MW to gain experience with wind turbines offshore.

At ECN, a study into the technical and economic feasibility of multi-rotor wind turbines for offshore applications was executed. Although multi-rotor wind turbines are dynamically more complex and their failure rate is higher due to the multiple number of rotors and components, multi-rotor wind turbines are technically feasible and no specific development problems are expected. The economic advantage of multi-rotor wind turbines increases with the power, because the relative costs per MW of the foundation and the electrical infrastructure drop. However, the study concluded that the multi-rotor concept for wind turbines currently under development (approximately 3 times 1 MW) has no economic advantages compared with 3 MW single rotor wind turbine.

17.6.6 International collaboration

The Netherlands Energy Research Foundation (ECN) and the Delft University of Technology, Institute of Wind Energy, are involved in several European Union projects. In this section results of some of these projects are given.

In the JOULE-III project BUCKBLADE, an investigation into the applicability of several buckling load prediction tools and methods to rotor blade design was performed. The investigation assessed the relevant aspects for buckling of rotor blades and collected, described and validated a number of buckling load prediction methods. Based on design handbooks and publications, Design rules were formulated, which were validated for application to rotor blade design.

During the period January 1996 through November 1998, the JOULE III project Development of a design tool for structural reliability analyses of wind turbine components (PRODETO) was carried out; in 1999 the final report was published.

Also in 1999, the final report on the EU-funded project Structural and Economic Optimization of Bottom-Mounted Offshore Wind Energy Converters (Opti-OWECS), in which the Institute of Wind Energy played an important role, was published (see the IEA Wind Energy Annual Report 1998).

Reference: Internet:
<http://www.novem.nl>

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CHAPTER 18

18.1 GOVERNMENT PROGRAMS

In 1999, one wind power plant was built. Two other wind plants received building permission, public financial support, and will probably be erected in 2000–2001. Several projects have applied or will soon apply for building permission during the winter of 1999–2000. The activity and interest is increasing in wind power as a commercial source for energy production. Although still dependent on government support, wind power will be the main new renewable source of electricity production in the years to come.

18.2 NATIONAL POLICY**18.2.1 Strategy**

In Norway, most of the electricity production is based on hydro power. Remaining new hydro power projects are limited both in size and quantity, thus national policy has begun to focus on wind energy.

The Norwegian Government recently presented a white paper for energy policy in Norway. The document defines a goal to have annual electricity production based on wind energy of 3 TWh/year by the year 2010. This represents about 1000–1100 MW installed capacity, at the 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, or 250 million USD. (1 NOK = USD 0.125.) In 1999, energy production based on wind energy was about 25 GWh, with an estimated full year production of about 37 GWh.

18.2.2 Progress towards national targets

Two wind farms, 39 MW and 4 MW respectively, received permission and financial support at the end of 1999 and will most likely be erected during 2000–2001. Furthermore, four projects with a capacity of 435 MW in total have applied for permission during the winter 1999–2000.

Depending on the annual grants in the national budget in the coming years, this could mean a total installed capacity of 490 MW by the year 2004, or approximately half of the national target.

18.3 COMMERCIAL IMPLEMENTATION OF WIND POWER**18.3.1 Installed capacity**

One wind power project was commissioned during 1999, thus increasing the total national installed capacity from 9.3 MW to 13 MW. The wind farm consists of five turbines, each rated at 750 kW, and is located on the western coast of Norway, at the island Sandøy. Estimated production is 11.2 Gwh/year. An overview of Norwegian wind turbines and their energy production, both in 1999 and accumulated, is shown in Table 18.1. The production is slightly less than estimated, mainly due to the wind conditions.

18.3.2 Rates and trends in deployment

Figure 18.1 illustrates the increasing capacity of wind energy in recent years.

18.3.3 Contribution to national energy demand

The total Norwegian electricity generating capacity is about 27,681 MW, with 98.9% generated by hydro power. The mean energy production from hydro power is 112.9 TWh/year. Thus, the contribution from wind power is merely 0.03% of the total production capacity.

18.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS**18.4.1 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 January 1, 1999. One is the exemption for wind turbines and related equipment

Table 18.1 Norwegian wind turbines and their energy production

WIND TURBINE PROJECTS	YEAR	NO. UNITS	TOTAL POWER (kW)	PRODUCTION 1999 (GWH)	ACCUMULATED PRODUCTION (GWH)
Frøya	1986	1	55	0,153	1,787
Frøya	1989	1	400	0,748	7,960
Vallersund	1987	1	75	0,180	2,259
Kleppe	1988	1	55	0,045	0,504
Smøla	1989	1	300	0,689	6,481
Andøya	1991	1	400	0,956	8,107
Vesterålen	1991	1	400	1,020	9,019
Vikna I & II	1991/93	5	2200	6,754	48,623
Hundhammarfjellet	1998	1	1650	4,452	5,913
Lindesnes	1998	5	3750	9,446	14,247
Sandøy	1999	5	3750	1,000	1,000
TOTAL		23	13035	25,444	104,901

from the investment tax of 7%. Another measure is an energy production support, equaling half of the general electricity levy (0.0297 NOK/kWh in 1999). 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 criterion 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 1999, three projects were given financial support in the range of 22–25% of the total investment cost.

18.4.2 Unit cost reduction

Some work has been done to reduce costs related to the foundations, due to the fact

that most wind turbines in Norway are located on solid rock. So far the new concepts being considered have not been tested in full scale.

18.5 DEPLOYMENT AND CONSTRAINTS

18.5.1 Wind turbines deployed

Reference is made to the text above, Section 18.3.1 and Table 18.1.

18.5.2 Operational experience

No serious incidents have occurred, however, some cases of fatigue in the gearboxes have been reported.

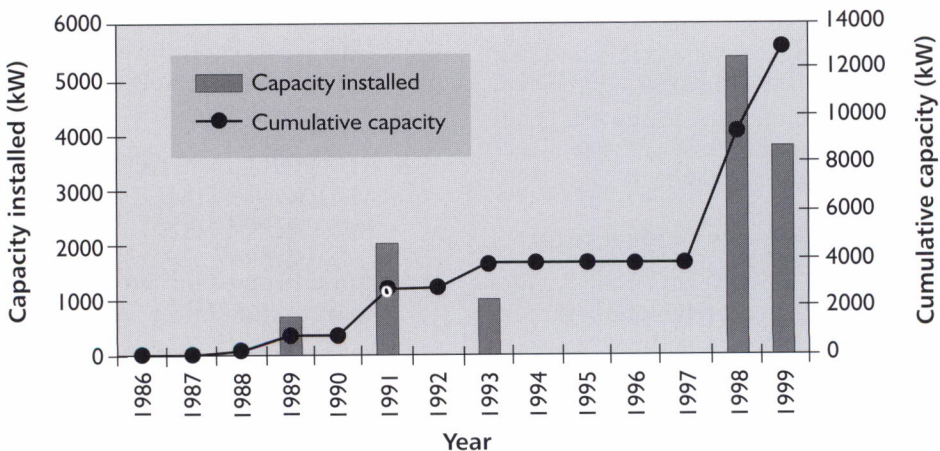


Figure 18.1 Wind energy capacity 1988-1999, (kW)

18.5.3 Main constraints on market development

In recent years, the interest in wind energy has increased, and several projects are being considered. However, the main constraint is low long-term energy prices. Furthermore, both visual and environmental concerns are major factors, limiting the possible deployment of wind energy in Norway. Many of the possible wind farm sites along the coast also play an important role as recreational areas to both tourists and the local population. The coastal areas are quite densely populated, by Norwegian standards, making it harder to find favorable sites not interfering with existing buildings. Choosing areas further away from the population, on the other hand, reduces the number of locations with sufficient grid capacity and other infrastructure.

18.6 ECONOMICS

18.6.1 Trends in investment

The cost of the Norwegian wind turbines erected in 1999 is about 29 million NOK (3,625,000 USD) implying a unit cost of 7733 NOK (967 USD)/kW. Generally, the unit cost for wind power has decreased to about 7500-8500 NOK (937-1062 USD)/kW for turn-key-installations.

18.6.2 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 18.2. The average price has steadily decreased since 1997. The price was 135.0 NOK/MWh in 1997, 116.3 NOK/MWh in 1998, and 111.9 NOK/MWh in 1999. This price may represent the typical buy-back price for wind-generated electricity, delivered into the grid transmission system.

Apart from the consideration of the spot market price, the customer must include costs covering transmission and taxes to estimate the resulting wind energy price.

Estimations of production costs from sites with favorable wind conditions suggest a production cost of as low as 250-300 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 wind energy projects are almost competitive.

18.7 INDUSTRY

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 company Scanwind has ambitions to produce 3-MW wind turbines, based partially on the Kvaerner experiences.

18.8 GOVERNMENT SPONSORED R, D&D

18.8.1 Priorities

The Norwegian Water Resources and Energy Directorate co-ordinates public support for projects in close collaboration with the Norwegian Research Council. The current priorities are for projects quite close to market introduction, and researchers should have an industrial partner in the project, where appropriate.

18.8.2 New R, D&D Developments

Some industrial companies provide components and related services for wind turbines. During 1999, the Norwegian Research Council supported the following projects related to technical wind energy development.

- The company F.K. Smith is developing a system measuring power transmission in rotating machinery. The system includes collaboration with Risø, and full scale testing will be done on a test wind turbine in Denmark

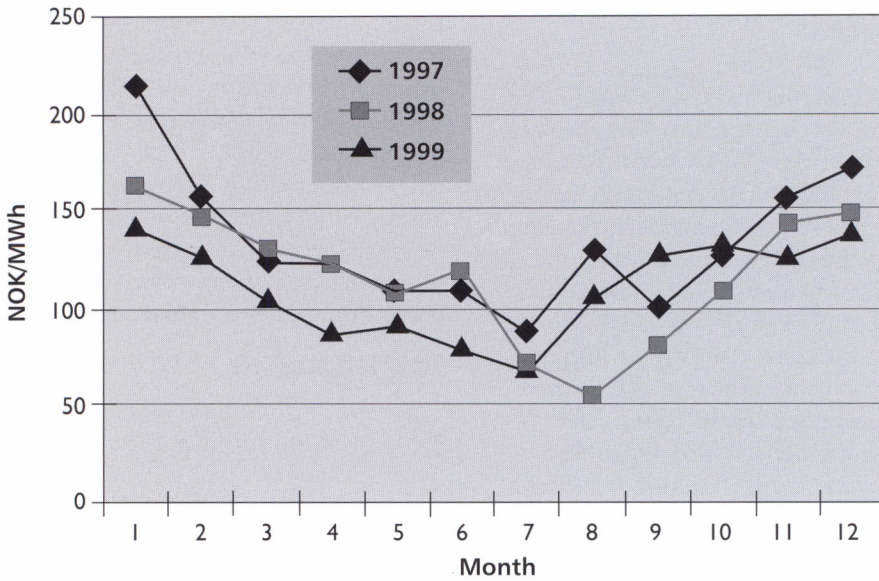


Figure 18.2 Spot market price of electricity 1997-1999 (Source: Nordpool ASA)

- The cast iron foundry, Kristiansand Jernstøperi, is working on a project to develop new and better products, in collaboration with the Casting Development Centre at the University of Birmingham, UK. The test samples will be analyzed with respect to stress and fatigue characteristics.

The following wind energy related projects were financed during 1999 by The Norwegian Research Council and/or by the Norwegian Water Resources and Energy Directorate, NVE.

- The company Contec Design has developed a system for wind speed measurements with very high resolution. The system is based on the interaction between radio transmission equipment and an acoustic system in a grid system. A Ph.D candidate is currently working on the subject. SINTEF Energy Research has developed guidelines on power quality requirements for grid connected wind turbines, mainly as a tool for utility companies.
- The company Vector is running a project using numerical flow simulations based on existing wind measurements to form

a rough wind atlas as a basis for deciding where to locate wind farms. The project will be finished in 2000, and 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.

- Institute for Energy Technology, IFE has, in collaboration with the utility company Nord-Trøndelag Elektrisitetsverk, started a wind resource project in the Nord-Trøndelag county. The project uses the meso-scale MM5-model, taking into consideration both atmospheric flow and also micro-scale parameters. The final resource estimations will be compared with in-situ measurements, and will also be compared with the estimations in the project done by Vector.

Several institutions collaborate on a wide study regarding environmental effects on reindeer, and the impact of wind turbines is one of the issues considered. Full-scale testing is carried out in Nord-Trøndelag.

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CHAPTER 19

19.1 INTRODUCTION

Spain is a country with a strong dependency on external sources of energy, because there are no oil or gas fields in its territory, and only a few coal mines producing low quality coal. Table 19.1 shows the distribution of the primary energy used for the year 1998.

In the year 1998, renewable energies contributed 6.3% to the total national energy balance. The production from Spanish wind power plants for 1998 was 1437 GWh and 3750 GWh for 1999.

Because Spain is a country with excellent wind resources and with a well-developed technology in the wind energy field, wind energy is now, together with biomass, solar thermal, and PV plants, a clear alternative for the integration of renewable energies into the Spanish energy structure.

At the present time, wind energy has a very promising future in Spain. The total power installed at the end of 1999 was 1539 MW and nearly 3000 wind turbines were in operation.

19.2 NATIONAL POLICY

19.2.1 Strategy

The strategy followed for the development of wind energy in Spain has been implemented in several steps. At the beginning of the program, and during the period from 1980 to 1985, the program was



Figure 19.1 Cabanilles 30-MW Wind Farm (50 wind turbines Ecotecnia 600 kW)

Table 19.1 Primary energy balance for 1998

SOURCE	Ktep	%
Oil	62,123	54.5
Coal	17,463	15.3
Nuclear	15,366	13.5
Gas	11,826	10.4
Renewable Energies	7,173	6.3
TOTAL	113,951	100

focused on the assessment of the national resource and also on the development of the national technology. As a result of these programs (the national and utilities programs), two of the present leaders of the Spanish wind industry, Made and Ecotécnia, emerged and developed wind turbines in the range of 20-30 kW. During the period 1985-90, resource assessment continued at the regional level and the Demonstration Program was launched by the public organization IDAE (Institute for Diversification and Saving of Energy). The Demonstration Program for installation of several small wind farms allowed the consolidation of the newly created industry. At that time, CIEMAT, the main public research center in the field of energy research in Spain, started its activities in wind energy through the development of the AWEC-60 project (a 60 m diameter, 1200-kW wind turbine) within the R&D program of the DG XII of the European Union.

Finally, in the period 1990-95, Spanish industry was ready to fulfill the requirements of a future wind market, and the Royal Law of 2366/1994 was enacted. This law guaranteed the electricity price to be paid by utilities to wind power plants, and was the beginning of a new era of wind energy in Spain.

At the end of 1999, the Ministry of Energy and Industry had prepared a new "Program for Promotion of Renewable Energies" that was pending approval by the Parliament. The program seeks to maintain the provisions of the Royal Law 2818/1998-23 December 1998, concerning 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. This fixed price will be up-dated every year by the Spanish Ministry of Energy and Industry according to annual variations of the market price.

Other actions to promote renewable energy include the following.

- Development of a new R, D&D National Program (large and small wind turbines)
- Financing the improvement of the electrical grids
- Regulation of the administrative procedures for renewable energy power plants.
- Support for Spanish participation in the working groups for Standards development
- Development of Information Programs
- Development of Educational Programs

The program is complemented by the new "National Plan for Scientific Research, Development and Technological Innovation (2000-2003)" that is also pending final approval.

19.2.2 Progress towards national targets

The majority of the autonomies have regional wind energy programs that set a total target of more than 10,000 MW to be installed in the next decade.

19.3 COMMERCIAL IMPLEMENTATION

In 1999, another 705 MW of wind power were installed, and the total capacity at the end of December 1999 was 1539 MW.

The new wind farms are large and medium sized, mainly owned by consortiums formed by utilities, regional institutions involved in local development, private investors, and in some cases the manufacturers. Private individuals are not playing an important role in the development of wind energy in Spain

Navarra, Galicia and Castilla y Leon are autonomous communities with much activity during 1999, with 217 MW, 205 MW, and 92 MW installed in the year 1999.

The wind turbines installed are rated at between 300 and 1650 kW. The majority of the installed capacity in 1999 was achieved using wind turbines manufactured in Spain

Table 19.2 Estimate of future wind power installations

REGION	ESTIMATED POWER (MW)	YEAR
Galicia	2800	2007
Aragon	2500	2012
Navarra	650	2010
Andalucia	1000	2005
Islas Canarias	300	2002
Cataluña	1000	2010
Castilla-La Mancha	1000	2010
Castilla-Leon	1000	2005
Murcia	50	2000
Pais Vasco	500	2005

(Gamesa Eólica, Made, Ecotécnia, and Bazan-Bonus), but also other manufacturers, such as Nordex and NEG-Micon, have installed wind turbines.

The production data of wind power plants for 1999 was 3750 GWh.

19.4 ECONOMICS

The Royal Law 2818/1998-23 December 1998, concerning the Electrical Special Regime for renewable energy plants connected to the grid fixed the conditions of the plants to be included in this special regime. This law was a new step in the strategy for promoting the use of renewable energies. It specified that "the contribution of the renewable energies to the Spanish energy

demand, will be at least 12% for the year 2010." All the installations using renewable energies 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 the producers. One choice is a fixed priced for the kWh generated, and a 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 values for the year 2000 are presented in Table 19.5.

Table 19.3 Spain's installed wind power capacity

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	1539	85%

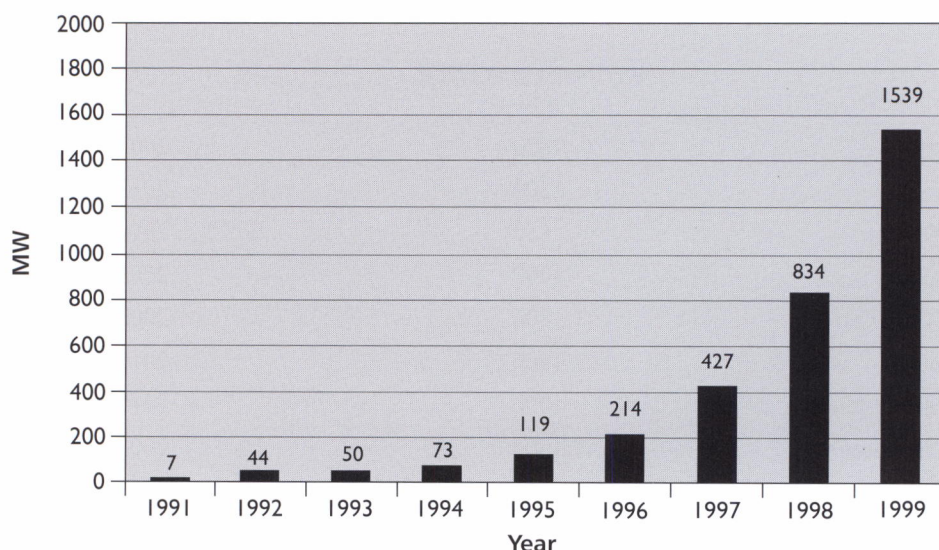


Figure 19.2 Total number of wind installations in Spain

19.5 INDUSTRY

All this activity in the wind energy field has enhanced the development of the Spanish wind industry, including not only the manufacture of complete wind turbines but also the manufacture of components such as blades, generators, gear boxes, towers, and wind sensors. Also, the service sector (installation, maintenance, engineering) has grown in the last year.

At the present time, the Spanish manufacturers are starting to design new large wind turbines. However, the general

position about large wind turbines is not so enthusiastic as in other European countries, mainly due to the difficult Spanish topography. In Spain, the windy areas are located in mountainous regions where difficult access makes the transport and erection of large machinery expensive. It is also not clear that large towers have the same advantages as in off-shore or plain terrain installations.

The companies that are leading the national Spanish industry are Gamesa Eólica, Ecotécnia, Made, Bazan-Bonus, Desa

Table 19.4 Distribution by Autonomies (31/12/99)

AUTONOMOUS COMMUNITY	NO. OF WIND FARMS	TOTAL POWER 31/12/1999 (MW)	NO. OF WIND TURBINES
Andalucía	13	126	349
Aragón	15	188	351
Canarias	21	102	316
Castilla y León	7	108	183
Castilla-La Mancha	3	111	132
Cataluña	4	59	160
Galicia	21	441	933
Murcia	1	6	9
Navarra	22	398	710
TOTAL	107	1539	2920

Table 19.5 Price comparison of renewable energies in Spain

RENEWABLE SOURCE	BONUS ADDED TO THE BASE PRICE (Pts/kWh)	FIXED PRICE (Pts/kWh)	FIXED PRICE (Euro/kWh)
Small Hydro	4.79	10.42	0.0626
Wind Plants	4.79	10.42	0.0626
Geothermal	4.97	10.59	0.0636
Wave	4.97	10.59	0.0636
Primary Biomass*	4.61	10.24	0.0615
Secondary Biomass*	4.26	9.89	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

and Taim-Neg Micon. Other manufacturers are initiating their activities in Spain, such as Dewind, Enron (Take) or Nordex.

Ecotécnia started activities in wind technology development in 1981 and has more than nineteen years of experience in that field. The company has a technical staff of 60 persons. Ecotécnia employs a total of 120 workers at its two factories located in Somozas (La Coruña) and Buñuel (Navarra). During 1999, Ecotécnia was incorporated into the MCC group, one of the world's biggest co-operatives with activities in the industrial, distribution, and financial sectors.

The models in production, the ECO/640 kW and ECO/750 kW are three-bladed, stall-controlled wind 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. A new prototype of 60 m diameter will undergo testing next year.

At the end of 1999, Ecotécnia had more than 100 MW in operation, with wind turbines from 150 kW to 750 kW. For the next year they foresee a production of 200 MW. Ecotécnia also has wind turbines in India and Cuba, and the company has signed a technology transfer and

representation agreement with the Japanese multinational Hitachi Zosen.

Made is another pioneer wind company in Spain that has developed ten different models of wind turbines. Since 1982, the company moved from the first design—a 24 kW—to the latest, an AE-46, 660 kW. During 1998, Made installed 178 wind turbines for a total capacity of 68 MW.

Gamesa Eólica is manufacturing wind turbines using Vestas Technology. The majority of the components are manufactured in Spain (including the blades). During 1998, Gamesa installed 290 units with a total of 189 MW.

Bazan-Bonus is manufacturing models of 600 kW, 1 MW, and 1.3 MW in its factory located in El Ferrol (La Coruña). At the end of 1999, Bazan-Bonus had 112 wind turbines in operation. During 1999, the company produced 65 units of the MK IV-600 kW model, and foresees the production of 100 units of the 600-kW model and another 100 units of the 1.3 MW for the year 2000.

NEG Micon Iberica S.A. installed 96 wind turbines in 1999, for a total of 137 wind turbines in operation in Spain. The company has 104 workers in Spain and plans next year to install another 400 wind turbines in Spanish territory.

Also there are new Spanish manufacturers active in the wind energy industry using foreign technology, such as Tacke Energía Eólica S.L. and Dewind. These manufacturers will increase the capacity of the Spanish industry to supply not only the internal market but also other markets. In particular, Spanish manufacturers are planning projects in North Africa such as in Tunisia, Morocco, Egypt, etc. and are also increasing their marketing activities in India, China, and South American countries.

In the small wind turbine sector, the company Bornay is the leader. The company has more than 200 units installed at the close of 1999. Bornay wind turbines are installed in Spain, in other European countries such as Germany, Portugal, Italy, and Greece, and in the South American market including Venezuela, Dominican Republic and others. Bornay is manufacturing eight models from 60 W to 12 kW. The company has opened a new factory during 1999.

19.6 RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

A new "National Plan for Scientific Research, Development and Technological Innovation (2000-2003)" was pending final approval at the close of 1999. The areas defined in the plan for wind energy projects follow.

- 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
- Telecontrol Systems for Grid Connection
- Wind Power Penetration in Weak Grids

The main R&D organization in the field of wind energy in Spain is CIEMAT, a public center for research in the technological and

environmental aspects of energy production. Inside CIEMAT, the Department of Renewable Energies (DER) is active in several projects, including resource evaluation, prediction models, and wind turbine testing (MEASNET network).

A new project has been launched devoted to the development of stand alone systems. The project covers a broad field of activity, from the development of components (small wind turbines, flywheel storage systems, control management units, etc), to the testing of the whole system. The systems will be tested in a new test center located in the CEDER plant in Soria.

As a consequence of the increasing activities, the number of University Departments working on wind energy technology is rapidly increasing. In particular, the Politechnical University of Madrid continues its work studying wakes in wind turbines, electrical systems, and blade technology. The University of Navarra is actively studying the effects of lightning on wind farms. The Vigo University is developing a simplified methodology for flicker analysis and voltage and frequency variations in wind farms. The University of Las Palmas (Canary Islands) works with wind farms' impact on grid stability and desalination plants powered by wind energy systems. The majority of the R&D activities in wind energy in Spain are developed under the umbrella of the European R&D programs. Other research centers are also very active, for example ITER and ITC in the Canary Islands, both centers are involved in R&D projects in desalination of seawater using wind energy plants.

Author: Felix Avia, CIEMAT, Spain

Table 19.6 Spain's main centers involved in wind R&D projects

CENTRE	FIELD OF RESEARCH	CONTACT PERSON
Politechnical University of Madrid E.T.S.I.I. Department of Fluidmechanic Engineering	<ul style="list-style-type: none"> • Wind resources • Wind turbine wakes • Wind farm modeling • Wind turbulence 	Prof. D. Antonio Crespo C/ Jose Gutierrez Abascal 2, 28006-Madrid Phone: +34-91-336-3152(30.23)/Fax: +34-91-336-3006 E-mail: crespo@enerflu.upm.es
Politechnical University of Madrid E.T.S.I.I. Department of Electrical Engineering	<ul style="list-style-type: none"> • Grid integration • Variable speed systems 	Prof. D. Carlos Vezanzones C/ Jose Gutierrez Abascal 2, 28006-Madrid Phone: +34-91-336 3060 E-mail: cvezanzones@inel.etsii.upm.es
University of Vigo E.T.S.I.I. Department of Electrical Engineering	<ul style="list-style-type: none"> • Grid integration • Electrical variable speed systems 	Prof. D. José Cidrás Lagoas-Marcosende, 9, 36280 VIGO Phone: +34-986-812-221/Fax: +34-928-812-173 E-mail: jcidras@uvigo.es
Instituto Tecnológicaico de Canarias (I.T.C.)	<ul style="list-style-type: none"> • Hybrid systems • Water pumping • Sea water desalination • Small WT 	Prof. D. Roque Calero C/ Cebrian 3, 35003-Las Palmas de Gran Canaria Phone: +34-928-452018/Fax: +34-928-452-007 E-mail: rcalero@cistia.es
I.T.E.R. Santa Cruz de Tenerife	<ul style="list-style-type: none"> • Hybrid systems • Water pumping • Water desalination • Small WT 	Ing. D. Manuel Cendagorta Polígono Industrial de Granadilla Santa Cruz de Tenerife, 38594- Tenerife Phone: +34-922-391000/Fax: +34-922-391001 E-mail: mano@iter.rcanaria.es
University Carlos III Department of Electrical Engineering Madrid	<ul style="list-style-type: none"> • Grid integration • Electrical variable speed systems 	Prof. D. J. Carlos Burgos Diaz C/ Butarque, 15, Leganés, 28911 Madrid Phone: +34-91-6249900/Fax: +34-91 6249430 E-mail: jcburgos@uc3m.es
Universidad Pública de Navarra	<ul style="list-style-type: none"> • Lightning in WT 	Prof. D. Blas Hermoso C/ Campus Arrosadía, 31006-Pamplona Phone: +34-948-169330/Fax: +34-948-169281 E-mail: hermoso@unavarra.es
Politechnical University of Madrid E.T.S.I.A. Departamento de Materiales	<ul style="list-style-type: none"> • Composite blades 	Prof. D. Alfredo Güemes Gordo C/ Plaza Cardenal Cisneros, 3, 28040 Madrid Phone: +34-91-3366327 E-mail: agüemes@dmpa.upm.es

CHAPTER 20

20.1 INTRODUCTION

Sweden has a good wind energy resource but so far the deployment has been slow. However, in the last couple of years deployment and development of wind power technology have speeded up. The wind turbines have become larger, cheaper, and more effective.

20.2 NATIONAL POLICY

The objective of Sweden's energy policy is to secure a long-term and short-term supply of energy on internationally competitive terms, and to promote economic and social development based on environmental sustainability. The policy specifies that the national energy supply is to be secured by an energy system based as far as possible on sustainable, preferably indigenous and renewable, resources and on energy efficiency. Sweden's energy policy approach places considerable emphasis on economic and environmental objectives.

In April 1998, the Ministry of the Environment set up a Government Committee with the task to analyze conditions for siting and permission procedures for wind farms in Sweden and to report the need for strengthening local electricity grids.

In the final committee report in June 1999, the Commission 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. The potential for a major expansion of wind power, the Commission believes, exists in sea and mountain areas. Investigations at the central level should focus on the feasibility of siting wind power stations in sea and mountain areas respectively. Those 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, and also to provide a solid foundation of knowledge for concrete wind power projects.

20.2.1 Strategy

On February 4, 1997, an inter-party Energy Policy Agreement between the Social Democrats, the Centre Party and the Left Party was reached. A new, long-term transformation program to develop an ecologically sustainable energy supply system was agreed upon. After some delay, the first nuclear reactor was closed in November 1999. The responsible authority for transforming the Swedish energy supply system into an ecologically sustainable system is the Swedish National Energy Administration (Statens energimyndighet), which was formed on January 1, 1998.

Sweden was one of the first countries to embark on a wind energy program in 1975. The government is supporting the development and installation of wind turbines in three programs managed by the Swedish National Energy Administration:

- A fully financed research program with a three-year budget of SEK 46.8 million for 1998-2001. The program is presented in Section 20.8.
- A development and demonstration program for wind systems, with a maximum of 50% support.
- An investment subsidy program.

The utilities are engaged in studies, demonstration projects, and evaluation projects. Since 1994, the research and development activities of utilities have been coordinated in a jointly owned company, Elforsk AB, which initiates projects and finds sponsors in the field of power generation. In addition to the activities of Elforsk AB, the largest utility, Vattenfall AB, has a

wind energy development program of its own.

20.2.2 Progress towards national targets

The target of the 5-year investment subsidy program (July 1997-June 2002) is 0.5 TWh of wind electricity production. With half of the program remaining, it appears that the goal of 0.50-0.55 TWh will be reached when the program ends.

20.3 COMMERCIAL IMPLEMENTATION

20.3.1 Installed capacity

The expansion of annual power generation from wind turbines and the installed capacity on December 31 each year in Sweden is shown in Figures 20.1 and 20.2.

The total installed wind power capacity in Sweden is 215 MW (99-12-31), an increase of 41 MW since 98-12-31 (+24%). The number of wind turbines has increased during 1999 by 59 to 480 turbines (+14%). Wind power generation during 1999 was 365 GWh, an increase of 18% since 1998 (310 GWh).

20.3.2 Rates and trends in deployment

No wind turbines in Sweden are erected today without the investment subsidy. The deployment is evenly distributed over

the years, since the investment subsidy budget is evenly distributed, with SEK 60 million per year.

20.3.3 Contribution to national energy demand

Wind power contributes to the national energy demand with 0.25% of the total electricity generation. The total installed electricity capacity and generation in Sweden is shown in Table 20.1.

20.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

20.4.1 Main support initiatives and market stimulation incentives

On January 1, 1996, a new Electricity Act came into force, replacing the old one from 1902. The aim of the new act is to introduce competition to the electricity market, thus creating the conditions for efficient pricing and a more open trade in electricity. Competition in trade in electricity makes it possible for buyers to choose freely between different vendors on the market. One obstacle for the buyers has until now been the cost of the electricity meter for hourly metering that has been necessary for buyers in the free market. However, from November 1, 1999, the requirement for an electricity meter has

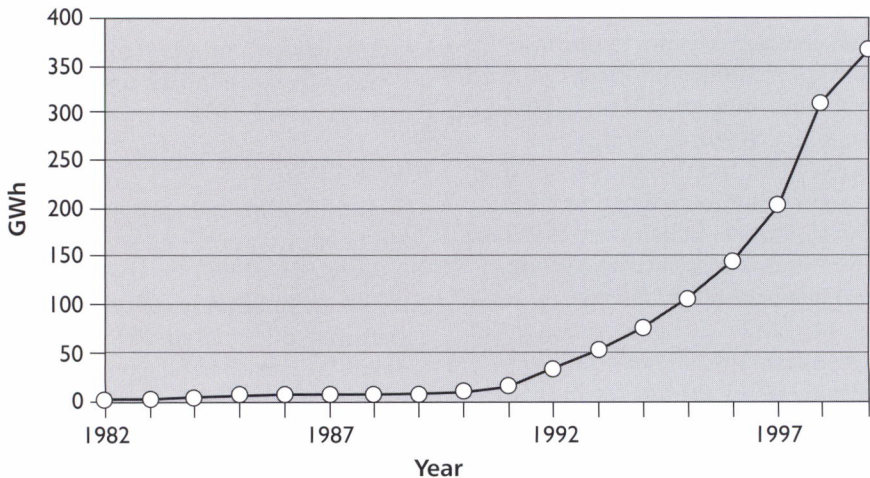


Figure 20.1 Wind Power Generation (Gwh)

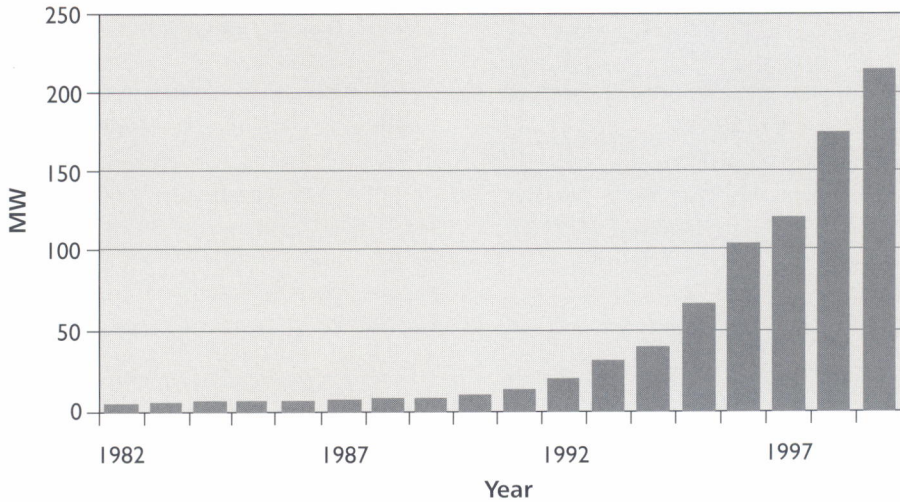


Figure 20.2 Wind Power Capacity (MW)

been replaced by “metering” with statistical profiles for consumption. Thus, the small customers are now able to freely choose a vendor, without the extra cost of electricity meters.

During 1999, a governmental committee evaluated the regulations on the deregulated electricity market, and the results were presented on November 1, 1999. The committee suggested that an overview of the promoting system for renewables should be performed during the year 2000, with a new system being introduced on January 1, 2001. From November 1, 1999, the wind energy producers compete on

the same market as conventional producers, but receive an “environmental bonus” of 15.2 öre/kWh (corresponding to the electricity tax for households). Additionally, a temporary support of 9.0 öre/kWh will secure the economy of the small-scale electricity producers.

The wind turbine owner also gets an income from the grid owner related to the value of the decreased grid losses. The deregulated market also gives the possibility to the turbine owner to sell his electricity to any customer. This gives opportunity for a “wind electricity market”.

Table 20.1 Total installed electricity capacity and generation in Sweden 1999

GENERATOR TYPE	1999 MW	1999 TWh
HYDRO POWER	16,246	70.20
NUCLEAR POWER	9,456	69.80
THERMAL POWER PRODUCTION (CHP, cold condensing)	3,810	9.90
WIND POWER	215	0.37
NET IMPORT		-7.30
TOTAL	29,727	142.90

A second market stimulation program (15% investment subsidy) started on July 1, 1997. The investment subsidy has a five-year budget of total SEK 300 million. By the end of 1999, the Swedish National Energy Administration had received applications for investment subsidies for projects with a total investment value of SEK 1128 million, and the total granted subsidies amounted to SEK 168 million. The granted subsidies for 1999 were SEK 64.3 million. These projects had a capacity of 41 MW.

20.4.2 Unit cost reduction

At good sites, today's commercial wind power plants can produce electricity at a cost of SEK 0.26–0.32 /kWh (without state subsidy) depending on the site, calculated with an interest rate of 5% over a period of 25 years. In Sweden, support is generally required for wind power to be viable.

The wind power plants that are erected today have a capacity between 250 and 1500 kW with a majority of 600 kW wind energy conversion systems.

The statistics are based upon the applications for investment subsidy, with quite few wind turbines.

20.5 DEPLOYMENT AND CONSTRAINTS

20.5.1 Wind turbines deployed

The wind turbines that are erected today in Sweden have a capacity between 200 and 1650 kW. The majority of turbines are 600-kW wind energy conversion systems, which can be seen in Figure 20.4. They are mainly manufactured in Denmark or in Germany.

20.5.2 Operational experience

According to the Swedish wind turbine monthly and annual statistics, the average availability during 1998 was 98.5%. This is an increase compared with the 1997 figure, which was 98.4%

20.5.3 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 may be more of a "technical" problem. So far the impact on bird life has been minimal, but questions are being raised as more off-shore wind power plants are planned.

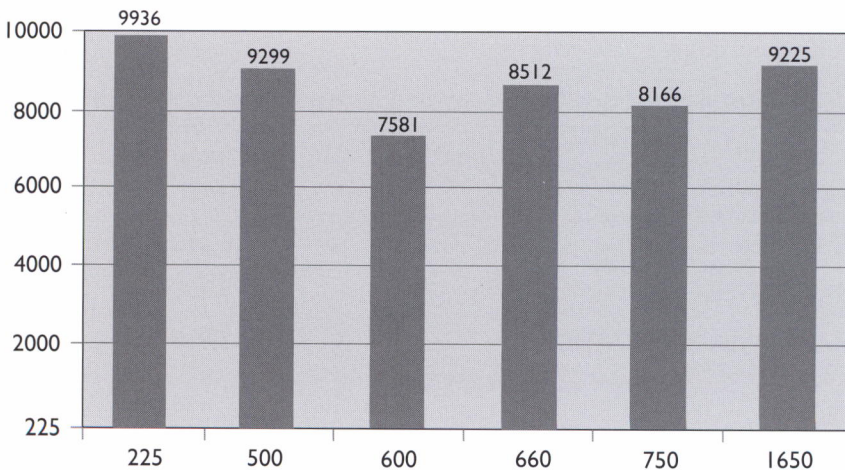


Figure 20.3 Unit costs in SEK/kWh with wind power projects grouped per capacity

*100 öre = SEK 1

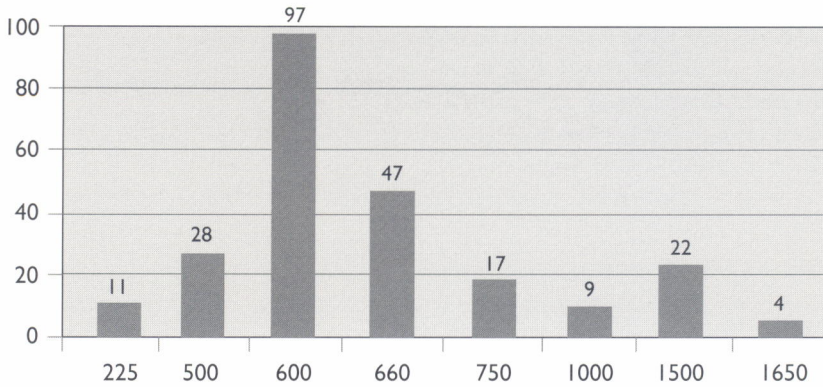


Figure 20.4 Number of wind turbines of specific capacity in projects in the investment subsidy program

Objections from the military have also stopped many wind projects. The military sees the risk of wind turbines causing disturbances to military microwave links, radar, and intelligence activities. They also fear for aircraft flying at low altitudes.

20.5.3.1 Public attitudes

A series of investigations on the public attitude towards wind power plants has been carried out. The investigations have included both permanent and summer residents around the plants and politicians and civil servants from the nearby 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 being investigated in a research project examining how attitudes can be improved, e.g. by public consultation in the permission process for wind power developments.

20.5.3.2 Noise

Noise is a subject frequently discussed when considering wind turbine projects. Assessments of wind turbine noise have shown that not only the sound level and its temporal pattern, but also several other factors are important for subjective responses. Work is continuing on how to

describe the noise disturbances in physical terms. Research has started on how people experience different sounds and noises, and what kinds of sounds are preferred compared to others.

20.5.3.3 Disturbances to military structures

A research project is aiming to create a reliable model of the disturbance wind turbines cause to military microwave links, radar, and intelligence activities. The results show that the disturbance due to wind turbines on radar so far has been quite overestimated.

20.6 ECONOMICS

20.6.1 Trends in investment

During the years 1998-2002 approximately SEK 400 million per year will be invested, since the investment subsidy of 15% has a budget of SEK 60 million per year.

20.6.2 Trends in unit costs of generation and buy-back prices

The unit cost per generation is SEK 0.26-0.32 /kWh at good sites (see Section 20.4.2).

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 20.2). The prices charged to various customer categories are determined by tariff systems, which are made up of a mixture of variable and fixed charges.

The price paid for wind turbine produced electricity during 1998 was linked to the local household tariffs and averaged around 0.25 SEK/kWh (including net value payment) plus an environmental bonus of 0.151 SEK/kWh.

During 1999, the prices decreased as the electricity prices to households fell. From November 1 the rules were changed and the wind turbine owner receives the following.

- market tender price of around 0.13 SEK/kWh,

- an environmental bonus of 0.152 SEK/kWh,
- a temporary subsidy of 0.09 SEK/kWh and
- the “local grid value” of in average 0.01 SEK/kWh, which comes to a total of 0.382 SEK/kWh.

This price model will remain in force until end of 2000.

20.7 INDUSTRY

20.7.1 Manufacturing

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 (2000 kW) and Näsudden II (3000 kW). Vattenfall AB is the purchaser of both turbines. Kvaerner has also been a part of the OPTI OWEC project for offshore wind turbines in Europe within the THERMIE program. During 1999, the company name for these

Table 20.2 Price of network service and electricity, excluding taxes, on January 1, 1999 in sales of electricity to various typical customers

CUSTOMER TYPE	NETWORK SERVICES öre/kWh			ELECTRICAL ENERGY öre/kWh		
	1998	1999	% Change	1998	1999	% Change
Apartment	42.3	42.3	0.0	29.0	27.1	-6.5
Single-family house without electric heating	37.1	37.2	0.2	26.8	26.3	-1.8
Single-family house with electric heating	20.7	20.6	-0.2	25.1	24.4	-3.0
Agriculture or forestry	21.7	21.8	0.5	24.1	23.1	-4.1
Small industrial plant	14.8	15.0	-1.3	24.1	22.8	-5.3
Medium-sized industrial plant				23.1	21.6	-6.4
Electric-intensive industrial plant				22.7	22.5	-1.0

Source: “Prices of electrical energy and transmission of electricity in 1999,” E17 SM 9901, Statistics Sweden

wind power activities has changed to SW Vindkraft AB.

Nordic Windpower AB has during 1999 developed and sold two new Nordic 1000-kW wind turbines for commissioning during 2000.

20.7.2 Industry development—MW-rated turbines

Näsudden II

The 3000-kW Näsudden II has generated 29,202 MWh during 27,414 operating hours (99-12-31). The generation during 1999 was 4112 MWh and the availability was 63%.

Nordic 1000

The 1-MW Nordic 1000 has generated 7873 MWh during 27,892 operating hours (99-12-31). During 1999, it generated 1988 MWh and its availability was 88%.

20.8 GOVERNMENT SPONSORED R, D&D

The overall goal for the Swedish wind energy research program is to develop the knowledge within the wind energy area so it will be possible to manufacture and develop wind turbines and utilize wind energy efficiently in the Swedish Energy system.

On July 1, 1998, a fully financed research program started with a three-year budget of SEK 46.8 million for 1998-2001. The budget has been increased over the previous period and the number of subjects of research has also been increased. The subjects of research are:

- 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 Programme—VKK (VKK stands for wind energy-knowledge-competence). VKK was formed in 1994 and is lead by the Aeronautical Research Institute of Sweden (FFA). More information can be found at the following Web page: <http://www.ffa.se/windenergy/windenergy.html>.

20.8.1 Priorities

The research has been very technology oriented, but in a stage when more wind turbines are fit 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 availability and reduce costs.

20.8.2 New R, D&D developments

In the following, some of the current research and demonstration projects are presented.

20.8.2.1 Complex terrain and cold climate siting

Rodovålen in Härjedalen

The company Agrivind has erected three wind turbines on a mountaintop 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 the Swedish National Energy Administration.

In connection with the project, a study of environmental effects on reindeers has been initiated.

Suorva in Lappland

At one of its large hydro power dams in the Lule River valley, the utility Vattenfall in October 1998 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 since 1995 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 the Swedish National Energy Administration.

20.8.2.2 Instrumentation and initial evaluation of the 2.5-MW Bockstigen off-shore wind farm

Whereas the goal of earlier off-shore projects has been to demonstrate the technical feasibility of off-shore wind power, the main emphasis of the Bockstigen project is to demonstrate the economic viability by developing technologies suitable for making offshore wind turbines economically compatible. The means to achieve the economical goal have been two-fold. The first one is the foundation method of mounting the wind turbine towers on 2.25-m diameter steel monopiles secured by grouting in 10 m deep holes drilled into the limestone rock. This method promises to be far more

economical than the previous methods that mainly used concrete gravitation foundations. The second one is the method for electrical grid connection, which enabled dimensioning the cabling by the thermal rating only, not by the short-circuit power, which normally is the case in wind turbine installations. Thus the electrical system is furnished with a frequency converter that allows variable speed operation at low wind speed and reactive power compensation during all operation. Furthermore, inside the water-filled monopiles, the turbines are furnished with dump loads that shed surplus power that cannot be transferred to the grid on the island.

The wind farm has been subjected to a primary technical evaluation within the original Thermie A-project. Further evaluation is carried out in projects supported by NUTEK/Energimyndigheten (The Swedish National Energy Administration). Although the complete measurement system is not yet operational, some initial observations have been made



Figure 20.5 Reindeers in the vicinity of wind turbines at the Härjedalen site

as the first results.

Transfer of loads from monopile to rock

Load conditions along the tower and the monopile are registered both as bending moments (at four levels) and as shear forces (at two levels). The transfer of the loads from the monopile to the limestone rock is expressed as a decrease of the bending moments along the monopile. The variation of the shear forces, measured and derived through the bending moments along the monopile, is used to evaluate the properties of the load carrying limestone rock.

Wave loads

Based on the assumption that the shear force measured close to the sea bottom is the sum of the tower forces and the forces from the sea waves and currents acting on the monopile, the latter loads are easily calculated as the difference between the shear forces measured at levels 3 and 4. The fatigue contribution of the forces emanating from the waves is far larger than that of the forces acting on the tower. This is further underlined by a larger standard deviation when the wind is blowing from the sea sector (SW–NW) as compared to the land sector (NE–SE). It is also obvious that the contribution is larger in the direction of the wind (and thus in the wave direction) than in the lateral direction.

Dynamics

FFT (Fast Fourier Transform) has been used to analyze the frequency contents of the bending moments and the shear forces along the structure. Turbine stops have been used to obtain information on the frequency response of the turbine, where 1p (once per turbine revolution) = 30 rpm = 0.5 Hz. The combined design of the tower and the monopile structure aimed at a first frequency of 0.62 Hz, which was easily identified in the FFT-analysis. During normal operation this frequency dominates almost all the bending moments along the structure.

Regarding the shear forces, there is a significant difference between those of the tower and those of the monopile below the sea level. In the tower also the shear forces are dominated by the 1p-contribution, whereas in the monopile the largest amplitude levels and energy contribution are observed at frequencies of 0.15–0.35 Hz, corresponding to wave periods of 7 to 3 seconds, which is typical for the sea waves in the area. This further demonstrates the importance of the wave loading for the fatigue of the monopile.

Extreme loads

On 2 February 1999, the turbine was running in a high westerly wind from the sea. During some ten minutes the wind speed increased even more, to a maximum of 35–40 m/s. The turbines stopped during the event, as expected. Visual observations indicated waves of about the same height as the water depth, around 6 m. A preliminary investigation reveals that the loads that acted on the structure were well below the design limits. This is in line with the basic assumption that the structure in general is dimensioned by a load case involving a floating sea ice cover pressing towards the monopile.

The high wind speed and wave height event, including its pre- and post-history, will be studied further.

20.8.2.3 Wind diesel systems

Chalmers Technical University in Gothenberg began research on wind-diesel systems in 1982. In 1994, the Chalmers research group provided a prototype installation on the island of Svenska Högarna in the Stockholm archipelago. Through this prototype work they have demonstrated a unique concept. The wind-diesel system is dimensioned and designed to provide continuous 220/380 V AC for the island, which is not connected to the national power grid. The average electrical load is around 12 kW.

The Chalmers concept is built to use the rotational energy in the wind turbine for short storage of energy, instead of the usual storage of energy in batteries. The wind turbine functions as a large flywheel, whose rotational energy can be used if the wind suddenly stops, or if a large load occurs in the system. If either of these situations occur for several seconds, the turbine speed sinks temporarily and the wind turbine provides electrical generation without the diesel generator starting. This is possible because the turbine has variable speed and a special control system. If there is too little wind to serve the load, then the diesel generator will start before the wind turbine reaches its lowest rotational speed. The process of stopping the diesel is controlled in such a way that excessive starts and stops are avoided. Big fuel savings and a small number of diesel starts are achieved with the unique concept of the control system.

The 20-kW wind turbine has special characteristics that fit well for this type of application. The turbine has a passive pitch control, plus the turbine uses a variable speed concept with a large inertial mass, which is a very important to maintain generation upon loss of wind. The large rotor diameter allows the system to shut down the diesel at wind speeds as low as 6 m/s. On average, the wind turbine produces 75% of the electricity on the island.

The concept demonstrated on Svenska Högarna has been further developed, to provide a commercial wind-hybrid system. In co-operation with Chalmers, the consulting company ÅF-Industrieteknik AB has developed a modern control system for the application. Pitch Wind AB sells a 20-kW wind turbine with suitable characteristics, but also larger machines with variable speed and pitch control can be used.

The result of these developments is a wind-diesel concept with high performance at low costs, making wind power attractive for remote locations.

20.8.3 Offshore siting

Nogersund

Since 1991, research programs have been conducted concerning the impact on the environment from the 220-kW off shore wind power station at Nogersund.

Bockstigen, Valar

An offshore demo-plant is erected 4 km outside of Näsudden on Gotland. The project was performed by the Swedish wind farm developer Vindkompaniet AB in co-operation with the Danish wind turbine manufacturer Wind World and the British off-shore construction company Seacore. The project consists of five plants, each of 500 kW. The Bockstigen Valar project is sponsored by EU (THERMIE) and the Swedish National Energy Administration. The turbines produced their first electricity to the main grid in March 1998.

Utgrunden

The company Enron/Tacke has applied for permission for a 10-MW wind energy project in the sound between the city Kalmar and the island Öland.

Lillgrund

In the sound between Sweden and Denmark, the company Eurowind has applied for permission for an offshore wind energy project with 48 1.5-MW wind turbines.

Offshore 3-MW farm

West of the city Karlskrona in south-east Sweden the utility Vattenfall has made a feasibility study for an offshore project with 3-MW wind turbines. In the city's preliminary oversight planning the offshore site is planned for about one hundred large MW-sized wind turbines.

Authors: Susann Persson, the Swedish National Energy Administration and Kenneth Averstad, Vattenfall AB, Sweden

CHAPTER 21

21.1 INTRODUCTION

The United Kingdom (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 the Non-Fossil Fuel Obligation (NFFO), a market implementation mechanism introduced in 1990.

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. The program will continue, pending the current review of renewable energy policy. Collaborative product development with 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 so contribute to national targets for generation from renewables and emissions reduction.

21.2 NATIONAL POLICY

Until 1997, Government policy concentrated on the development of new and renewable energy sources wherever they have prospects of being economically attractive and environmentally acceptable in order to contribute to the following.

- diverse, secure, and sustainable energy supplies
- reduction in the emission of pollutants

- encouragement of internationally competitive industries.

Since 1997, the present Government has proposed a new and strong drive to develop renewable energy sources. A policy review announced by the Minister for Science, Energy and Industry is considering what will be necessary and practicable in order to achieve 10% of the UK's electricity needs from renewables by the year 2010. A strategy which will explain how this target will be achieved is expected to be published in the spring of 2000.

21.2.1 Strategy

The Government has initiated a market enablement strategy to implement its policy, stimulating the development of sources and industrial and market infrastructure. The strategy aims to give new and renewable sources the opportunity to compete equitably with other energy technologies in a self sustaining market. For wind energy, the strategy seeks to encourage its uptake by:

- stimulating an initial market via the Non-Fossil Fuel Obligation
- stimulating the development of the technology as appropriate
- assessing when the technology will become cost effective
- quantifying the associated environmental improvements and dis-benefits
- removing inappropriate legislative and administrative barriers
- ensuring the market is fully informed.

The Government also seeks to encourage internationally competitive industries to develop and utilize capabilities for the domestic and export markets. The Government (through its Department of Trade and Industry—DTI) supports a

program or R, D&D aimed at both helping industry and addressing key deployment barriers. The industry program seeks to improve market share, reduce the cost of wind energy, and improve competitiveness. The deployment barriers program seeks to 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.

21.2.2 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 March 1999, it issued a consultation paper "New and Renewable Energy; Prospects for the 21st Century" and is currently in the process of developing policy on renewable energy, taking into account the responses received. A further paper on the UK climate change program is expected in 2000 and a statement on renewable energy policy will follow.

In addition to the commitment to Kyoto, the Government has set its own domestic target of achieving a 20% reduction in CO₂ emissions by the year 2010.

The government has expressed its intention of working towards the aim of achieving 10% of the total electrical energy consumption from renewable sources by the year 2010. It is anticipated that this will be met from a combination of sources including both onshore and offshore wind, land-fill gas, and energy from waste. Achieving 10% of national requirements of electrical energy needs from renewable sources will require between 6-7 GW from a range of renewable technologies. Although there is some flexibility as to the mix of technologies necessary to achieve the UK target, offshore wind will need to supply in excess of 1GW (installed capacity).

21.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

21.3.1 Installed capacity

By the end of December 1999, the UK had 60 wind schemes with 779 wind turbines operating with non-fossil fuel contracts, and these comprise 344 MW of installed capacity. This is much less than the 2675.8 MW of contracted capacity (Table 21.1). The lack

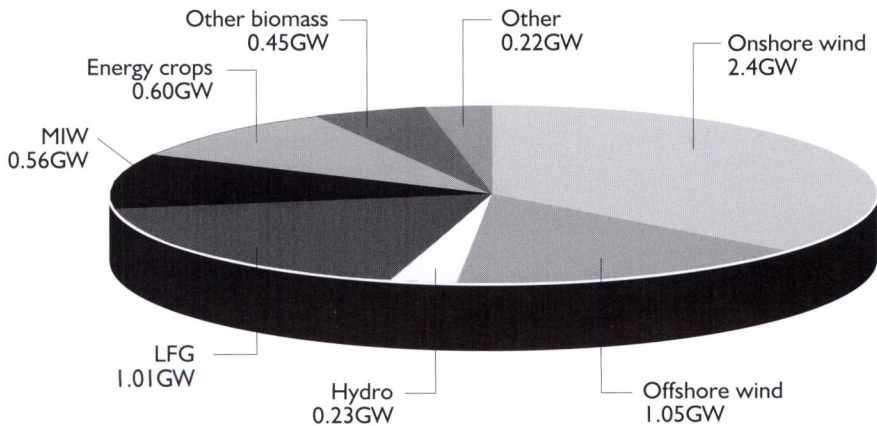


Figure 21.1 Technology contribution, assuming 10% of total 2010 electrical energy supplied from renewable sources

Table 21.1 Size and timing of 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	5	28.0	26.40	73
NFFO-2	1992	49	18	192.0	123.37	357
NFFO-3 (>3.7 MW)	1995	31	8	339.0	83.75	147
NFFO-3 (<3.7 MW)	1995	24	8	46.0	15.60	30
NFFO-4 (>1.76 MW)	1997	48	—	768.0	—	—
NFFO-4 (<1.876 MW)	1997	17	1	24.2	1.50	1
NFFO-5 (>2.3 MW)	1998	33	—	791.0	—	—
NFFO-5 (<2.3 MW)	1998	35	—	64.9	—	—
SRO-1	1995	20	7	106.0	62.60	110
SRO-2	1997	7	—	101.5	—	—
SRO-3 (>2.3 MW)	1999	11	—	147.5	—	—
SRO-3 (<2.3 MW)	1999	17	—	32.7	—	—
NI-NFFO1	1994	6	6	29.0	30.00	60
NI-NFFO2	1996	2	1	6.0	1.00	1
TOTAL		281	60	2675.8	344.00	779

*Source: BWEA website

of progress with deployment primarily reflects difficulties with obtaining planning consent. Future capacity will also be limited by network constraints without major re-enforcement.

21.3.2 Rates and trends in deployment

Figure 21.2 clearly shows the dramatic slow down in deployment since 1997 when 84.5 MW was installed. In the following year, only 13 MW was installed and there has been only a minor increase during 1999 to 19 MW. These figures reflect the biggest impediment to deployment, obtaining planning consent. An interesting exception to this is the recent installation of an Enercon 1.5-MW machine at Swaffam, Norfolk. This has attracted much attention because it has been installed with a viewing platform accessed via a spiral staircase, and was visited by many attending the British Wind Energy Conference. It is currently the largest machine in the UK, but NEG-Micon have planning permission for a 2-MW machine on Orkney Island, Scotland. With an annual mean wind speed of around 11m/s at hub height, Orkney Island will serve as a high wind test site.

21.3.3 Contribution to national energy demand

In 1998, the most recent year for data on annual energy demand from all sources, 2.8% of the national demand was met from renewable sources of which 0.26% came 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.

21.4 SUPPORT INITIATIVES AND MARKET STIMULATION INSTRUMENTS

21.4.1 Main support initiatives and market stimulation incentives

The main support mechanism for wind energy, and other renewables has been a series of Renewable Energy Orders. Each order allows developers to bid for power supply contracts, which are index linked for fifteen 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 selected after a pre-determined deadline. This mechanism has

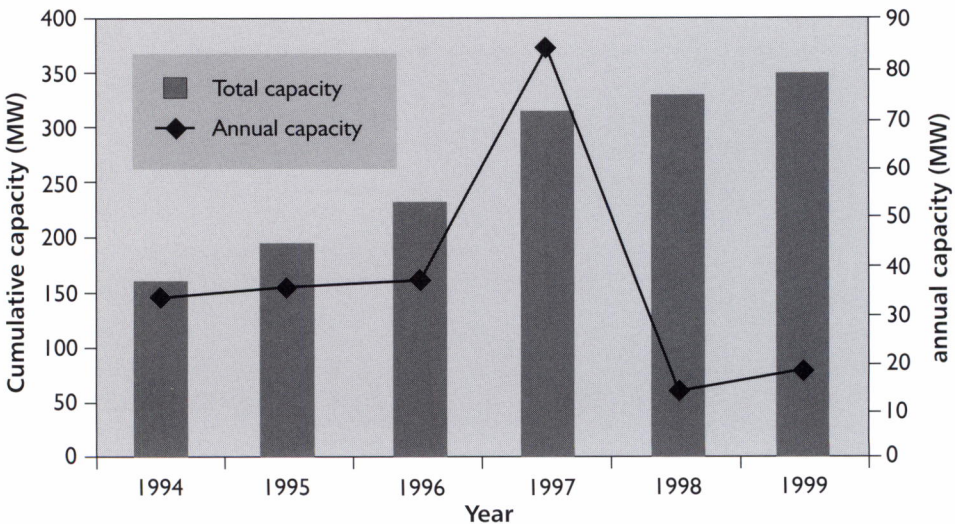


Figure 21.2 Wind turbine capacity and growth in th UK

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 Non Fossil Fuel Obligation (NFFO). This activity has been mirrored by three rounds of the Scottish Renewable energy Order (SRO) and two Northern Ireland rounds of NFFO.

In September 1999, the third round of the Scottish Renewables Order was announced in April 1999, adding a further 180.2 MW. The Government will be announcing a new support mechanism to replace NFFO and the SRO. A final decision is not expected until the summer of 2000. The most likely system will be an obligation on suppliers of electricity to purchase a proportion of the power from renewable sources. Unlike NFFO, there are unlikely to be technology specific requirements with the possible exception of new technologies such as off-shore wind and biomass. Electricity will be traded in a new market, which will include an obligation on suppliers to buy 10% of their electricity from renewable sources via a certification system. In addition, the Government has proposed that a Climate Change Levy (CCL) is introduced for business consumers only. The proposed CCL of 0.43 p/kWh is exempt for electricity supplies derived from renewables.

The Government is also proposing further reform of the country's electricity trading arrangements. The New Electricity Trading Arrangements (NETA) are designed to encourage greater competition between conventional suppliers. Emphasis will be placed on the ability to predict output and quantity against predicted demand with penalties on intermittent supply. This new mode of trading could place intermittent generators such as wind at a significant disadvantage unless there is some specific recognition of intermittent suppliers. The introduction of the new support mechanism for renewables and the effect of NETA

have yet to be fully resolved. New legislation is expected later in 2000.

21.4.2 Unit cost reduction

During 1999, most developments in the UK were proceeding at investment costs similar to the 1998 figure. On this basis £15.2 million was invested during 1999. Some developers consider that development costs can be reduced still further to between £550 and £700 per kW of rated power for completed projects. These cost projections are partly reflected in the low bid prices for NFFO-5. Experienced developers believe that both experience, and knowledge of the terrain where prospective sites have been identified, contribute to these economies as well as the favorable £/Euro exchange rate.

21.5 DEPLOYMENT AND CONSTRAINTS

21.5.1 Wind turbines deployed

At the close of 1999, there were 779 turbines deployed throughout the UK at sixty sites that were either 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 future support mechanisms for renewables make future predictions extremely uncertain.

During 1999, 27 new machines, exclusively of Danish manufacture, were installed on three separate wind farms. One development of six 600-kW machines was commissioned at a dock site in Liverpool. The other two developments of fourteen 600-kW machines and seven 660-kW machines were commissioned in Scotland and the North West of England respectively. In addition to the 1.5-MW machine opened at Swaffam another single 1-MW machine also started operation last year. The prototype device, which is situated at a site in Northern Ireland, is being developed by

the well established UK developer, Renewable Energy Systems.

21.5.2 Operational experience

In the first three quarters of 1999, 340.1 GWh/year was generated from wind farms in the UK. Northern Ireland produced 72.9 GWh/year, Scotland 105 GWh/y with the remaining 162.2 GWh/year coming from England and Wales. Records from the earliest wind farms developed in the first two rounds of the NFFO were unavailable from January 1999. Electricity produced by these wind farms is no longer traded via the NFFO system. Power output is now undertaken through private contracts with local suppliers and information on the quantity of electricity generated is no longer obtainable. The figures for wind generated electricity presented here are therefore lower than reality. The quarter by quarter output from the projects is shown in Figure 21.3.

No major problems were reported during 1999 with high availabilities achieved.

21.5.3 Main constraints on market development

Only 19 MW of new capacity was commissioned during 1999, mostly at three wind farms. Although this is a marginal improvement on the previous year, the deployment rate still reflects the difficulties encountered by developers in gaining planning consent. The figures presented in Table 21.2 clearly show that there are a large number of projects which could be developed. At present the Renewables Orders, introduced in 1990, are the only mechanism for securing a guaranteed tariff for renewable sources of energy. A new support mechanism is planned for 2000, but until this is introduced there will be a hiatus in further deployment, particularly for offshore schemes.

Further initiatives are also under consideration to address the impasse on obtaining planning consent. Current proposals include a demand for different regions throughout the UK to accept a proportion of their energy supplies from renewable sources. This policy could then provide a rational basis for wind farm development to meet regional requirements.

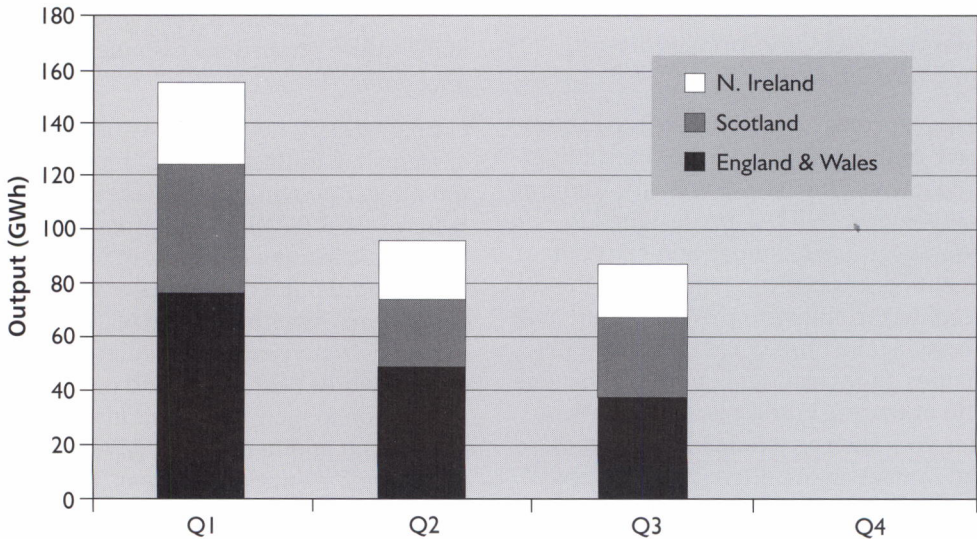


Figure 21.3 Wind energy output during 1999

21.6 ECONOMICS

21.6.1 Trends in investment

Type of funding available—Finance for wind farms is obtained largely from corporate investors and banks though there is a small amount of private investment. There is no direct public funding available for capital investment in wind farms. The premium prices from the Renewables Energy Orders are considered sufficient incentive.

Changes to the electricity trading system and support mechanism for renewables will need to be fully understood before any new phase in either corporate or individual investment.

Typical financial interest rates—Interest rates asked by banks are typically 1.5% above the London Inter Bank Offered Rate (LIBOR). Equity/debt ratios are typically 25/75, with investors requiring a post tax return on equity of typically 15% to 25%. Clearly these figures can vary considerably from project to project. However, many of the recent developments are financed off the balance sheet of larger companies (mostly utilities). They accept lower real rates of return of between 8% and 12% dependent on the associated risk. This has contributed to the reduction of costs and accounts for the lowest bid prices.

21.6.2 Trends in unit costs of generation and buy-back prices

Table 21.2 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 repayment on investment could be achieved in a short time scale.

Later rounds of NFFO and the SRO allowed a more reasonable planning window of five years followed by a 15 year index linked contract. 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 development time for wind farm projects few wind farms in the final two rounds of the NFFO have been commissioned (see Table 21.2). The competitive system induced by 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 and NFFO-5 rounds has yet to be demonstrated.

21.7 INDUSTRY

21.7.1 Manufacturing

The UK's leading wind turbine manufacturer is now NEG-Micon (UK), which was formed in March 1998 when NEG-Micon bought the only UK turbine manufacturer, WEG. NEG-Micon have retained a core team of engineers in the UK and have established an assembly facility used to develop and assemble hubs for the new 2-MW turbines for the offshore market, as well as for smaller machines. NEG-Micon also purchased WEG's wood laminate blade business now called Aerolaminates. Renewable Energy Systems (RES) has now commissioned a 1-MW prototype. The company is better known for its involvement in wind farm development.

In 1999, Aerpac has moved and expanded its blade manufacturing operation to a

Table 21.2 Contracted capacity and process 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	—
NFFO-2	1992	192.0	49	11.0*	—
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	24.2	17	4.09–4.95	4.57
NFFO-5 (>2.4 MW)	1998	791.0	33	2.43–3.10	2.88
NFFO-5 (<2.4 MW)	1998	64.9	36	3.40–4.60	4.18
SRO-1	1995	106.0	12	3.79–4.17	3.99
SRO-2	1997	101.5	7	2.70–2.94	2.82
SRO-3 (>2.3 MW)	1999	147.5	11	1.89–2.19	2.04
SRO-3 (<2.3 MW)	1999	32.7	17	2.63–3.38	3.01
NI-NFFO1	1994	29.0	6	N/A	N/A
NI-NFFO2	1996	6.0	2	N/A	N/A

*In NFFO-2 a single maximum strike price was offered to all contracts in the wind band.

new facility in Kirkcaldy, Fife in central Scotland. The company reports an expanding order book mostly for exports.

The continuing unfavorable exchange rate and a static home market have inhibited the market for component suppliers. However, in addition to blades, some towers, castings, pitch bearings, and elastomers are being manufactured in the UK to be supplied to foreign manufacturers.

The UK now has well established expertise in consultancy for site exploration, performance and financial evaluation, planning applications, and environmental impact statements as successive tranches of the Renewable Energy Obligations are announced. Growing interest in the offshore market has attracted new business for consultants in environmental assessment, meteorology, and oceanography (MetOcean).

21.7.2 Industry development and structure

The UK industry is dominated by developers, the most prominent of which have much larger parent companies. There are a number of smaller developers some of whom specialize in niche development such as small wind farms or single wind turbines. Most developers concentrate on development prospects in the UK and some have interests in the Irish Republic. Few developers have invested in projects outside this region.

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 installation in the Baltic.

21.8 GOVERNMENT SPONSORED R, D&D

Around £1.6 million of the budget for DTI's Program on New and Renewable Energy was allocated to wind energy development during 1999 which is a slight increase comparable to the previous year.

21.8.1 Priorities

The Government program continues to support a cost-shared program with industry but as the technology achieves maturity, and subject to the renewables review currently being undertaken, the trend is towards decreasing contributions from Government in this area. 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 construction techniques.

A series of generic projects were completed during 1999 to address barriers to deployment. These include cumulative impact, visual intrusion, and large-scale integration with the national electricity distribution system.

21.8.2 New R, D&D developments

A new 1-MW prototype, developed by RES, began operation in January 1999. With greater operational experience the company hopes to extend the use of this design on at least one of its other wind farms. The developer Border Wind, in collaboration with an oil company and a utility company are currently planning the UK's first offshore wind development, which will consist of two 2.0-MW turbines. The turbines will be situated 1 km off the Northumberland port of Blyth, which is 15 km north of Newcastle-upon-Tyne.

21.8.3 Offshore siting

In addition to the planned turbine instalments at Blyth, five wind monitoring masts have been deployed around the coasts of England and Wales. Exact locations have not been publicized. Further investment in site selection, resource assessment and environmental monitoring is not anticipated until the Government announces its support mechanism for offshore wind.

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CHAPTER 22

22.1 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 will describe 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) and its role in leading efforts to develop new wind energy technology that will be economically competitive with other electricity sources, without the need for subsidies. Working with industry, electric utilities, state and local governments, and other stakeholder groups, DOE is organizing a new initiative called "Wind Powering America" that will sustain the growth in use of wind energy with the target to provide at least 5% of the nation's electricity by 2020.

22.2 NATIONAL POLICY

The Wind Energy Program, conducted by DOE, continues its leadership role, focusing on research and development (R&D) 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 new Wind Powering America initiative under the DOE Wind Program is providing an important role in helping to move the technology to the market place. The initiative is planned to help support a dramatic increase in the deployment of commercial wind systems by partnering with and providing information on wind technology and business to stakeholder groups in the supplier, user, financial, regulator, and environmental communities. DOE also administers the Renewable Energy Production Incentive that provides financial incentives of \$0.017/kWh for energy production by municipally owned wind power plants. In addition to DOE's

programs, other Federal and state government agencies are expanding renewable energy application demonstration projects and incentive programs, some of which include wind systems. These agencies include the United States Department of Defense, Environmental Protection Agency, the Agency for International Development, and a growing number of state and local governments. The federally supported Wind Energy R&D Program is operated by DOE and is discussed in detail below.

22.2.1 Strategy

The general strategy of the DOE Wind Energy Program is to work in partnerships with industry and electric utilities to develop cost effective and reliable wind energy technology and establish understanding and use of wind turbine technology in a multi-regional application of wind systems. Specific objectives of the DOE Wind Energy Program are to: continue research on basic sciences needed to improve future wind energy technology, develop improved wind energy systems performance and reliability, participate in development of international consensus standards and U.S.-based wind equipment certification, and verify the performance of new technology in actual field operation.

The approach used in the DOE Wind Energy Program is to emphasize 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. National Laboratories operated for DOE conduct research and provide technical management and direction 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 its performance is verified in cooperative projects that are cost-shared by the users.

22.2.2 National targets

Under the Wind Powering America initiative, targets for wind energy development in the United States have been established between DOE and industry. These targets may be revised periodically depending on DOE program funding levels, changing policies on tax and other financial incentives for renewable energy development, cost of fuels for other power generating options, electric industry restructuring, and many other factors. Based on current projections for continuing progress on technology development programs, combined with financial incentives, and the Wind Powering America initiative, the following targets for wind power should be achieved:

- Provide at least 5% of the nation's electricity with wind by 2020
 - 5,000 MW online by 2005,
 - 10,000 MW by 2010, and
 - 80,000 MW by 2020.
- Double the number of states with more than 20 MW installed (from eight 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).

22.3 COMMERCIAL IMPLEMENTATION OF WIND POWER

One of the fastest growing markets for large-scale wind power plants is in the United States. There are several reasons for the renewed growth in wind energy deployment in the United States. First, new and better turbines are now available and their performance has been proven in

operation. Also, prices for turbines and the resulting cost of energy are decreasing, making wind energy more competitive. Economics and available financial incentives are discussed later in this report.

22.3.1 Installed capacity

During 1999, the installed capacity in the United States increased to about 2,455 MW, up from 1,890 MW at the end of 1998. The largest construction surge occurred during the period from July 1998 through June 1999 (when the tax credits for new wind plants were scheduled to expire). During that twelve-month period, the U.S. wind industry added a record 1,014 MW of new installations that included 841 MW of new generating capacity as well as 173 MW of re-powering projects, where new turbines replaced older, less efficient machines, generally in California. New installations were mainly in the Midwestern section of the country. Most of the new turbines were in the 600 to 750 kW size range.

In September 1999, the world's largest wind power generating facility was dedicated near Storm Lake, Iowa (See Figure 22.1). Owned and operated by Enron Wind Corporation, the 193-MW facility includes 257 of the 750-kW turbines jointly developed and tested by Enron Wind, with technical support from DOE.

American companies manufacturing small wind turbines with less than 100 kW peak capacity are deploying machines in the rapidly expanding domestic and international markets. The United States is considered a world leader in sales volume for this market segment. Four active U.S. manufacturers are estimated to supply 30% of the new small turbine capacity added during 1998 worldwide and this market share was expected to be similar in 1999. Preliminary estimates indicate that the United States has 15 MW of small wind turbines installed in the 50 states. The last two years have seen a growth rate approaching 30% per year. Both



Figure 22.1 This 193-MW wind power plant at Storm Lake, Iowa uses Zond Energy Systems 750-kW turbines

off-grid and isolated diesel-based power generation applications are expected to grow even more rapidly.

22.3.2 Rates and cost trends

Wind can currently compete economically in selected markets in the United States. At current costs, large wind power plants can produce energy at about \$0.04/kWh with favorable financing. This cost of wind energy is competitive where new generating capacity is needed in high wind regions where fossil fuel cost is high, or where there are other incentives available to encourage the use of clean energy. With utility industry restructuring, discussed later in this report, wind must increasingly compete against power pool spot prices, as low as \$0.01 to \$0.025/kWh for non-firm power. Therefore cost reductions in wind power systems, meeting the targets discussed in Section 22.6 on Economics, are considered both necessary and technically feasible for wind energy to compete without subsidies in the vast windy regions of the United States.

22.3.3 Contribution to national electricity demand

Energy production from all wind systems in the United States during 1999 is estimated to have been 5.9 terrawatt-hours, assuming an average capacity factor of 27%. Currently, wind energy is only 0.2 % of the national electricity supply, but it is of growing importance in local areas with good wind resources and incentives for development.

22.4 MARKET SUPPORT AND STIMULATION

The price for wind energy is continuing to decline so the need for market support and stimulation is limited. In addition, utility restructuring is progressing and states are resolving power purchase, transmission access, and other related issues. Uncertainties relating to utility restructuring had delayed wind project development in some regions in the past. Third, and most important, financial incentives are being implemented at the national and state levels that are considered a primary driver of wind power growth in the United States along with growing public support and green power pricing.

22.4.1 National level market incentives

At the national level, the wind energy Production Tax Credit (PTC) has been extended for 2.5 years and other additional financial incentives are under consideration. The PTC, started in 1993, was scheduled to expire in June of 1999, but has now been extended through December 2001. Currently the tax credit is \$0.017/kWh (all \$ are USD), adjusted annually for inflation. For municipal utilities that do not pay taxes, there is a payment of \$0.017/kWh from DOE (subject to funds availability) under the Renewable Energy Production Incentive (REPI). Payments totaling \$124,000 were made to four municipal wind plants under REPI during 1998 and are expected to be about the same for energy produced

during 1999. The payment period for REPI or for the tax credits end ten years after the plant begins operation.

DOE is also working to expand the use of wind power in facilities owned by the United States government. In June 1999, President William Clinton issued an Executive Order on "Greening the Government" that included a goal to reduce greenhouse gas emissions attributed to Federal facility energy use by 30% by 2010. One of the provisions in that Order directed each government agency to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects and by purchasing electricity from renewable energy sources. Responding to the Order, the U.S. Army is considering plans and options to develop wind resources on bases in the United States, and perhaps overseas. There are many other vast areas of land owned by the government that have excellent wind resources, which potentially could be used for wind power plant development.

22.4.2 State level market incentives

There are a variety of incentives that are implemented independently at the state level. These incentives include: price premiums (up to \$0.02/kWh) for "green energy" such as wind, waivers or reductions on property taxes for wind energy facilities, reductions or elimination of sales taxes for wind equipment, net billing for electricity bought and sold, low interest loans, accelerated depreciation of wind equipment for tax purposes, and mandatory additions of wind power or other renewables to utility generation portfolios.

Some states are setting capacity or "green energy" production goals. Texas, for example, has established a goal to add 2,000 MW of renewable energy generating capacity within the state by 2009. Intermediate goals are provided requiring

an addition of 400 MW by 2003, another 450 MW by 2005, another 550 MW by 2007, and another 600 MW by 2009. To ensure that retail energy suppliers in Texas add their share of new renewable energy capacity, a Renewable Credits Trading Program will start January 1, 2002, and continue through 2019. Retailers in the state with insufficient new renewable capacity can buy credits from other suppliers or be subject to a penalty of \$0.05 per kWh or 200% of the average cost of credits traded during the year. Wind plants are expected to dominate the new market in Texas.

22.4.3 Future restructured markets

Future domestic commercial markets for wind power are expected to be driven by a combination of several factors:

(1) declining costs of wind energy, (2) new wind energy production tax credits that are discussed in Section 22.5 below, (3) expected increases in fossil fuel costs and the additional cost of reducing atmospheric pollution, (4) renewable energy portfolio standards with federal or state utility regulators mandating a portion of new generation be from renewable sources, (5) green power pricing where energy sales companies, in restructured utility markets, charge higher prices for electricity produced from "green" renewable energy sources, and (6) public pressures to reduce atmospheric emissions from power plants.

Many states pursuing utility restructuring have seen the importance of the last three factors and begun implementing some form of renewable energy incentive. Utility restructuring is underway in most states. See Figure 22.2.

In another approach to encourage wind energy market development, DOE works with and in some cases supports, a variety of organizations and stakeholder groups. A key organization is the National Wind Coordinating Committee (NWCC). The NWCC is a collaborative endeavor that

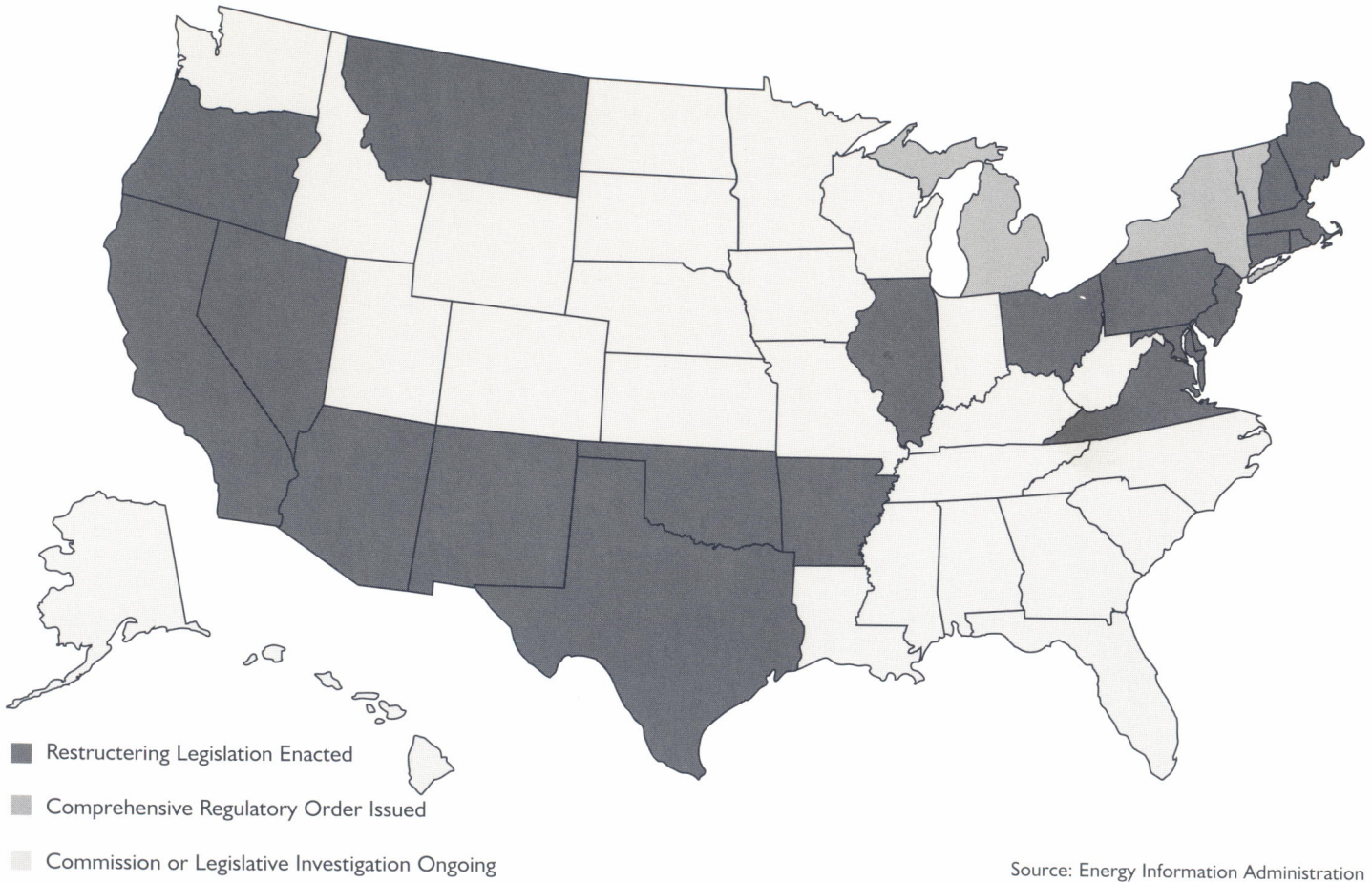


Figure 22.2 States that have issued deregulation orders and/or restructuring legislation as of October 1, 1999

includes representatives from utilities, state legislatures and utility commissions, consumer advocacy offices, wind manufacturers and developers, environmental groups, and state and federal agencies. This Committee provides a forum and voice for stakeholders who envision a self-sustaining commercial market in the United States for wind power that is environmentally, economically, and politically sustainable. Another group supported partially by DOE is the Utility Wind Interest Group (UWIG), an independent nonprofit corporation formed by a group of 24 member utilities, and other organizations that promote utilities' interests in wind energy at the national level. This group serves as a source of information on government/utility cost-shared programs, and provides wind energy planning and implementation support to other utilities and to the public. These organizations are important partners in the Wind Powering America Initiative.

22.5 DEPLOYMENT CONSTRAINTS

Cost of wind energy has been the primary constraint on commercial development, but costs are declining and alternative sources for electricity generation are becoming more costly, especially when air pollution reduction costs are included. Environmental concerns can also be an issue in planning and development of wind plants. In some cases, areas populated with protected species of birds may have to 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 aesthetics are not considered to be significant constraints.

Until recently, turbine certification requirements in some international markets were constraints for U.S. turbine manufacturers. Wind turbines developed under the DOE program meet international

standards for design and performance, but until recently there was no recognized third party, U.S. based, turbine certification agent. American manufacturers relied solely on European-based agents to certify that their machines met the internationally accepted standards. Recently however, Underwriters Laboratories (UL), which has a long history in the field of electrical equipment testing and rating, has developed a wind turbine certification program in partnership with the National Renewable Energy Laboratory (NREL). UL ratings are recognized worldwide in hundreds of other product areas, including fire and security equipment, insulation, fuses, transformers, relief valves and other safety systems, as well as many other types of industrial and commercial products. UL is using its background in electrical equipment certification and manufacturing quality reviews (ISO 9000), with NREL's turbine testing expertise, to implement a certification program that will meet International Electrotechnical Commission standards (IEC 61400 Series).

Currently, American utilities, wind plant developers and other customers in the United States do not require certification of entire wind systems, although turbine certification is needed to enter some of the international markets. In the domestic markets, customers tend to rely more on manufacturers' business track records, warranties and independent assessments to reduce their risk. There are no plans to significantly change that approach.

22.6 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/kWh (in 1980 dollars) to less than \$0.04/kWh today. Current costs are based on large wind plants (100 MW or larger) operating at good wind sites with annual

average 6.7 m/s, measured 10 m above ground. Project financing costs are assumed to be 7.5% annual return on debt and 13% or less return on equity, which are considered to be reasonable rates for an established power generating company.

Future wind energy costs are projected to be among the lowest of five renewable energy technologies studied recently by DOE and the Electric Power Research Institute (EPRI). By 2010, wind was found to have by far the lowest Cost of Energy (COE) at \$0.025 to \$0.031/kWh, compared to other intermittent technologies (solar thermal and photovoltaics) with similar project financing assumptions. Wind was found to be directly competitive with geothermal energy, the lowest cost "dispatchable technology." 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* that is available on the DOE Office of Power Technologies Web site at <http://www.eren.DOE.gov>.

22.7 INDUSTRY

Six American 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, including mail

and email addresses, phone numbers, and other data are available on the American Wind Energy Association Web site <http://www.awea.org>.

Some of the larger European wind turbine manufacturers are establishing assembly and component manufacturing plants in the Midwest of the United States, including large turbines from NEG Micon and rotor blades built by LM Glasfiber, both Danish firms. Projects are also being developed in Europe with turbines manufactured under licenses by American Companies. For example, Enron Wind Corporation, a subsidiary of Enron Corporation, announced a 75-MW project will be built with turbines manufactured by a new subsidiary, Tacke Energia Eolica, S.L., in Spain.

22.8 DOE-SPONSORED PROGRAMS

Key elements in the DOE Wind Energy Program and current fiscal year funding are shown in Figure 22.3. The program funding was \$34.1 million in Fiscal Year 1999.

22.8.1 Priorities

The emphasis of the DOE Wind Energy Program has been research and technology development. The DOE wind R&D program is structured with three elements:

1. *Applied Research*—to develop the basic wind energy sciences and technology;

KEY ACTIVITIES	APPLIED RESEARCH	TURBINE RESEARCH	COOPERATIVE RESEARCH & TESTING
Elements	<ul style="list-style-type: none"> • Aerodynamics • Structural dynamics • Materials • Hybrid systems 	<ul style="list-style-type: none"> • Industry partnerships for advanced turbines 6 kW to 1.8 MW • Field verification 	<ul style="list-style-type: none"> • National Wind Technology Center • Industry support • Certification testing and support • Wind farm monitoring
Fiscal Year 2000 Budget (\$ millions)	10.7	15.8	7.6

Figure 22.3 U.S. DOE Wind Energy Program and Funding

2. *Turbine Research*—to develop and test advanced wind turbines in various sizes from less than 10 kW to more than one MW; and
3. *Cooperative Research and Testing*—to support industry in resolving near term technical issues and in concept evaluation, field testing, initial deployment, and certification of new wind energy systems and technology.

R&D efforts are focused at the National Wind Technology Center (NWTC), at the National Renewable Energy Laboratory, located near 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 NWTC conduct in-house and contracted research, development, and testing for DOE and U.S. industry.

22.8.2 New programs and laboratory facilities

Wind Powering America—is a new initiative supported by DOE, working with industry to accelerate the use of wind energy in the United States. The Initiative is being formed as a partnership between a variety of government and private sector stakeholder organizations with a common interest in employing wind power for power generation; regional economic development, especially in rural farm communities; environmental improvement primarily by reduced air pollution; and increased energy security by diversifying energy sources.

Dynamometer—In mid-1999, installation of a major wind turbine drive train dynamometer was completed at the NWTC. This unique \$3 million research facility allows wind turbine gearboxes and generators to be operationally tested at full power, up to 2.0 MW, under controlled laboratory conditions. Figure 22.4 shows

two engineers standing next to a 750-kW wind turbine gearbox/generator system being tested on the new dynamometer. The electric drive motor, shown in the upper left of Figure 22.4, simulates the output from the wind turbine rotor. Additional information on the facilities at the NWTC is included in the 1998 IEA Annual Report and at <http://www.nrel.gov>.

Applied Research—The Applied Research activity addresses fundamental 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 the fundamental behavior of the wind, atmospheric physics, interaction between the wind and wind turbines, structural dynamics, rotor aerodynamics, and electric power system integration issues.

One element of the Applied Research Activity is a joint research task underway between NWTC and Sandia, is called the Long-term Inflow and Structural Test Program (LIST). Comprehensive measurements on a full-scale turbine rotor are planned, 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 flat terrain in Texas and the second at the NWTC. Part of the

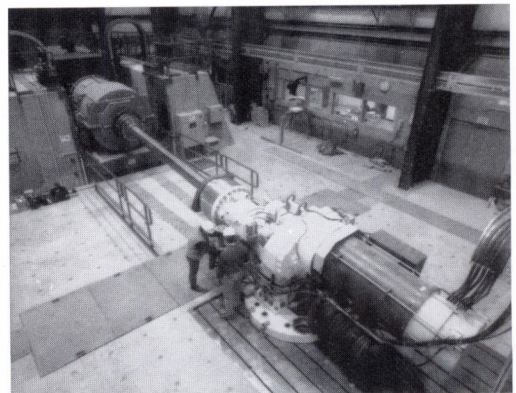


Figure 22.4 New 2.0-MW wind turbine dynamometer located at the National Wind Technology Center

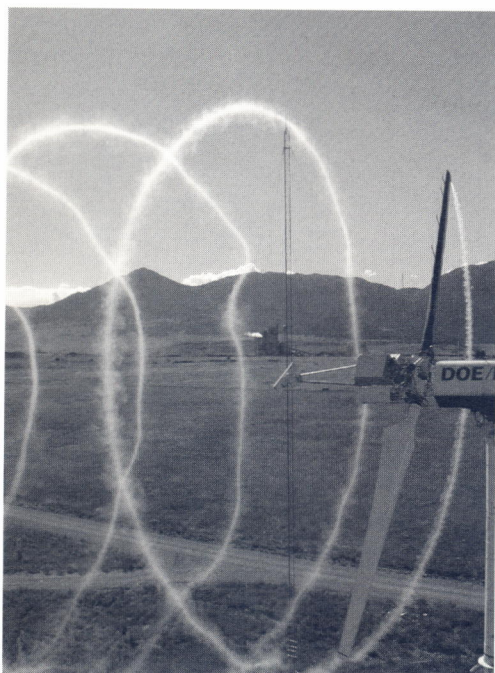


Figure 22.5 Aerodynamics research wind flow visualization study test at the National Wind Technology Center

LIST testing includes wind flow visualization studies shown in Figure 22.5.

A related element of aerodynamics research is being conducted in the wind tunnels at the National Aeronautics and Space Administration (NASA) Ames Laboratory. A 10 m diameter 19-kW experimental wind turbine will be tested in different configurations in the 80 x 120 foot section

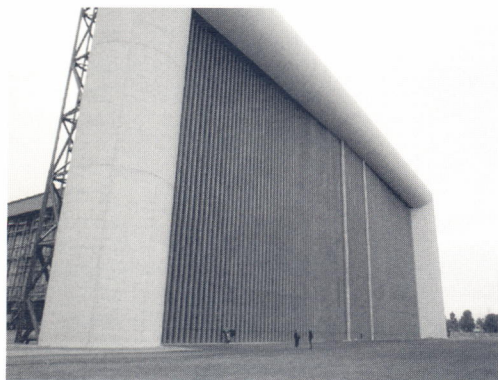


Figure 22.6 Inlet for the NASA Ames wind tunnel being used for testing wind turbine rotor and blade configurations

of the open throat wind tunnel beginning early in 2000. The NASA tunnel, in Figure 22.6, is normally used for testing full-scale models of sub-sonic aircraft.

A new effort beginning this year is called Wind PACT, meaning Wind Partnerships for Advanced Component Technologies. Wind PACT is designed to support development of new high-risk technologies, such as, flexible rotors, new drive trains, on-site blade manufacturing, and self erecting towers for wind turbines. Results of this research will be publicly available.

Turbine Research—The role of the 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. Turbines currently under development are shown in Figure 22.7, along with dates of expected deployment.

Specific goals are set by DOE for the turbine development projects under the Turbine Research Program. These program goals are based on the required cost of energy for new turbines systems being developed to be economically competitive in broad markets, which are key to achieving the national targets described above. Using cost of energy as the primary design goal has the benefit of integrating the effects of all aspects of a new turbine system, accounting for improved high performance technology and for lower projected turbine costs resulting from simpler, light weight designs. The goal for utility-scale, grid-connected wind power systems is to produce electricity at a cost of

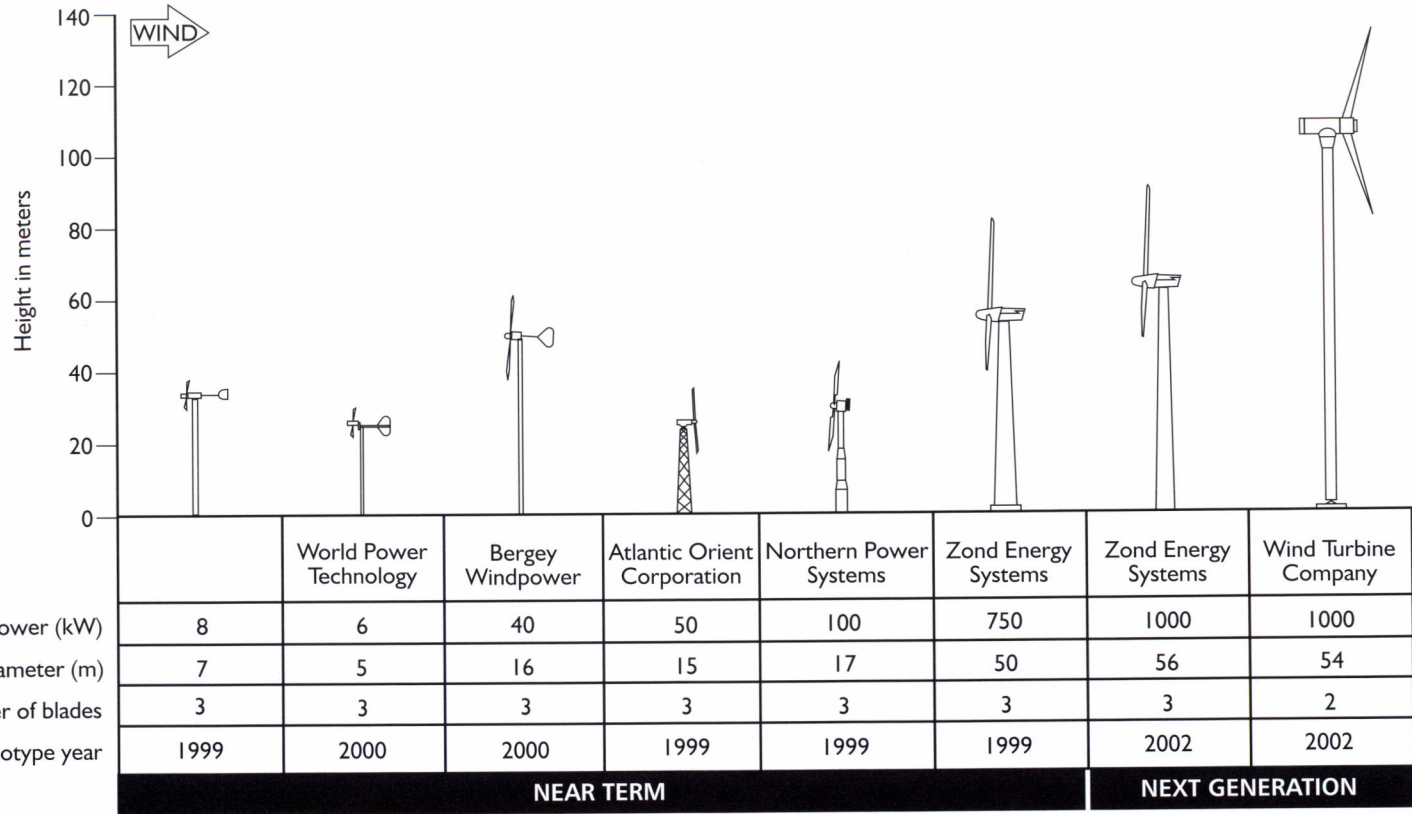


Figure 22.7 Wind turbines under development by industry with DOE/NREL support

\$0.025/kWh by year 2002, 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 target includes all turbines, land, and the balance of station costs for a 50-MW wind power plant project located near power transmission lines. See Section 22.4, Economics, below for more details. 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 to 40 kW. Specific machine goals depend on the type of turbine and the planned operating environment and application requirements.

Two large-scale (at least 1 MW), next generation turbines are being developed for bulk electric power markets without the need for subsidies. Subcontracts with industry to develop and test next-generation turbines include, Zond Energy Systems, Incorporated in Tehachapi, California (a subsidiary of Enron Wind Corp.), and The Wind Turbine Company in Bellevue, Washington. Each company will cost-share 30% of their \$20 million contract. Individually hinged rotor blades are one concept being considered for The Wind Turbine Company machine and this configuration will be tested on a sub-scale proof-of-concept turbine installed in 2000. See Figure 22.8.

Field tests of advanced utility-scale turbines have been underway for several years under the Turbine Verification Program. This Program is jointly funded by DOE and Electric Power Research Institute to document actual turbine performance and other operational data at seven wind power plant sites. More information is available at <http://www.epri.com>.

Six companies are developing near-term turbines for both grid-connected and off-grid power generation. The companies selected to develop the new machines are: World Power Technologies, Inc. from Duluth, Minnesota, for a 6-kW turbine;

WindLite Company (that was recently acquired by the Atlantic Orient Corporation), for an 8-kW turbine; Bergey Windpower from Norman, Oklahoma, for a 40-kW turbine; Atlantic Orient from Norwich, Vermont, for improvements to their 50-kW machine; and Zond for improvements to their 750-kW commercial turbine. The 100-kW turbine is being developed by Northern Power Systems located in Moretown, Vermont, under a cooperative program between the National Aeronautics and Space Administration (NASA), the National Science Foundation, and DOE. This machine is being designed for the frigid environments of northern Alaska and Antarctica.

Cooperative Research and Testing—The 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 for turbine certification testing. Grants were recently awarded to industry and state energy offices for small turbine field performance verification in a variety of applications in projects in ten states.

Standards development is another element of the Cooperative Research and Testing Activity. Under this element 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.



Figure 22.8 This 250-kW proof-of-concept turbine has hinged rotor blades

The certification test results from NWTC can be used by the U.S. certification agent, UL, or by others, as the basis for certifying the designs of U.S. industries' machines.

Author: Peter Goldman, Department of Energy, United States

CHAPTER 23

The Non-Nuclear Energy Programme of the Fourth Framework Programme (FP4) ended in December 1998. It has been followed by the "Energy, Environment and Sustainable Development" (EESD) Programme of the Fifth Framework Programme. EESD represents the new means by which the European Commission supports scientists, developers, manufacturers, and users in the research, development, and demonstration of renewable energy technologies. The ultimate goal is safe, reliable, efficient, and environmentally friendly alternative energy sources.

The Fifth Framework Programme (FP5) for research, technological development, and demonstration (RTD&D) sets strategic guidelines for the European Union in the areas of science and technology for the period 1999-2003. It was adopted on December 12, 1998 with an overall budget of Euro 14.96 billion, while the specific programs were adopted on January 25, 1999. Details about FP5, the specific programs, implementation procedures, specific criteria (participation rules, procedure for the selection of projects etc.), financial resources, and, most importantly, the research activities to be supported and rules for the participation of third countries can be found on the CORDIS site which is accessible via the World Wide Web.

As part of the renewable energies, Wind Energy RTD&D is included among the activities for Promoting Competitive and Sustainable Growth (first activity), Theme IV-Energy, environment and sustainable development, under two specific key actions, according to the new structure of the program: "Cleaner energy systems, including renewable energies" (key action 5) and "Economic and efficient energy for a competitive Europe" (key action 6). Both key actions deal with research and

demonstration activities (i.e. the separation between the R&D part and the demonstration part, such as JOULE and THERMIE in FP4, no longer exists in FP5).

The first call for proposal of the new program was launched in March 1999.

With the general objective of the program being the promotion of sustainable development enabling competitiveness and employment, with a close and strong relation between environmental and energy issues, this first call was focused on research and demonstration projects which could provide innovative solutions to the well known technical and non-technical (mainly environmental) barriers that the sector is facing.

The basic challenge for wind energy being nowadays the reduction of both installation and operation costs, which will make wind energy production more competitive, the majority of projects were supported in the framework of key action 6. These have been mainly projects that aim towards such a reduction through new techniques and innovative wind turbine components.

As a matter of fact, EU funded research and the awarding of projects in FP5 has become more selective and more demanding in terms of results and achievements. Most important, in the new program, the benefits of EU supported RTD&D should be visible to both the industry involved and the participating researchers and should be to the service of the European citizens. This situation has been clearly shown by the total number of funded projects which amount to 10 (4 for research and 6 for demonstration).

The following diagrams represent the situation resulting from the first call of FP5.

The number of wind energy and other renewable energy sources (RES) projects

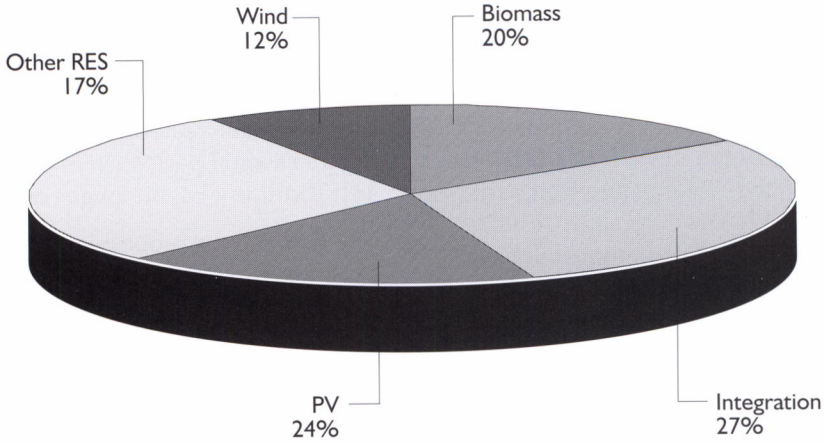


Figure 23.1 EESD Programme, first call for proposals 1999: number of supported projects per sector of RES (R and DEMO)

supported by the EESD programme as a result of the first call, including research (R) and demonstration (DEMO), is given in Figure 23.1.

The distribution of funds as a result of the first call for proposals is given by Figure 23.2, for research and demonstration activities.

For research projects, the situation is illustrated in Figure 23.3 and 23.4, which show the distribution of the number of projects and support for the first call of FP5 in 1999.

Figure 23.5, on the other hand, gives the situation in terms of funds for wind

energy only, under the first call of FP5. The diagram corresponds to research and demonstration projects, which are managed respectively by DG RTD and DG TREN.

The four supported wind energy research projects deal essentially with the development of innovative wind turbine components and new computation methods and software tools for various applications.

For demonstration activities, offshore wind energy has been well represented in the projects retained for support in 1999. Among the six demonstration projects supported, there is an offshore installation of 42 MW, (21 X 2 MW wind turbines) in

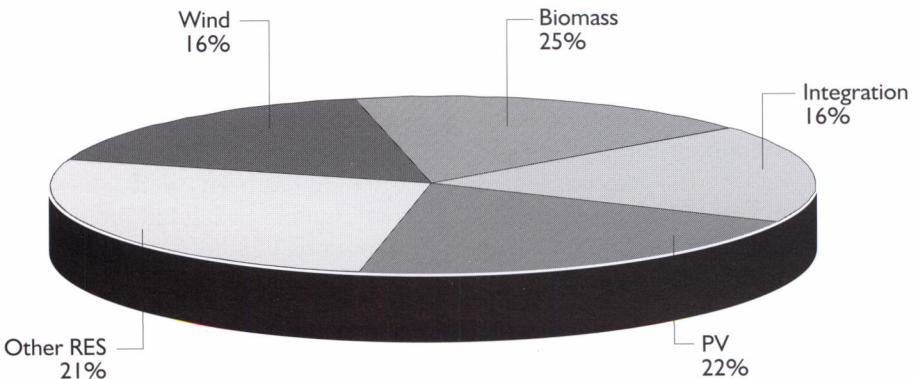


Figure 23.2 EESD Programme, first call for proposals 1999: distribution of funds per sector of RES (R and DEMO)

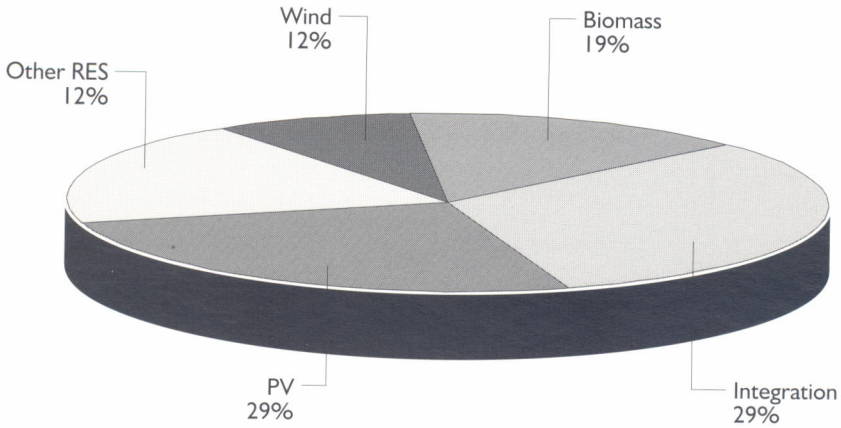


Figure 23.3 EESD Programme, first call for proposals 1999: distribution of research projects supported by FP5 in 1999

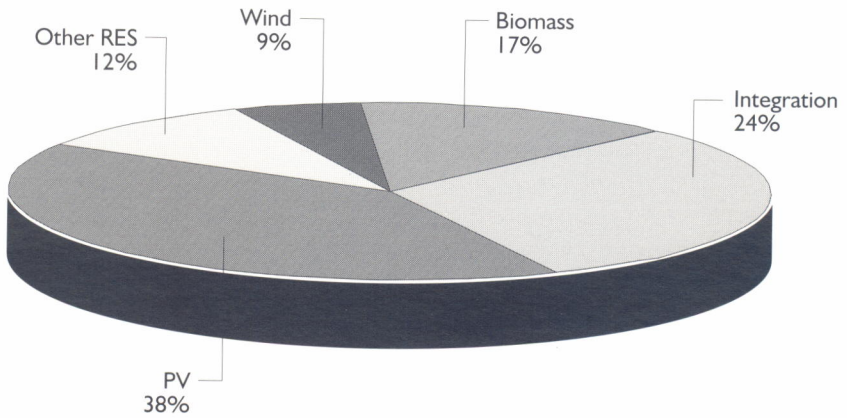


Figure 23.4 EESD Programme, first call for proposals: distribution of support given by FP5 in 1999 to research projects

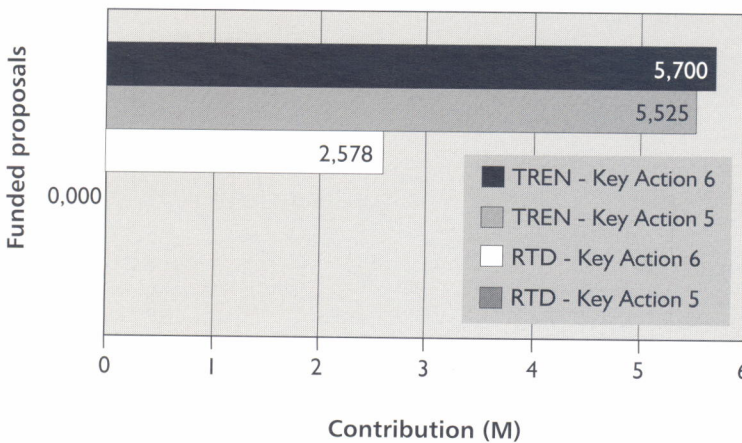


Figure 23.5 EESD Programme, first call for proposals 1999: support given to wind energy projects (key action 5 and key action 6 of the work programme)

Sweden, a 30-MW installation (12 X2.5 MW wind turbines) for North Wales, as well as the demonstration of a large, second generation offshore wind turbine of 2.5 MW. A concerted action on offshore wind energy with the participation of 17 European organizations will also be supported. Two other demonstration projects have been supported, one dealing with megawatt scale wind turbines operating in arctic conditions and another to demonstrate the prototype of a medium-sized (350 kW) suitable for installations in sites with difficult access.

Of course, the quantified targets set out in the work program of FP5 may be ambitious and not easy to be realized. However, the EU-15 wind energy installed capacity nowadays exceeds 6.6 GW and it is expected that by 2000 the goal of 8 GW of installed capacity will be reached. If the target of 40 GW of installed power is to be achieved by 2010, the present annual rate of installation should increase from 1 GW/year today to at least 2 GW/year by the end of 2002. Therefore, the new structure of the work program indicates the scale of socio-economic impact to which the proposals should aspire.

Authors: S. Fantechi, Directorate-General Research (DG RTD) and A. Kotronaros (Directorate-General Transport and Energy) (DG TREN), European Commission.



Attendees of the 43rd ExCo meeting April 20-21, 1999 hosted by CIEMAT, in Madrid.

APPENDIX B

APPENDIX B

IEA R&D EXECUTIVE COMMITTEE 1999

M = Member A = Alternate Member

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Since 1977, when the IEA R&D Wind Implementing Agreement was begun, wind energy technology has developed and matured into the most cost-effective renewable source of electricity. In 1999, more than 10,000 MW of installed wind capacity was delivering more than 20 Terawatt hours of energy to citizens worldwide. This worldwide growth in wind energy is being driven by improved technology, supportive government policies, and improved information about the advantages of wind energy.

To improve information exchange and conduct joint research projects, parties from 17 countries and the European Commission collaborate in wind energy research and development under the auspices of the International Energy Agency. This Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind) encourages and supports the technological development and global deployment of wind energy technology. This report reviews the progress of the joint projects conducted during 1999 and highlights the national wind energy activities in the member countries of IEA R&D Wind.

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