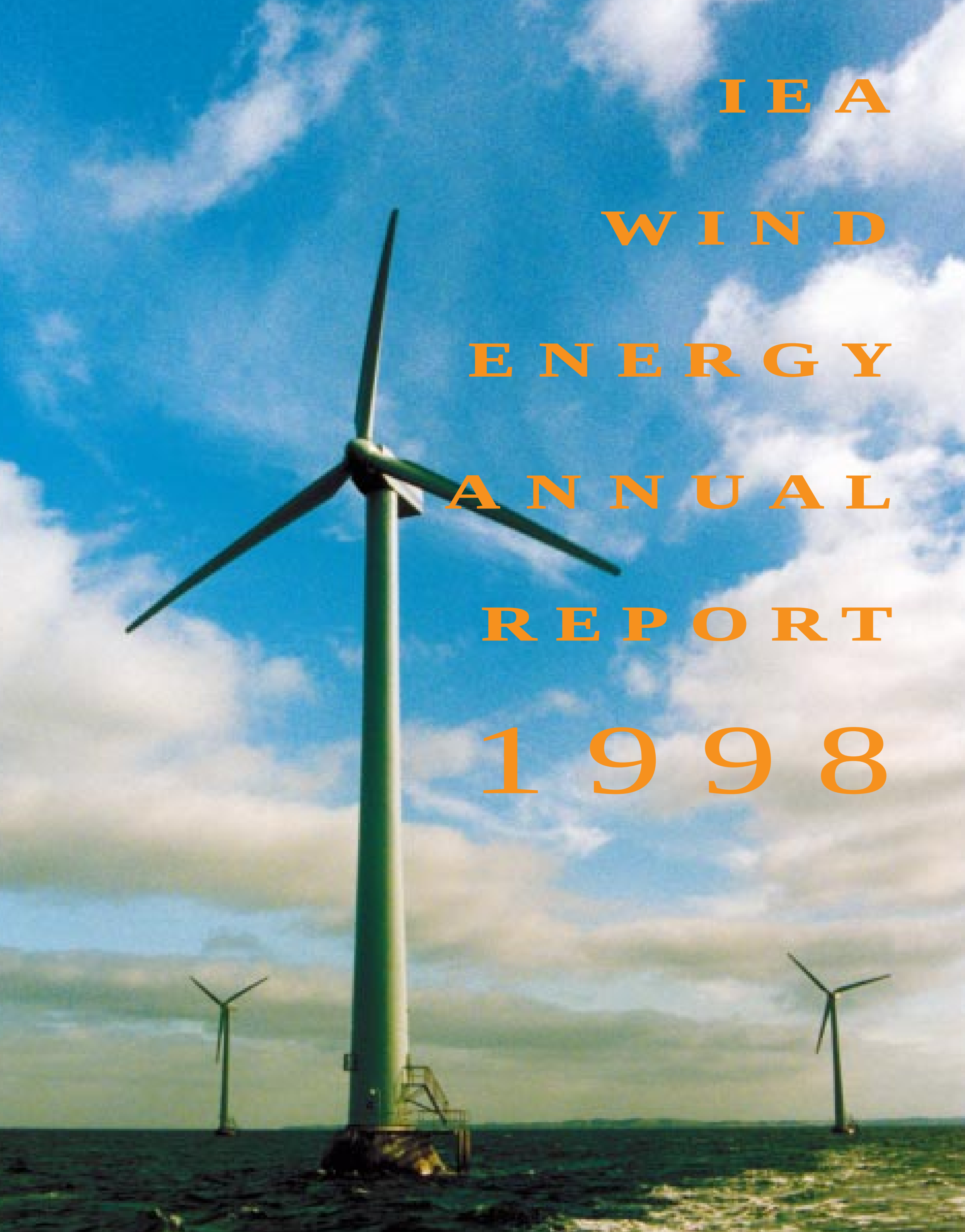
IEA WIND ENERGY ANNUAL REPORT 1998



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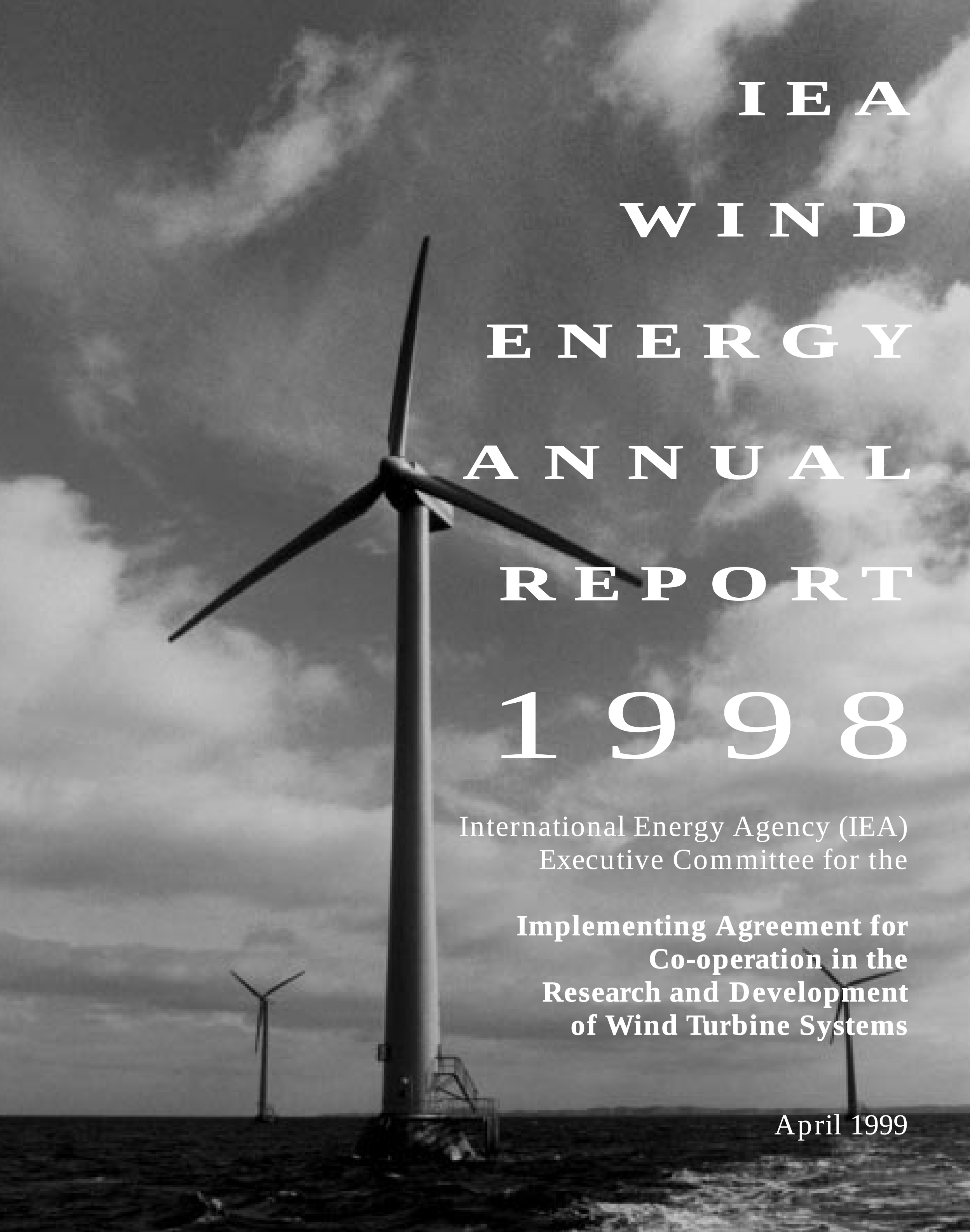

IEA WIND ENERGY ANNUAL REPORT 1998

International Energy Agency (IEA)
Executive Committee for the

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

April 1999

NREL

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
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Cover Photo

This wind farm at Turnoe Knob is located 5 km from the mainland cost of Jutland in Denmark. The ten 500-kW Vestas V39 wind turbines produce an average of 15 million kilowatt hours per year. Within the windfarm sea depths range from three to five meters. Photo courtesy of Midtkraft company.

The twenty-first IEA Wind Energy Annual Report reviews the progress during 1998 of the activities in the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems under the auspices of the International Energy Agency (IEA). The agreement and its program, which is known as IEA R&D Wind, is a collaborative venture between 19 contracting parties from 17 IEA member countries and the European Commission.

The International Energy Agency, founded in November 1974 within the framework of the Organization for Economic Co-operation and Development (OECD), implements an international energy program. It carries out a comprehensive program of cooperation among 24 of the 29 OECD member countries.

This report is published by the National Renewable Energy Laboratory (NREL) in Colorado, United States, on behalf of the IEA R&D Wind Executive Committee. It is edited by P. Weis-Taylor with contributions from Australia, Canada, Denmark, the European Commission, Finland, Germany, Greece, Italy (two contracting parties), Japan, Mexico, the Netherlands, New Zealand, Norway, Spain, Sweden, the United Kingdom, and the United States.

Jaap ´t Hooft
Chair of the
Executive Committee

Patricia Weis-Taylor
Secretary to the
Executive Committee

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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 21st year, global deployment of wind power has risen to around 9,500 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 1998 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 – 5. 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: Department of Fluid Mechanics of the Technical University of Denmark

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).

The original Task expired in 1997. Members voted to extend the Task through 1999.

Recommended Practices

In 1998, the Experts Group on point wind speed measurements finalized a draft recommended practices volume that will be ready for distribution in 1999.

Expert Meetings and Joint Actions

In 1998, the 12th symposium within the Joint Action on Aerodynamics of Wind Turbines was held in Lyngby, Denmark. IEA also supported the 31st Meeting of Experts on the State-of-the-Art on Wind Resource Estimation at RISØ National Laboratory, Denmark.

Task XV - Annual Review of Progress in the Implementation of Wind Energy by Member Countires 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 will be available in 1999.

Extension of this task is under consideration 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 1998. 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 adopted by the ExCo 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. The final text of this Annex to the Implementing Agreement is under review at IEA Headquarters.

TASK XVIII - ENHANCED FIELD ROTOR AERODYNAMICS DATABASE

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

In 1998, the ExCo approved a proposal for a new 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.

EXECUTIVE COMMITTEE ACTIVITIES

Officers

R. Rangi (Canada) and F. Avia (Spain) served as Chair and Vice-Chair during 1998. At the fall meeting, J. ´t Hooft (the Netherlands) was elected Chair and F. Avia (Spain) was re-elected to serve as Vice-Chair for 1999.

Participants

In 1998, total membership continued to be 19 organizations participating. See Appendix B for an updated list of Members, Alternate Members, and Operating Agents. During the year, the Executive Committee invited Brazil, China, Ireland, and Portugal to attend ExCo meetings as observers.

Meetings

The Executive Committee normally 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 41st ExCo meeting, scheduled to be held in May in Copenhagen, Denmark was canceled due to a transportation strike in the host country.

The 42nd ExCo meeting was held on September 8–10, 1998 in Copenhagen, Denmark. There were 29 participants representing 14 of the 19 contracting parties. In addition, a representative from IEA Headquarters attended the meeting.

Operating Agents reported on progress since the last meeting. ExCo members approved an End of Term Report (summarizing IEA R&D Wind activities from 1993 to 1998) and the New Strategic Plan for the Implementing Agreement. Then the members voted unanimously to extend the Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems for another five years (through September 30, 2003).

The Secretariat budget for 1999 was approved as a draft. The audit report for 1997 was accepted.

The Newsletter Committee was expanded and authorized to continue its assessment of future directions for this ExCo publication and as well as publication of information in an Internet site.

The Annual Report for 1997 was distributed to members.

On September 10, 1998 the Committee visited the Vestas manufacturing facilities and the MW-scale wind turbines at the Tjæborg / Esbjerg test site.

IEA Wind Energy Newsletter

Two final issues of the current Newsletter (#12 and #13) were published, reviewing the progress of the joint Tasks and the wind energy activities in the member countries. The Executive Committee acts as the editorial board for the Newsletter with a technical editor overseeing production. A committee is reviewing the content and purpose of the newsletter to present proposals about format, content, and production of future issues to the full ExCo.

CHAPTER 1

The Implementing Agreement

The IEA co-operation in wind energy began in 1977 when The Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems was written. Referred to as IEA R&D Wind, 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 1998 are listed in Table 1.1.

The 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—1998

Australia	Energy Research and Development Corporation
Austria	The Republic of Austria
Canada	Natural Resources Canada
Denmark	Risø National Laboratory
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	XVIII Enhanced field rotor aerodynamics database
Australia	x			
Canada	x		x	
Denmark	OA	x	x	x
European Commission	x	x		
Finland	x			
Germany	x	x		
Greece	x	x	x	
Italy	x	x	x	
Japan		x		x
Mexico	x			
Netherlands	x	x		OA
New Zealand	x	x		
Norway	x	x		
Spain	x			
Sweden	x	x		
United Kingdom	x	OA		
United States	x	x	OA	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 their respective country R&D programs, to discuss work progress on various Tasks, and to plan future activities. Decisions are reached by majority vote.

The R&D Tasks performed under IEA R&D Wind are approved by the ExCo as Annexes to the original Implementing Agreement. (They are sometimes referred to as Annexes.) Each Task is managed by an Operating Agent, usually one of the contracting parties in the IEA R&D Wind agreement. The level of effort varies for each Task. Some Tasks involve only information exchange and require each country to contribute less than 0.1 person-year of work. Other Tasks involve test programs requiring several people working over two or more years. 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.

All Tasks undertaken to date are listed in Table 1.2.

Current Tasks and participating countries 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: Department of Fluid Mechanics, Technical University of Denmark Continuing through 1996 and 1997.
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 To be completed in 1998.
Task XVI	Wind turbine round robin test program Operating Agent: the National Renewable Energy Laboratory (NREL), United States To be completed in 1998.
Task XVII	Database on wind characteristics Operating Agent: RISØ National Laboratory, Denmark. Final text for this Annex is under review at IEA Headquarters.
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.

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 hae been part of the Agreement since 1978, when they were carried out before the formal annex was adopted in 1987. Over the eleven years since Task XI (also known as Annex XI) was initiated, 31 volumes of proceedings from expert meetings and 10 documents in the series of Recommended Practices have been published. Five of the Recommended Practices have come out in revised editions. The Annex was extended in 1997 for the years 1998 and 1999.

The Base Technology Information Exchange 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 lightning protection of wind turbine generator systems drafted a document published in 1997. Also published in 1997 were the documents drafted by the Experts Group on noise immission measurements. In 1998, a draft has been finalized by an Experts Group on point wind speed measurements and the document will be ready for distribution 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, fatigue of wind turbine blades, wind characteristics, and deployment of offshore wind systems.* In each of these topic areas symposia and conferences have been held.

Figure 2.1 With coordination by IEA R&D Wind, experts assemble to discuss the technical issues surrounding wind turbines capable of generating several megawatts (MW) of electricity.

In 1998, the 12th Symposium within the Joint Action on *aerodynamics of wind turbines* was held in Lyngby, Denmark. There were 18 participants from six countries. Thirteen papers were presented.

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. In 1998, the 31st Meeting of Experts on State of the Art on Wind Resource Estimation was held at RISØ National Laboratory, Denmark. There were 19 participants from 11 countries and 13 presentations were made. Proceedings from topical expert meetings are called Meetings of Experts. They can be obtained by contacting the Operating Agent.

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 standardization body which generates international standards in cooperation with ISO. The standards which are

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	POINT WIND SPEED MEASUREMENTS	in preparation		

emerging often take the IEA Recommended Practices as precursors.

Documents produced under Task XI, published by the Operating Agent, are available from the Operating Agent (Department of Energy Technology, Attn. B. Maribo Pedersen, Building 404, Technical University of Denmark, 2800 Lyngby, Denmark) and from representatives of countries participating in Task XI (Australia, Canada, Denmark, European Commission, Finland, Germany, Greece, Italy, Mexico, Netherlands, New Zealand, Norway, Spain, Sweden, United Kingdom, and United States).

Table 2.2 List of Topical Expert Meetings Held Since 1978

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

CHAPTER 3

Task XIV – Field Rotor Aerodynamics/Task XVIII Enhanced Field Rotor Aerodynamics Database (EFRAD)

Task XIV (also known as Annex XIV) was established to coordinate full-scale aerodynamic test programs on wind turbines in order to acquire the maximum experimental data at minimum cost. After more than four years of close cooperation among participating institutes, the task was completed in 1997 and a final report has been published which includes conclusions and recommendations arising from the work.

In 1998, Task XVIII was approved by the Executive Committee to maintain and extend the database developed in Task XIV and disseminate the results so that extensive use of the database can be expected for years to come. In addition, the project will work to define the problem of angle of attack and dynamic pressure.

The partners in Annex XVIII include:

- The Ministry of Energy (Denmark)
- The Netherlands Agency for Energy and Environment (NOVEM) (Netherlands)
- The Department of Energy (US)
- The Ministry of International Trade and Industry (Japan)

As a result of the original project, a well-documented database has been created with aerodynamic measurements on all participating facilities. The database is accessible on an ftp site at ECN and on CD-ROM available from the Operating Agent. For parties not participating in the original Task, the data can be obtained under the condition that feedback will be delivered on the experiences with the database. So far a total of five parties have requested the database and accepted this condition.

Under Task XIV, a total of five full-scale aerodynamic test programs were coordinated by:

Delft University of Technology, DUT Netherlands

Imperial College, IC and Rutherford Appleton Laboratory, RAL, United Kingdom

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

National Renewable Energy Laboratory, NREL USA

RISO National Laboratory, Denmark.

In these full-scale test programs local aerodynamic quantities (forces, inflow velocities, inflow angles, etc) are measured at several radial positions along the blade. The local aerodynamic data these test programs supply is a major step forward in understanding the very complicated aerodynamic behavior of wind turbines. In conventional test programs only blade (or rotor) quantities are measured. Usually these quantities are integrated over the rotor blade(s) and they are not only influenced by aerodynamic effects, but also by mass effects. In this case the local aerodynamic properties of the blade can only be derived indirectly, introducing an uncertainty.

The work of Task XIV has been documented in Final Report of IEA Annex XIV: Field Rotor Aerodynamics, ECN-C-97-027, in June 1997. The report, written by J.G. Schepers et al, was published by the Netherlands Energy Research Foundations. The report contains the following series of conclusions and recommendations stemming from the work.

1. IEA Task XIV served as a platform where very specific knowledge associated with aerodynamic measurements could be exchanged. All participants agreed that this has been very instructive and has enabled the acceleration of their experimental programs.

2. A unique, well-documented database was developed in which detailed aerodynamic measurements are stored. About 125 time series of aerodynamic field measurements are available. The measurements are obtained on five very different wind turbine configurations. The diameter of these turbines ranges from 10 to 27 meters. Measurements have been supplied for very different conditions. As a result, more accurate aerodynamic models can be developed and validated.

3. In order to create the database, a joint measurement program was agreed upon. It was agreed that measurements should be supplied in which the angle of attack ranges from negative values to deep stall values. Also, measurements at yaw misalignment and at stand still have been supplied. The data file formats and the conventions have been harmonized in order to make the database easily accessible.

4. In interpreting the measurements and when comparing field data with wind tunnel experiments, it should be kept in mind that the definition of angle of attack, dynamic pressure , and aerodynamic coefficients is less straightforward than in the wind tunnel case. Several methods are applied by the IEA Task XIV participants for the determination of these quantities. Although the project results indicate that the mean angle of attack and dynamic pressure which result from the different methods yield a reasonable mutual agreement, the differences in standard deviations are considerable and more investigation on this subject is required.

5. There is a clear need to maintain the database. The objective of Task XIV was to develop the database, not to use it. Extensive use of the database in the near future and over the long term will identify “gaps” and methods to fill them. Furthermore, most of the experimental facilities that contributed to the database are still operational. Several very useful measurements are still expected and the storage of these data will definitely improve the quality of the database.

6. There is a clear need for the wind energy community to reach consensus about common conventions, definitions, notations, and reference systems for wind turbines. Within IEA Task XIV much effort had to be spent on the exact definition of wind turbine conventions, notations and reference systems. This item was essential in the present project where data from different institutes had to be harmonized. This required the participants to reprocess their data files. Several data exchange rounds were necessary before all participants supplied the measurements according to the common specifications.

CHAPTER 4

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 will remain in force for a period of three years. It may be extended by agreement of two or more participants acting in the Executive Committee. ETSU, on behalf of the United Kingdom, is the Operating Agent for this Task.

4.1 OBJECTIVE

The objective of this Task is to produce an annual review giving an 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.

4.2 MEANS

The annual review will be based on the annual national reports submitted to the Executive Committee. A summary of progress in the implementation of wind energy during 1997 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 el'Ambiente (ENEA); and ENEL, Società per Azione
Japan	The Government of Japan
Netherlands	The Netherlands Agency for Energy and the Environment (NOVEM)
New Zealand	Electricity Corporation of New Zealand (ECNZ)
Norway	The Norwegian Water Resources and Energy Administration (NVE)
Sweden	The National Board for Industrial and Technical Development (NUTEK)
United Kingdom	Department of Trade and Industry
United States	The Department of Energy

Figure 4.1 Technical and institutional issues of offshore wind turbines are being explored by some IEA R&D Wind member countries.

CHAPTER 5

Task XVI – Wind Turbine Round Robin Test Program

5.1 INTRODUCTION

International recommended practices for developing and testing wind turbines are being developed by the International Energy Agency (IEA). International norms and standards are being developed by the International Electrotechnical Commission Technical Committee 88 (IEC-TC88) and other agencies. When countries adopt these new standards, a mechanism should be in place to ensure that turbines are tested and certified to common criteria. Common criteria could enable different countries to accept foreign certification in lieu of their own.

However, countries have found that there can be discrepancies between tests conducted in different locations using different test equipment. A round robin test of anemometers demonstrated that even simple wind speed measurements can 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 can 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.

5.2 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.

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.

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 follow-on calibration of anemometers at CRES. These tests are scheduled for completion in March 1999.

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 site calibration tests in 1999.

The Standard Turbine is an AOC 15/50, a 50 kW, free-yaw turbine that is relatively easy to transport and install. Participants will test three of these turbines, one at Canada's Atlantic Wind Test Site, one at the United States' NREL, and one at several European test stations. The first two turbines have been in operation for several years. However, their turbine was damaged by a lightning strike in 1998. They now plan to begin testing in late 1999 in accordance with procedures defined for this Annex. NREL staff have completed power performance and noise tests of their turbine. They expect to complete load tests by June 1999.

The third turbine was shipped to Denmark and began operation at RISØ in early December, 1997. RISØ staff completed power performance and loads tests in June 1998. The turbine was then shipped to CRES. Original plans called for testing at ENEA but difficulties with funding have forced indefinite postponement of that installation. Instead, the turbine was shipped to CRES. CRES anticipates installation in late Spring of 1999 and test completion in autumn of 1999.

A status meeting was held at RISØ in June 1998 to discuss results to date, continue formalization of the test plan, and plan the transfer of the RISØ test turbine to CRES. Another meeting was held in February 1999 at CRES for additional discussions of status and plans. At that meeting participants agreed to conduct their tests in accordance with the schedule described above and to request a one-year extension of the Task. Activities would then extend to October 2000 to accommodate these plans.

Figure 5.1 Three of these Standard Turbines are being tested in Canada, the U.S., Denmark, and Greece.

Chapter 6

Overview

6.1 INTRODUCTION

Wind energy activities in the individual countries participating in IEA R&D Wind are reported regularly to the Executive Committee of the Implementing Agreement and published in the Annual Reports of the Committee. A need has been identified for an overview of the national reports to compare approaches to promoting the technology. This work is carried out in Task XV Annual Review of Progress in the Implementation of Wind Energy by the Member Countries of the IEA.

The activity to produce an overview started with a review of the national reports for 1994 and then reviewed reports for 1995 and 1996. This fourth annual overview draws from the national reports for 1997 and supplementary information provided by Executive Committee members. It includes information from the overviews of 1994–96, where appropriate for comparison. By its nature, an overview is a generalization and readers who wish detailed information or clarification for individual countries should refer to the specific national annual report in the *IEA Wind Energy Annual Report 1997*. National reports for 1998 were not reviewed for this overview, but can be consulted in Chapters 7-23. Where information relates to a specific country, a two-letter national identification code is included in parentheses. If information on a specific aspect of wind energy development is not reported by an individual country, that country is omitted from the analysis and a blank entry is shown in the accompanying table or figure.

To allow comparison, all costs and prices are presented in US dollars. A list of the monetary conversion factors used in this report is given in Table 6.5. The data used to produce the figures is presented in Tables 6.6 And 6.7.

6.2 GOVERNMENT POLICIES

6.2.1 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.

6.2.2 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, which are often state owned.

Some 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.

Table 6.1 The Six Main Support Activities in National Programs.

ACTIVITY	AU	CN	DK	SF	DE	GR	IT	JP	MX	NL	NZ	NO	ES	SW	UK	US
Government-funded R,D&D program	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Capital investment subsidies				●	●	●	●	●					●	●		
Premium price for generation			●		●	●	●			●			●	●	●	●
Green electricity	●	●		●						●				●	●	●
Support for industrial development	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●
Tax incentives		●						●		●						●

Table 6.1 lists the six main support activities and indicates their use by the IEA member countries.

6.2.3 Targets for Installed Capacity

About half of the national governments of the participating countries have announced formal targets for the amount of wind power capacity they wish to see installed. The years for realization of these targets are usually 2005 to 2010. Progress toward the targets is uneven across the countries. Germany and Denmark are ahead of schedule. The Spanish target (based upon a summation of regional targets) has been greatly increased. By 1997, deployment in Spain had reach a modest 421 MW compared with a national target of 8,000 MW. Denmark and the Netherlands also have additional long-term targets with significant contributions coming from offshore wind energy. The targets are shown in Figure 6.1 along with the total installed wind energy capacity achieved to date.

6.2.4 Market Stimulation Instruments

As shown in Table 6.2, the trend is away from investment subsidies and toward the payment of a premium price for energy

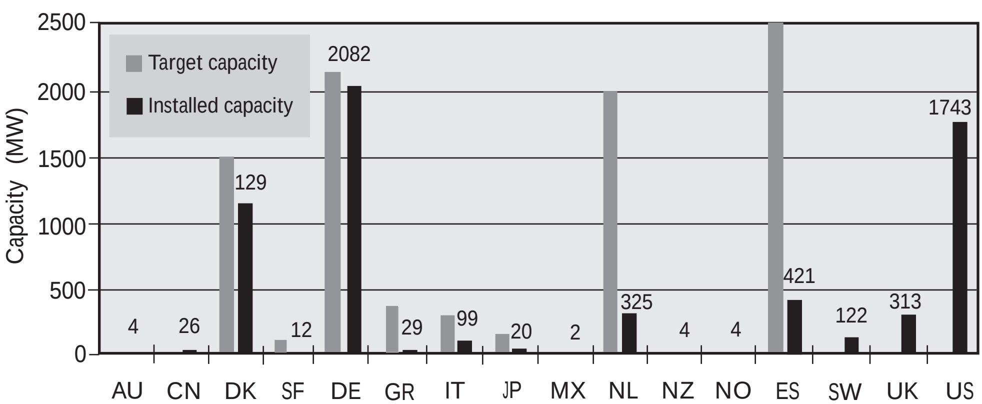


Figure 6.1 Total Installed Wind Power Capacity in Participating Countries Compared to National Targets.

Table 6.2 The Main Market Stimulation Instruments in the Participating Countries.

COUNTRY	MARKET STIMULATION INSTRUMENTS
Australia	Green Power
Canada	Capital investment write-off (30% per annum of the declining balance), Green Power purchase program.
Denmark	Production subsidies for energy produced by private generators and utilities; buy-back rates linked to utility production costs from conventional fuels; Low voltage connection paid by owner. Grid reinforcement costs paid by utilities.
Finland	Investment subsidies—up to 40% total costs depending on level of technical innovation. Production subsidy for wind and other small local energy production.
Germany	Electricity feed law fixes buy-back price at 90% of average private consumer tariff. Individual states may offer capital subsidies or soft loans.
Greece	Up to 45% capital investment subsidies and possible 45% soft loan. Premium price for energy since end 1995.
Italy	Premium price for renewable and assimilated energy sources. Some Regional Authorities provide investment subsidies (up to 70% in Sicily).
Japan	Subsidy for installation - 100% wind measurements, 50% design costs, 50% construction costs. Some finance at preferential rates and tax incentives for profitable companies. Buyback price negotiated between generator and utility.
Mexico	None at present.
Netherlands	Deduction of 40% of wind turbine investment from company profits and accelerated depreciation. Income from “Green Funds” exempt from income which results in lower interest rates on capital borrowed. Premium price for energy produced. 3c Regulatory Energy Tax paid to generators. “Green Label” program introduced for 1998.
New Zealand	None at present.
Norway	Shared development and operation costs within small budget (up to 50%).
Spain	Investment subsidies up to 30% in particular applications. Premium price for energy produced.
Sweden	Investment subsidy of 15%. Household tariff minus administration costs for small power producers (<1500kW).
UK	Premium price for energy produced. Contracts awarded after competitive bidding.
US	Federal subsidies of USD 0.015/kWh, adjusted annually for inflation, in form of tax credits for investor-owned utilities and production incentive payments for municipal (tax-exempt) power producers. Wide range of individual state incentives (e.g. waiving of sales or property taxes).

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.

6.3 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.

6.4 COMMERCIAL IMPLEMENTATION OF WIND POWER

6.4.1 Installed Capacity

The annual installed wind power capacity in the IEA R&D Wind participant countries increased in 1997 by 1,230 MW compared to 880 MW in 1996, 863 MW in 1995, and 521 MW in 1994. This brought the total installed capacity in the participating countries to 6,333 MW at the close of 1997. The number of new turbines rose to 2,253 (compared to 1,796 in 1996, 1,951 in 1995, and 1,523 in 1994) as the trend toward machines of higher rated capacity continued. The average rating of the turbines installed during 1997 is around 550 kW.

Figure 6.1 shows the total wind power capacity installed in each country compared to the announced national targets. The numbers above the bars indicate total installed capacity.

Figure 6.2 shows the annual installation rate for each year from 1994 to 1997. The numbers above the bars indicate 1997 only

The rate of installation rose in the majority of countries in 1997 although it fell slightly in Italy. Significant increases occurred in Denmark and Germany with Spain establishing itself as the third-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. The total capacity and numbers of turbines for all member countries are shown in Table 6.3 where the upward trend in rated capacity of turbines over the years is clearly discernible.

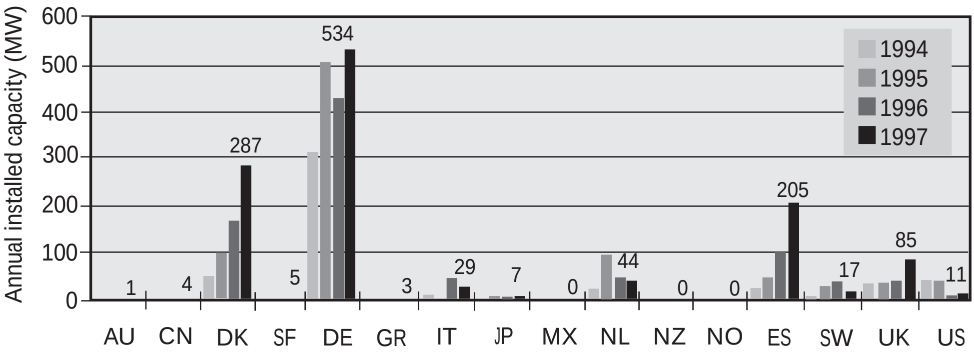


Figure 6.2 Wind Power Capacity Installed From 1994–1997 (to nearest MW) in IEA R&D Wind Participants.

6.4.2 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.

6.4.3 Performance of Installed Plants

Electricity Generation

The total amount of electricity generated from wind power in the participating countries was 10,800 GWh during 1997 compared to 8,500 GWh in 1996; 7,100 GWh in 1995; and 6,250 GWh in 1994. Figure 6.3 shows the generation in each country for the years 1994-97.

Availability and Load Factors

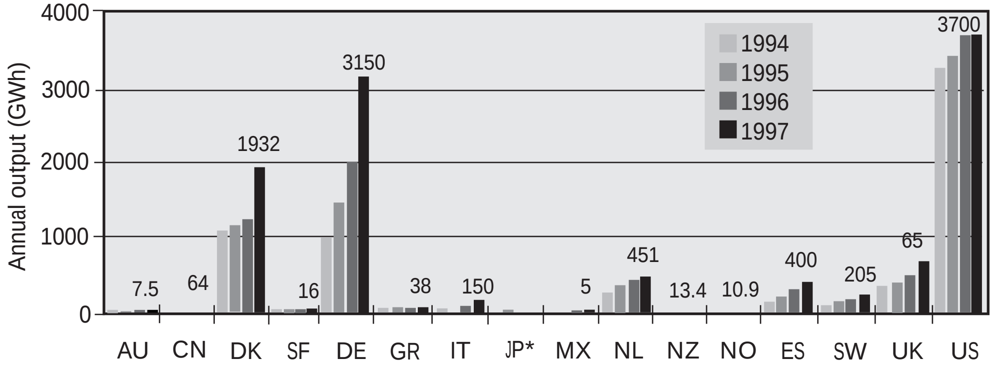
Information on performance of installed plants continues to be sparse. One reason is because few countries have an official reporting system in operation. Another reason data is scarce is that performance information is regarded as commercially sensitive. Most commercial plants were reported to be operating with availabilities of 97-99%.

6.4.4 Operational Experience

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

Table 6.3 Capacity and Number of Turbines in IEA R&D Wind Participants.

	1994	1995	1996	1997	TOTAL
Installed capacity (MW)	521	863	880	1,230	6,333
Number of turbines	1,523	1,951	1,796	2,253	31,261
Average turbine capacity (kW)	340	440	490	550	200



*Data not available from country.

Figure 6.3 Total Wind-Generated Electricity in IEA R&D Wind Participants during 1994-1997.

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.

6.5 ECONOMICS

6.5.1 Manufacturing and Project Costs

Nine of the reporting countries (CN, DK, DE, IT, JP, NL, ES, SW, US) had turbine manufacturing industries while seven (US, DE, DK, ES, NL, SW, UK) had more than 100 MW of plants in operation. This information allows good estimates of manufacturing, project, and generation costs to be made.

During 1997, the ex-factory costs of turbines fell slightly from the 1996 levels probably due to increased demand and reduced production costs per rated kW as the size of turbines increased. In 1997, the reported prices ranged from USD 670-960 per rated/kW with an average of around USD 800/kW. Figure 6.4 shows the ranges reported for the ex-factory costs of turbines.

Total project costs also decreased in 1997 compared to 1996, with average reported costs varying in the range USD 880-1430/installed kW with an overall average of around USD 1,080/installed kW. The variation in these costs would be expected to arise from differences in the size of

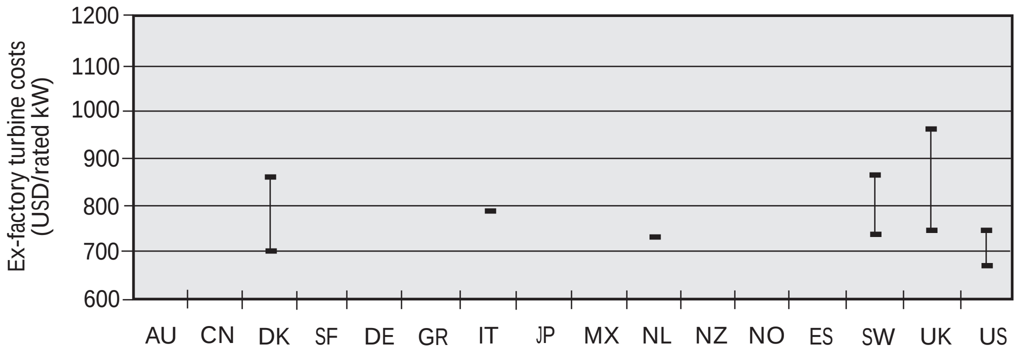


Figure 6.4 Ex-factory Costs of Commercial Wind Turbines in IEA R&D Wind Participants (USD/rated kW).

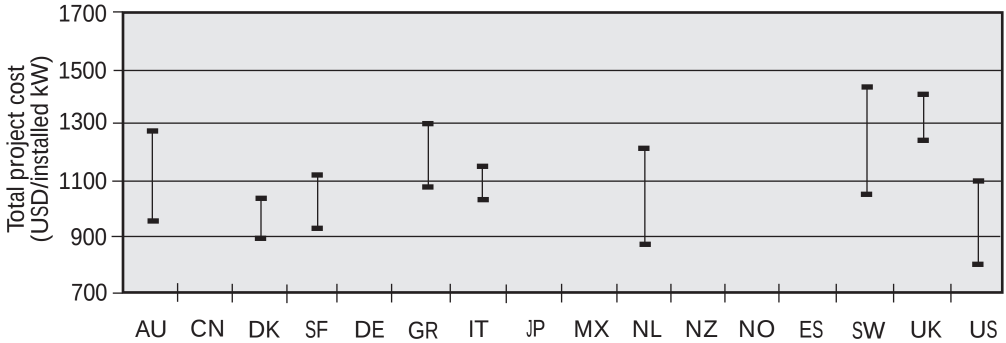


Figure 6.5 Cost of Total Project (USD / installed kW).

projects, the degree of difficulty of working in the terrain in which the wind farm is installed, and the ease of access to the electricity network. Currency exchange rates can also have a significant effect on project costs in countries where the majority of turbines are imported. Figure 6.5 shows the ranges reported for the total project costs.

6.5.2 Electricity Prices and Value of Generated Energy

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 6.6 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.

6.5.3 Invested Capital

The capital investment in commercial wind power can be calculated from the installed capacity and estimated total project costs per installed kW. Assuming that plants installed during 1997 cost on average USD 1,080 per installed kW (see Figure 6.5), 1996 plants cost

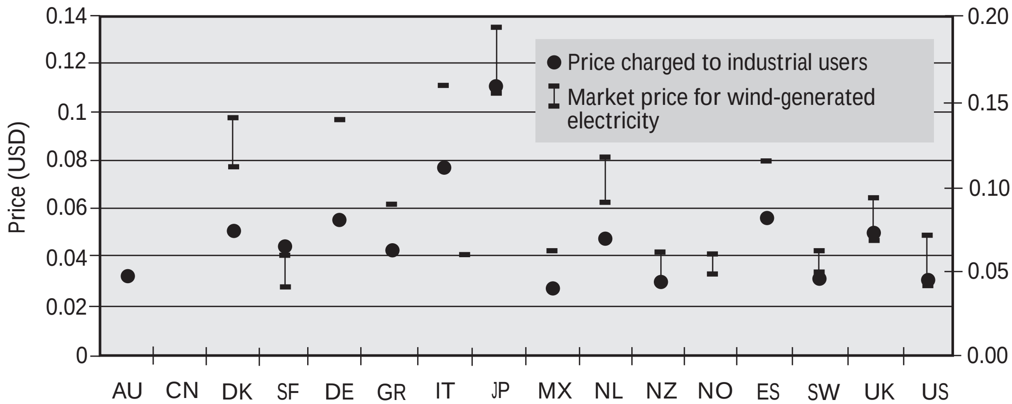


Figure 6.6 Wind Energy Market Prices Compared to Industrial Electricity Prices.

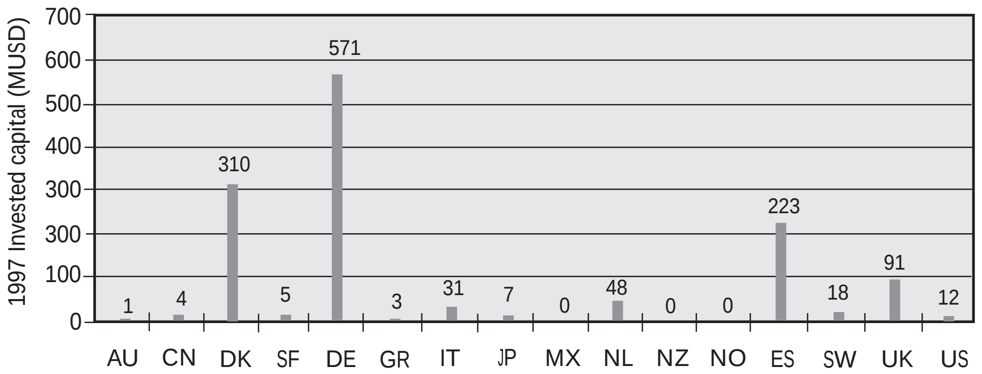


Figure 6.7 Estimated Capital Investment in Wind Power Plants for 1997.

USD 1,200/kW, and plants over all other years cost USD 1,350 per installed kW. The aggregate investments in wind energy generation by the reporting countries are very approximately USD 1,340 million during 1997 and USD 8,100 in total. It should be recognized that these investment costs are very approximate and are only indicative of the magnitude of the investments. The capital investments are shown in Figures 6.7 and 6.8.

6.6 MANUFACTURING INDUSTRY

6.6.1 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 6.4 summarizes the national situations.

6.6.2 Technical and Business Developments

The trend of installing turbines with increased rated capacity for the commercial market continued during 1997. The 600/750-kW machines were further refined and manufacturers began producing commercial machines rated at or over 1 MW. Smaller machines continued to be developed (“advanced machines”), usually

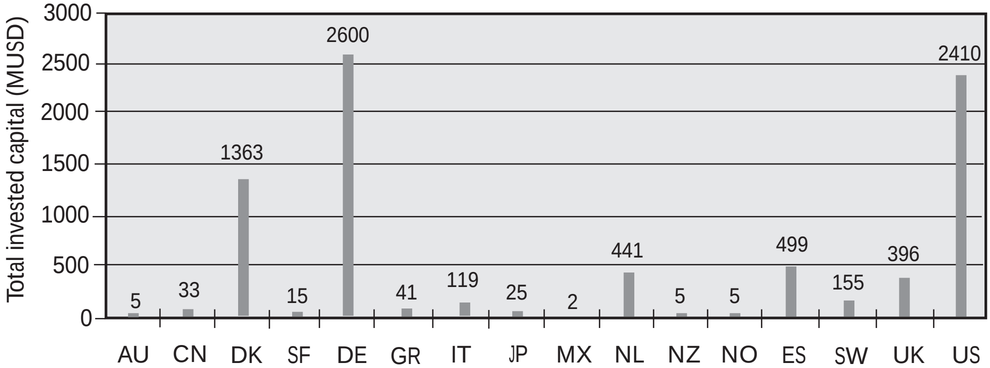


Figure 6.8 Estimated Total Capital Investment in Wind Power Plant.

through value engineering to make them lighter and more cost-competitive.

6.6.3 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.

6.7 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

Table 6.4 Status of National Manufacturing Industries.

	STATUS OF TURBINE MANUFACTURING INDUSTRY	NUMBER OF MANUFACTURERS
Australia	None exist for large turbines.	2 small manufacturers of remote area systems.
Canada	Small/medium but growing.	1 VAWT manufacturer (150 kW) 3 Joint Ventures with foreign manufacturers.
Denmark	Strong—founded on subsidies during formative years. Component industry including large blade manufacturer.	7–8 major manufacturers, more than 10 in total. Numbers steady.
Finland	None exist for large turbines.	0
Germany	Strong as a result of 250 MW demonstration program.	Two large (dominating sales), several small.
Greece	None exist for large turbines, 2 small turbine manufacturers. some components including towers.	0
Italy	Medium—collaboration with government–sponsored programs.	2
Japan	Strong through overseas sales.	2 manufacturers of turbines rated >250 kW.
Mexico	None at present except for small turbine manufacturer.	1
Netherlands	Strong—founded on subsidies during formative years. Blade manufacturers.	3
New Zealand	At prototype stage.	0
Norway	Small components industry.	0
Spain	Strong—government support for industry.	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 manufacturer—can receive government R,D&D support.	0
US	Consolidating as rate of commercial deployment is slowed by utility restructuring and low energy prices; government R,D&D support.	12

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.

Most countries require a planning application to include an environmental impact assessment that addresses the following topics.

Visual Intrusion

Visual intrusion continued to be a major issue in obtaining planning consent for projects and, as would be expected, the concern was greatest in countries with a high population density. Thus the concern is greatest in European countries and less so in the other countries.

Noise Emission

The assessment of noise levels from turbines is seen by most countries as a local issue but national statutory limits are already in force in Denmark, Italy, the Netherlands, and Germany and are being considered in others. Developers and manufacturers in all countries regard noise emissions as a technical problem which can be solved through good engineering practice. However the complexity of sound transmission, especially in hilly locations and the subjective nature of sound perception means many acoustic studies are being undertaken within national programs.

Impact on Bird Life

Concern continues in all countries about wind turbines killing birds. Bird kills were reported as minimal and studies carried out in several countries suggest that compared to other human activities turbines have no significant impact on bird life. The problem of birds varies greatly from site to site and the vast majority of wind power plants report no problems.

Ecology

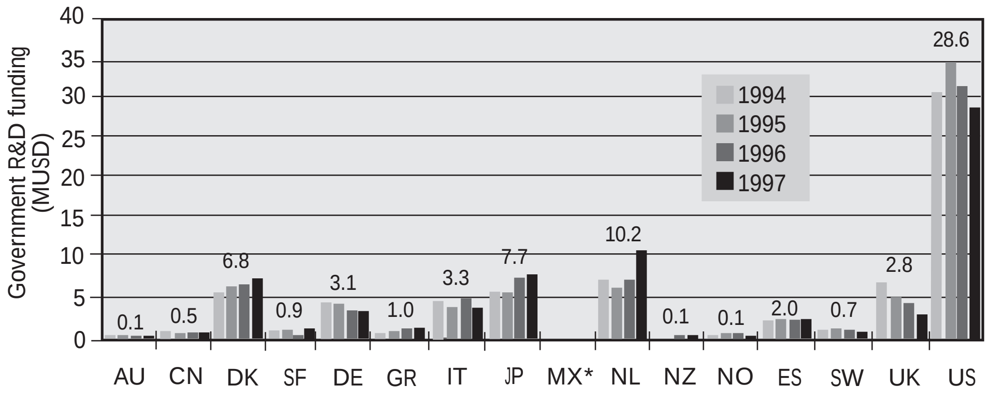
Planning consents usually lay down conditions for the development of a wind farm site and for its restoration afterwards. Little or no long long-term damage to the ecology has been reported from the installation of wind farms.

6.8 GOVERNMENT SPONSORED R, D&D PROGRAMS

6.8.1 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 1997 annual budgets for direct R&D work, excluding support for large-scale demonstration, range from less than USD 1 million (AU, CN, SF, MX, NZ, NO, SW), through USD 1.0 to 10.2 million (DK, DE, GR, IT, JP, NL, ES, UK) to USD 28.6 million for the US.

The reported 1997 annual budgets are shown in Figure 6.9 and compared with budgets for 1996, 1995, and 1994. All funding for basic applied research and development are included, as well as funding of specific demonstration projects. Subsidies and indirect support for large-scale demonstration are not included although these represent lost revenue to the government. 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. The 1997 national



*Data not available from country.

Figure 6.9 Budgets for Government Sponsored R&D Programs from 1994–1997.

funding levels show only small changes compared to those of 1996.

6.8.2 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.

6.8.3 New R, D&D Developments

The main trends in turbine development during 1997 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.

6.8.4 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.

6.8.5 International Collaboration

International collaboration takes place in the IEA R&D Wind activities called Tasks.

These are described in Chapters 2–5 of this Annual Report.

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).

Table 6.5 Monetary Conversion Factors Used in This Report.

COUNTRY	CURRENCY	RATE/USD
Australia	AUD	1.570
Canada	CND	1.439
Denmark	DKK	6.733
Finland	FIM	5.367
Germany	DDM	1.766
Greece	GRD	307.000
Italy	ITL	1741.000
Japan	JPY	132.700
Mexico	MPS	8.480
Netherlands	NLG	1.990
New Zealand	NZD	1.835
Norway	NOK	7.337
Spain	SPP	150.100
Sweden	SEK	7.580
United Kingdom	GBP	0.602
United States	USD	1.000

Source: Federal Reserve Bank of New York, May 6, 1998.

Table 6.6 Capacity and Output Data.

COUNTRY	NATIONAL INSTALLED CAPACITY (GW)	WIND TARGET CAPACITY 1997 (MW)	TOTAL WIND CAPACITY END 1997 (MW)	TOTAL INSTALLED MACHINES END 1997	ANNUAL INSTALLED CAPACITY 1994 (MW)	1995 (MW)	1996 (MW)	1997 (MW)	ANNUAL OUTPUT 1994 (GWH)	1995 (GWH)	1996 (GWH)	1997 (GWH)
Australia	37.25		3.9	23		0.0	0.02	1.1		6.3	7.5	7.5
Canada	114.00		26.0	86	18.9	0.6	0.20	3.5	35.4	55.0	61.0	64.0
Denmark	10.00	1500	1129.0	4857	52.0	98.0	169.00	287.0	1083.0	1175.0	1245.0	1932.0
Finland	11.50	100	12.0	31	0.0	1.8	0.90	4.6	7.2	10.8	11.0	16.6
Germany	99.00	2200	2082.0	5193	309.0	505.0	428.00	534.0	1000.0	1450.0	2000.0	3150.0
Greece	9.20	350	29.0	159	0.7	0.7	0.00	3.0	37.0	33.4	37.2	38.0
Italy	54.00	300	99.0	250	10.2	0.6	48.40	28.5	11.0	11.0	30.0	150.0
Japan	213.00	150	20.0	86	0.9	3.6	4.00	6.5		5.7		
Mexico			2.0	7	1.6	0.0	0.00	0.0	5.0	5.0	5.0	5.0
Netherlands	13.00	2000	325.0	1144	22.0	100.0	47.00	44.0	251.0	317.0	430.0	451.0
New Zealand	1.00		3.7	8	0.0	0.0	3.50	0.0	0.9	1.0	8.0	13.4
Norway	27.00		3.9	12	0.0	0.0	0.00	0.0	10.2	11.3	9.6	10.9
Spain	45.30	8000	421.0	1332	23.4	47.0	96.50	205.0	145.0	180.0	280.0	400.0
Sweden	33.70		122.0	342	7.0	28.8	38.00	17.0	75.0	105.2	142.0	205.0
United Kingdom	62.00		313.0	731	33.0	35.1	36.80	84.5	337.0	361.0	483.0	655.0
United States	750.00		1743.0	17000	42.0	41.6	7.20	11.0	3250.0	3400.0	3700.0	3700.0

Table 6.7 Financial Data.

	TOTAL PROJECT COST (1997) USD/KWH		EX-FACTORY TURBINE COST USD/KWH		WIND ENERGY MARKET PRICE USD/KWH		INDUSTRIAL CONSUMER IEA 1996	GOVERNMENT R&D FUNDING					
								94 USD (M)	95 USD (M)	96 USD (M)	97 USD (M)	INVESTED CAPITAL TOTAL (MUSD)	1997 (MUSD)
COUNTRY	FROM	TO	FROM	TO	FROM	TO							
Australia	955.50	1274.00	0.00	0.00	0.00	0.00	0.0460	0.00	0.00	0.16	0.13	4.944	1.134
Canada	0.00	0.00	0.00	0.00	0.00	0.00		0.49	0.45	0.45	0.45	33.180	3.780
Denmark	891.13	1039.66	699.09	858.46	0.08	0.10	0.0721	5.57	5.91	5.94	6.77	1363.260	309.960
Finland	931.62	1117.94	0.00	0.00	0.03	0.04	0.0620	0.69	0.61		0.93	14.688	4.968
Germany	0.00	0.00	0.00	0.00	0.10	0.01	0.0790	3.96	3.91	3.12	3.12	2599.620	576.720
Greece	1075.00	1303.02	0.00	0.00	0.06	0.06	0.0589	0.81	0.65	0.98	0.98	40.500	3.240
Italy	1034.00	1148.95	787.61	787.61	0.11	0.11	0.1104	4.60	3.79	4.94	3.30	119.235	30.780
Japan	0.00	0.00	0.00	0.00	0.11	0.01	0.1572	5.61	5.39	6.99	7.65	24.645	7.020
Mexico	0.00	0.00	0.00	0.00	0.04	0.04	0.0398					2.1263	0.000
Netherlands	876.51	1214.76	734.28	734.28	0.06	0.08	0.0695	6.78	6.03	7.04	10.15	441.420	47.520
New Zealand	0.00	0.00	0.00	0.00	0.03	0.04	0.0440			0.18	0.13	4.504	0.000
Norway	0.00	0.00	0.00	0.00	0.03	0.04		0.08	0.20	0.27	0.07	5.265	0.000
Spain	0.00	0.00	0.00	0.00	0.08	0.08	0.0788	2.00	2.00	2.00	2.00	498.525	221.400
Sweden	1055.41	1434.04	736.54	865.02	0.03	0.04	0.0451	0.92	0.92	0.92	0.69	154.650	18.360
United Kingdom	1245.00	1411.00	747.00	962.80	0.05	0.06	0.0702	6.47	5.15	4.15	2.82	395.970	91.260
United States	800.00	1100.00	670.00	750.00	0.03	0.05	0.0400	30.40	34.50	31.40	28.60	2410.020	11.880

CHAPTER 7

7.1 GOVERNMENT PROGRAMS

7.1.1 Policy

The Commonwealth Government released a discussion paper in 1996 entitled *Sustainable Energy Policy for Australia* to stimulate public consideration of a sustainable energy policy. The objective of the policy is to establish a framework that will ensure the Australian energy sector is well placed to capitalize on the economic and environmental opportunities and challenges that will emerge domestically and internationally over the next 25 years. Essential elements under formulation in the paper to achieving that objective include the following.

1. Provision of an efficient, open and competitive energy market that will provide market signals to enable the emergence of new technologies, including the renewables,
2. Improvement of the efficiency with which energy is supplied and used which is vital to economic competitiveness and environmental objectives,
3. Investment in innovative technologies, management systems, education, and training that will offer opportunities to simultaneously reduce costs, improve international competitiveness and mitigate the environmental impacts of energy supply and use,
4. Cooperation with the international community and positioning to influence developments that may affect trade and investment opportunities, and
5. Ensure sufficient diversify in the energy supply and reduce exposure to energy supply risks.

The sustainable energy policy is expected to be completed in the first half of 1999.

In recognition of the importance of reducing greenhouse gas emissions, the Commonwealth Government is developing a National Greenhouse Strategy (begun in 1996) or Greenhouse Policy to provide a strategic framework for Australia's greenhouse response and to meet international greenhouse reduction target commitments. The increase in the proportion of renewable energy in the energy supply mix is one of the cornerstones in that policy.

7.1.2 Strategy

The current broad strategies for the development of renewables include the following:

Support Green electricity schemes

Establish a mandated target for the uptake of renewable energy by specifying a proportion of renewables in new generation requirements.

Fund the development, commercialization and demonstration of renewable energy and greenhouse technologies.

The strategies are being implemented through the Commonwealth Government agencies including the Australian Cooperative Research Centre for Renewable Energy (ACRE) and Australian Greenhouse Office (AGO), and State Government agencies, including Sustainable Energy Development Authority as discussed below.

The Sustainable Energy Development Authority (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, through assisting the development, commercialization, promotion and use of sustainable energy technologies. SEDA's Green Power scheme has in 1998 been widened to encompass all of Australia.

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 major Commonwealth climate change and greenhouse programs including the Renewable Energy Showcase, Renewable Energy Commercialization Program and Renewable Energy Equity Fund. The government, through the AGO, is working with the States and Territories to set a mandatory target for electricity retailers to source an additional percentage of their electricity from renewable energy sources by 2010.

This strategy is expected to accelerate the uptake of renewable energy in grid-based electricity and provide a larger base for the development of commercially competitive renewable energy.

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 through cooperative arrangements between universities, government organizations and industry. ACRE currently has eight programs. Those programs that address the application of wind power cover Power Generation, Power Conditioners, and System Integration and Demonstration projects.

7.1.3 Targets and Market Stimulation

The application of wind turbine technology is being stimulated by government instruments, non-profit industry bodies, and external factors as described below.

The government has set a mandatory target for electricity retailers to source an additional two percent of their electricity from renewable energy sources by 2010. Renewable and electricity industry bodies have estimated that the yearly total output of between 4000 GWh and 9000 GWh from new renewable energy sources will be required to meet the target. The estimated contribution from wind energy would necessitate the installation of more than 500 MW of wind turbines.

A Renewables Target Working Group has been established to develop proposals that will assist the implementation of the mandatory target. The Renewable Target Working Group is represented by States, Territories and industry and chaired by the Australian Greenhouse Office. It is currently proposed that the mandatory target for new renewables would include arrangements for establishing a Green Premium. The mandatory target operating arrangements are expected to be in place by 2000.

The Australian Greenhouse Office in 1998 called for grant applications for the first program in a set of three renewable energy industry development programs. The total is AU $60 million in grants programs over 5 years. The grants are planned to foster investment and commercialization of renewable energy technologies and to demonstrate some leading edge “showcase” projects. The funding is to be allocated to renewable energy R, D&D projects that both promise a significant contribution to increased local employment and have export potential. It is expected that these programs will stimulate interest in the development of the manufacture of small turbines and components and in the formation of committed technology transfer schemes associated with long-term and/or large wind farm construction programs.

Sustainable Energy Development Authority's renewable energy program has significantly contributed to the demand for renewable energy and the provision of capital by promoting Green Power in New South Wales (NSW). Eight electricity retailers in NSW and Victoria offer accredited Green Power products as an option. Around 17,000 customers now support Green Power in NSW.
AU $43 million of new investments in renewable energy infrastructure under construction or in operation is attributed to Green Power. This includes AU $30 million in wind farm projects.

In 1998, there has been an improvement in the alignment of the renewables industry interest groups with the establishment of an industry body called the Sustainable Energy Industry Association. This body includes ACRE and the International Centre for Application of Solar Energy (CASE). Its aims include the promotion of energy sources that reduce greenhouse gas emissions, lobbying of government, and establishing appropriate standards for equipment, practices and services.

The Electricity Supply Association (ESAA), the national body representing the interests of the electricity supply industry, is to become the new signatory to the IEA R&D Wind Implementing Agreement following the demise of ERDC. R&D Wind will join a number of other IEA Implementing programs that are already administered by ESAA.

There has been significant improvement in the development and implementation of government policy and programs for renewable energy in 1998. There is, however, still uncertainty at the end of 1998 as to the detailed operating arrangements for the 2% mandatory target for renewables.

In the meantime, the re-focusing of funding support for renewables through ACRE, AGO, and other programs and the continuing support for Green Power schemes by electricity customers is continuing to stimulate the development of wind farms in Australia.

7.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

7.2.1 Installed Wind Turbine Capacity

Increases in wind power capacity in Australia for 1998 have for the first time involved significant grid-connected wind farms while development of wind-diesel power systems continue to occur in suitable remote sites.

Approximately 5 MW for grid connected and 1 MW of remote wind-diesel machines has been added bringing Australia's total capacity to about 10 MW at the end of 1998.

See Table 7.1 for further details.

7.2.2 Installed Conventional Capacity

Australian generation capacity totals 38,116 MW. Total electricity generated is more than 160,000 GWh. The States of New South Wales, Victoria, and Queensland 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%).

NSW, Victoria, and the Australian Capital Territory have an interconnected electricity supply system with the Snowy Mountains hydro-electric scheme an important component. Victoria and South Australia have a 500-MW transmission interconnection. Development of interconnection between NSW and Queensland is in the planning stages, and interconnection between

Victoria and Tasmania via an underwater cable is being considered.

7.2.3 Numbers / Type, Make of Turbines / Ownership

Twelve wind turbines were installed in 1998 by State Government-owned electric utilities—eight in New South Wales by Pacific Power at Crookwell, three on King Island by the Hydro-Electric Corporation, and one in Western Australia by Western Power Corporation.

The Crookwell Wind Farm was commissioned and officially opened in August, 1998. There has been great community support for the wind farm and many visitors make use of the viewing area. The Crookwell Wind Farm consists of eight Vestas 600-kW wind turbines. The wind farm was a joint venture between Pacific Power and Great Southern Energy, with all the output being sold to Great Southern Energy for use in their green energy Earth Saver scheme.

The installation of the three 250-kW machines on King Island was completed in February 1998. The stall-regulated Nordex turbines on 30-m towers form part of an off-grid wind diesel power system designed to reduce fuel costs. Wind generation to date has been between 14% and 21% of the total monthly power station generation with minimal loss of power quality on the system.

Western Power Corporation completed the installation of a single 230-kW Enercon turbine, on a 50-m tower, in a small diesel grid at Denham. The installation was designed to both save diesel fuel and to test the suitability of variable speed turbines on “soft” grids. Central to the project has been a computer control developed to control the diesel / wind interaction and the use of blade pitching and inverter systems to limit the turbine power output. The project has been very successful. Instantaneous penetration has exceeded 60% and, on average, about 23% of the town’s electricity load is being met from wind energy.

Several wind farms were also in various stages of development at the end of 1998.

A development application has been lodged for the biggest wind farm in Australia at Blayney in NSW. The wind farm, which would be connected to the grid, would consist of 15 wind turbines of total 10-MW capacity installed on private grazing land. Subject to final studies and development approval, the wind farm would be operational in early 2000.

Table 7.1 Wind Turbine Installations in Australia at end of 1998 (greater than 25 kW)

LOCATION	MANUFACTURER	NO.	TOTAL
Malabar	WindMaster	1 x 150	0.150
Breamlea	Westwind	1 x 60	0.060
Flinders Is.		1 x 55	0.080
		1 x 25	
Salmon Farm	Westwind	6 x 60	0.360
Cooper Pedy	Nordex	1 x 150	0.150
Ten Mile Lagoon	Vestas	9 x 225	2.025
Kooragang	Vestas	1 x 600	0.600
Thursday Is.	Vestas	2 x 225	0.450
Armadale		1 x 30	0.030
Huxley Hill	Nordex	3 x 250	0.750
Crookwell	Vestas	8 x 600	4.800
Denham	Enercon	1 x 230	0.230
*estimated		TOTAL	9.680

Following an AU $1million grant from the Australian Greenhouse Office, Western Power will be adding two more variable speed 230-kW Enercon turbines, batteries and inverter at Denham in 1999. This project will then become a wind / diesel / battery / inverter system that will allow the community of 800 to rely at times completely on wind energy. The diesels supplement the system. An average penetration of 70% is the aim. The difficult control necessary is being developed with the Northern Territory firm, Powercorp, who specializes in such power station automation and control.

In 1998, Western Power also began a feasibility study into a nominal grid-connected 20-MW wind farm at Albany in the South of Western Australia. Presently community consultation, transmission and environmental approval processes have begun, and wind monitoring is continuing from two 65-m masts installed following several years of wind prospecting in the area. Present study results are very encouraging. Simultaneously, a site in Geraldton on the State's mid West Coast is also being monitored for a possible wind farm site of a similar size to Albany.

EnergyAustralia is in the early planning stages of a wind farm of up to 5 MW to meet growing demand for a Green electricity scheme.

In the Northern Territory, an 80 kW wind turbine is planned to be installed in a remote Aboriginal community hybrid power system.

7.2.4 Plant Types and Form of Ownership

All new wind turbine installations use medium to large-size machines with less than 10 in number. No megawatt size machines are located in Australia.

Government-owned utilities have developed and own most of the wind turbine installations developed in Australia over the last decade. A few are owned by private companies or individuals. The ownership profile could change over the next decade with increasing interest in the development of wind farms by private companies.

7.2.5 Performance

An estimated 9.7 GWh of energy was produced by wind generation in 1998 and is almost 30% higher than that produced in 1997. This is despite another below average wind year experienced in the southern states. Estimates of the energy generated are shown in Table 7.1.

COMMISSIONING	OWNERSHIP	APPLICATION	1998 GWH*
1986	Government Utility	Grid Connected	
1987	Private Individual	Grid Connected	0.160
1988	Private Company	Wind Diesel	0.180
1996	Private Company		0.040
1989	Government Utility	Wind Diesel	0.800
1991	Government Utility	Wind Diesel	0.275
1993	Government Utility	Wind Diesel	5.700
1997	Government Utility	Grid Connected	0.100
1997	Government Utility	Wind Diesel	0.600
1997	Private Company	Grid Connected	0.080
1998	Government Utility	Wind Diesel	1.810
1998	Government Utility	Grid Connected	10.000
1998	Government Utility	Wind Diesel	0.340
		TOTAL	20.080

7.2.6 Operational Experience

No wind turbine operational experience data is available for Australian installations in 1998.

7.3 MANUFACTURING INDUSTRY

Manufacturing continues to be limited to small size machines and a number of low volume manufacturers of small size machines and turbine components.

The expected development and commercialization of a new 3-kW to 5-kW Power-On machine in 1999 may dramatically increase the production of Australian small turbines in the next few years. There is also an increased expectation that the market volume for medium to large grid-connected wind turbines in Australia will become sufficiently high within the next five years to make local manufacturing and / or assembly facilities an attractive investment.

7.4 ECONOMICS

7.4.1 Electricity Prices

The electricity supply industry has completed major reforms to structure and operation in 1998 and there has been continuous assessment of the public support for changes of ownership from the public to the private sector.

A competitive National Electricity Market (NEM) has been developed on the south-eastern seaboard. By the year 2000, all business customers and possibly all domestic customers in the region will be able to choose their electricity supplier. The electricity market is designed around a competitive spot market in which all generators with nameplate capacity beyond 30 MW must participate in central bidding to the pool and dispatch.

Before NEM, electricity prices varied State by State. Currently, generators from Victoria, New South Wales, and South Australia are bidding on the spot market to supply electricity and wholesale purchasers (retailers and large customers) buy electricity at the spot price set every half hour. The introduction of the NEM has established a common price for electricity for the participating eastern states. The daily weighted average spot price for electricity generation on the spot market has typically varied from about AU $0.01 / kWh to AU $0.02 / kWh

Although wind energy is not currently subsidized and is therefore uncompetitive in the electricity spot market, the proposed mandatory target operating arrangements for a Green Premium described earlier should improve its competitiveness when implemented in 2000–2001.

7.4.2 Turbine / Project Costs

Although the cost of the 500-kW to 750-kW class of machines appears to have decreased in 1998, this cost decrease has been substantially offset in Australia by a worsening in the exchange rate between the manufacturing countries in Europe and Australia. This, plus the cost of freight for shipping the machines from manufacturing facilities in Europe to Australia, means that the estimated costs have stayed about the same this year. Estimated costs including towers and excluding foundations remain at about AU $1300 / kW to AU $1500 / kW installed.

Wind farm projects are currently costing from AU $5000 / kW installed for small wind-diesel applications to about AU $2000 / kW for small wind farms connected to the grid. There is the potential for a drop towards AU $1500 / kW for larger wind farms over the next few years as exchange rates improve and production costs further decrease.

7.5 MARKET DEVELOPMENT

7.5.1 Market Stimulation Instruments

For complying R&D projects, accelerated tax concessions are available.

7.5.2 Planning and Grid Issues

There is currently a degree of uncertainty in the planning process associated with wind farms as they are a relatively new type of development for most local and state governments and as such they have little experience in their assessment. Only in some isolated areas have efforts been made to allow for future wind turbine developments in planning schemes and land management plans.

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 taken place at sites relatively close to transmission lines. Although current low levels of wind power development in the local feeders of centralized electricity grids have not caused concern regarding integration of wind turbines into either the grid or power system, the issue is being monitored. Proposed development of wind farms distant from strong points in the grid are in some instances being constrained by the need for long new transmission lines.

7.5.3 Institutional Factors

Green Premiums from the proposed mandated new renewables strategy and promotion of Green Power are emerging as the most likely mechanisms for encouraging increased rates of wind power development over the next few years, particularly the mandated targets. Uncertainty in the introduction of the mandated renewable operating arrangements will dampen the actual rate until the strategy is implemented in 2000–2001. The rate is then expected to increase dramatically to meet the target capacity by the 2010 deadline.

7.5.4 Impact of Wind Turbines on the Environment

Wind farm developments are new to Australia and, as most sites are in remote locations, they have attracted little opposition in the planning and government approval processes. This is now changing as the scale of the developments increase and farms are developed closer to provincial townships.

In Victoria, the private developer Energy Equity Corporation has lost a planning appeal for a 25-MW wind farm that was to be located at Cape Bridgewater on the grounds that the benefits from Green Power did not outweigh the coastline's aesthetic importance. The farm was stated as posing a threat to the landscape and the area's existing and future tourism income. Of particular concern were the proximity of the wind farm to the coastline and a walking trail of high historical significance.

Concerns about possible impacts of the Kooragang wind turbine on bird life in the area have proved to be unfounded. Monitoring studies by The University of Newcastle's Department of Biological Sciences have concluded that the impact has been negligible.

There are no reports of significant environmental concerns with either the other new or the established wind farms.

7.5.5 Financing

Hurdle rates for assessing the economic viability of government-owned utility projects is currently about 6% to 8%.

7.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

7.6.1 Funding Levels

The Commonwealth Government is to provide AU $60 million in funding for the Australian Greenhouse Office climate change and greenhouse programs over the next five years. The Renewable Energy Showcase program consisting of AU $10 million over the three years, starting in 1998 has been allocated to qualifying renewable energy projects. In the showcase program, AU $1million was allocated for a high wind penetration wind / diesel / inverter / battery power system. Other programs are the Renewable Energy Commercialization Program of AU $30 million and Renewable Energy Equity Fund of AU $20 million that is to be allocated over the next four years starting in 1999.

The budget for the Commonwealth Government-funded and industry-supported Australian Cooperative Research Centre on Renewable Energy (ACRE) totals about AU $25 million spread over the next four years for all its programs. About 10% are allocated to programs that directly benefit the development of wind energy.

The NSW Government continues to be committed to funding the Sustainable Energy Development Authority's operations, at a total budget of about AU $13 million for 1998. An identifiable funding allocation within that program for wind energy has not been made.

7.6.2 Priorities

The funding for Australian Greenhouse Office programs is planned to be allocated to renewable energy R, D&D projects that promise a significant contribution to increased local employment and have 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.

7.6.3 New Concepts

Western Australia has continued development of several small wind turbines through the Australian Cooperative Research Centre in Renewable Energy, with new 5-kW and 20-kW machines being developed for the remote area power market to compliment existing 2.5-kW and 10-kW machines. These sizes of machines are proving popular with export markets, especially to Asia.

Testing and design refinements are continuing on the 5-kW Power-On wind turbines being developed in a partnership among The University of Newcastle, EnergyAustralia, and industry (BEST).

7.6.4 MW rated Turbines

R&D is currently not being conducted for MW-class wind turbine technology.

7.6.5 Offshore Developments

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

CHAPTER 8

8.1 GOVERNMENT PROGRAMS

8.1.1 Aims and Objectives

The focus of the Canadian National Program continues to be on R&D to develop safe, reliable and economic wind turbine technology, to support field trials, and to exploit Canada's large wind potential.

8.1.2 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.

8.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

8.2.1 Installed Wind Capacity

Total installed capacity at the end of 1998 of 73.5 MW.

1. Canadian Niagara Power Co. (Ontario) 18.9 MW (Southern Alberta) Keneteck 350-kW turbines,
2. Vision Quest Windelectric (Alberta) 2.4 MW (Southern Alberta) Vestas 600-kW turbines,
3. Le Nordais (Quebec) 50 MW (Gaspe, Quebec) NEG-Micon 750-kW turbines,
4. Various other installations with a total capacity of 2.2 MW.

8.2.2 Installed Conventional Capacity

The total installed conventional capacity in Canada at the end of 1996 (the most recent year for which statistics are available) was 116,939 MW, which includes coal, oil, natural gas, nuclear, and hydro-power plants.

8.2.3 Number, Type, and Make of Turbines

Keneteck, 350-kW turbines; NEG-Micon, 750-kW turbines; Tacke, 600-kW turbines; and Vestas, 600-kW turbines are operating in Canada.

8.2.4 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.

An 80-kW Lagerwey turbine was installed at Cambridge Bay, NWT in October 1994. It has been performing very well.

Polymarin Huron Composites Inc. (formerly Tacke Windpower of Huron Park, Ontario) has installed a Tacke 600-kW turbine near Kincardine, Ontario as per an agreement with Natural Resources Canada. The turbine, modified for cold weather conditions, has been operating very well. After more than three years of continuous production, it has achieved its highest output ever, 175 MWh, in the harsh weather of December 1998.

8.3 MANUFACTURING INDUSTRY

8.3.1 Status / Number / Sales of Manufacturers

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

5. Some components for the Atlantic Orient 50-kW and for Lagerway 80–kW are also manufactured in Canada.

8.3.2 Support Industries

Control system, inverter, tower manufacturers operate in Canada.

8.4 ECONOMICS

8.4.1 Electricity Prices

Electricity prices varied depending on the province and sometimes varied even within the same province. The price range, in January 1997 was:

1. For residential customers: from CAD 0.067 / kWh to CAD 0.151 / kWh,
2. For commercial customers: from CAD 0.067 / kWh to CAD 0.134 / kWh (based on 100 kW billing demand),
3. For industrial customers: from CAD 0.048 / kWh to CAD 0.084 / kWh (based on 1,000 kW billing demand).

8.4.2 Invested Capital

The budget for the Wind Energy R&D (WERD) program of Natural Resources Canada is about CAD 650,000 with contribution of about CAD 1.5 million from contractors, research institutions, and provinces.

In addition, 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. In terms of specific renewable energy programs, such as wind, the requirement is for 25% of the project cost, resulting in a 3:1 leverage ratio.

8.5 MARKET DEVELOPMENT

8.5.1 Market Stimulation Instruments

Currently, Class 43.1 of the federal Income Tax Act provides an accelerated capital cost allowance (30% capital cost allowance rate computed on a declining balance basis) for certain types of renewable energies — equipment used to generate electricity or to produce thermal energy for direct use in an industrial process.

In addition, the government has legislated the extension of the use of flow-through share financing currently available for nonrenewable energy and mining projects to include intangible expenses in certain renewable projects. This was accomplished 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 utility 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, 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 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 in Calgary.

8.5.2 Constraints

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

8.5.3 Environmental Impact

Observations of bird flights were carried out during the spring (mid April to mid May) and fall (September 20 to October) migrating periods, at the Haeckel Hill site of the 150- kW Bonus wind turbine, which is installed in the proximity of bird migration routes. Monitoring was carried out for five years, and there have been no bird kills reported from that installation, nor from the five wind turbines at the Atlantic Wind Test Site.

8.5.4 Financial Aspects

The only financial support for Renewable Energies in Canada comes from these sources: Class 43 of the Income Tax Act which allows capital write-off at 30% per year on the remaining balance; CRCE which allows the first, exploratory wind turbine of a wind farm to be fully deducted in the year of its installation; and the Green Power Procurement program.

8.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

Development of the Wind / Diesel Integrated Control System (WDICS) at the Atlantic Wind Test Site (AWTS) has been completed and the system has been fully tested on the AWTS wind / Diesel test bed. The implementation of a full scale system in a remote community is now being evaluated.

The program also supports the Atlantic Wind Test Site (AWTS) at North Cape, PEI for testing electricity generating wind turbines and wind / diesel systems.

CHAPTER 9

9.1 GOVERNMENT PROGRAMS

9.1.1 Aims and Objectives

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 for sustainable development of the energy sector. The present “Energy 21” published in 1996 is the fourth of the energy strategies. It lays down the energy policy agenda for the time period up to 2030.

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

9.1.2 Strategy

To achieve the overall targets for wind energy utilization in Denmark a number of policy instruments have been used in 1998 (See Table 9.1).

Energy 21 generally considers new, large wind turbines as one of the cheapest technologies for reducing CO_2 emissions from power production. The most economical way is still to erect wind turbines on land, rather than at sea. But area resources on land are limited when housing, nature, and landscape considerations are taken into account. Furthermore, wind conditions at sea are considerably better than at sites on land and wind turbines erected offshore are expected to become competitive in step with the development of technology.

Energy 21 predicts that a significant part of the expansion of wind power 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 planning. In the

Table 9.1 Policy Instruments Used in 1998 to Promote Wind Turbine Technology and Installations

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

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

The government of Denmark intends to continue its promotion of employment and export opportunities for wind power development by continued research and development.

9.1.3 Targets

Denmark has one of Europe's best climates for utilizing the wind for power production. Only countries with a coastline directly on the Atlantic Ocean have better conditions in general. Wind energy could, in theory, provide more energy than is consumed in Denmark today. However, economical viability and siting difficulties limit this vast theoretical potential.

Denmark is a densely populated country, so the Danish onshore wind resource is primarily limited by zoning restrictions and the balance between wind energy development and other claims or interests in the open land. Therefore most of the 205 municipalities have prepared wind turbine plans. The Danish Energy Agency has analyzed this local planning and estimates the onshore wind energy potential to be between 1,500 MW and 2,600 MW.

Several investigations of 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 available areas with water depths up to 15 m are included. The wind speeds in the areas allow 3,530 "net full load hours" at the North Sea (Horn's Reef) and between 3,000 and 3,300 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 2000–25000 hours.

Total capacity for electricity production has been estimated. On shore there could be 2,600 MW realistic capacity with a realistic production of 5.7 TWh or 17–18% of annual electric consumption. Offshore there could be 12,000 MW realistic installed capacity with a realistic production of 30–40 TWh or nearly 100% of annual Danish electric consumption.

In *Energy 21* the targets for wind energy are 1,500 MW of wind power by 2005 (12% of electricity consumption) and 5,500 MW of wind power by 2030, of which 4,000 MW is offshore (40–50% of electricity consumption).

9.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

9.2.1 Installed Wind Capacity

During 1998, approximately the same amount of new capacity was added as in 1997. By the end of 1998, the total installed capacity of wind turbines was approximately 1,400 MW. This data is based on manufacturer information.

9.2.2 Number/Type, Make of Turbines

During 1998, approximately 400 wind turbines were installed bringing the total number of turbines in Denmark to 5,250. 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.

9.2.3 Plant types and Form of Plant Ownership

Wind turbines in Denmark are typically installed in clusters of three to seven machines. Clusters of wind turbines are preferred 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 machines of 600 kW each.

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

Local ownership of wind turbines has been promoted politically by the Danish government and the Parliament. The reason is that wind power's environmental advantages are on a global and national level, whereas, wind power's environmental disadvantages are on a local or neighborhood level. 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-operatives or companies to benefit from the wind turbines) can secure local acceptance of projects. Co-operatives have been encouraged that spread ownership of a wind turbine among 20 to100 families in the vicinity of the wind turbine.

During the 1980s and early 1990s, most new turbines were installed by co-operatives. 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, laws for facilitating structural changes in the farming sector have unintentionally left open possibilities for farmers to purchase small pieces of land for wind turbines.

9.2.4 Performance of Wind Power Plants

In 1998, new machines in Denmark (mostly 600 kW and 750 kW) were often placed in areas corresponding to roughness classes between 1.0 to 1.4 (Beldringe data in the European Wind Atlas); equal to 6.7 m/s as annual mean wind speed at 50-m height. For a 750-kW turbine with a 48 m rotor on a 45-m tower, this means an average production of approximately 1,800 MWh annually.

The total electricity production in 1998 is estimated to be approximately 2,800 GWh, equal to 8.5% of the total electricity consumption in Denmark. Corrected to a "normal wind year," this equals 7.3% of Denmark's annual electricity production. The wind's energy index in 1998 was 101. (Numbers are based on an estimate by E&M-Data.)

9.2.5 Operational Experiences

The 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*. Operational data are voluntarily reported on 2,830 turbines with a total installed capacity of 700 MW in this database.

Table 9.2 Status of Wind Turbines in Denmark by the end of 1998

OWNER TYPE	TURBINES ADDED	MW ADDED	TOTAL TURBINES	TOTAL MW
Private individuals	308	210.0	2305	771.0
Private cooperations	93	63.0	2277	402.0
Power utilities	40	28.0	707	248.0
Municipalities, industries, others	11	7.0	208	46.0
Total	452	308.0	5497	1467.0

Technical lifetime or design lifetime for modern Danish machines is typically 20 years. Individual components are to be replaced or renewed in a shorter interval. Consumables such as oil in the gearbox, braking clutches, etc. are often replaced at intervals of one to three years. Parts of the yaw system might be replaced in intervals of five years. Vital components exposed to fatigue loads such as main bearings and bearings in the gearbox might be replaced halfway through the total design lifetime. 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 and RISØ National Laboratory have developed a model for annual operation and maintenance costs. The model is based on statistical surveys and analyses for 1991, 1994, and 1997. The model includes a large re-investment after the tenth operational year of 20% of the cost of the wind turbine. This re-investment is distributed over the operational years 10 to 20. (See Table 9.3.)

9.3 MANUFACTURING INDUSTRY

9.3.1 Status / Number / Sales of Manufacturers

Danish-based manufacturers of large commercial wind turbines in the 150-kW to 2 MW range are: Bonus Energy A / S, NEG-Micon A / S, Nordex Energi A / S, Vestas Wind Systems A / S, Wind World af 1997 A / S, Wincon West Wind A / S. In 1998, NEG-Micon A / S took over Wind World af 1997. Two companies produce smaller turbines in the 5.5-kW to 22-kW range. Calorius-Westrup A / S produces a 5-kW heat producing turbine.

The wind turbine manufacturers had a turnover in 1998 of more than 6.5 billion DKK. Total wind turbine manufacturing in Denmark was more than 1,200 MW of which 280 MW was sold domestically. Increasingly more manufacturing takes place in foreign subsidiaries and joint-ventures and does not appear in the Danish export numbers.

9.3.2 New Products / Technical Developments

Industrial development in 1998 focused on refining the 600-kW to 1,500-kW size of turbines. This includes, among other things, upgrading turbines with larger generators and larger rotor diameters. In the autumn, Bonus introduced a commercial 2.0-MW machine.

9.3.3 Support Industries

A number of industrial enterprises have developed important businesses as suppliers of major components for wind turbines. LM Glasfiber A / S is a world-leading producer of fiberglass blades for wind turbines. 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,

Table 9.3 Annual Operational and Maintenance Costs as a Percentage 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

ABB, SKF, FAG, etc. have developed businesses in the wind power industry.

Service and maintenance of the more than 5,000 wind turbines in Denmark is carried out by the manufacturers' service departments. In addition, a handful of independent service companies have been established. These are companies such as DWP Mølleservice A/S and DanService A/S. Some of the electricity companies service their own turbines.

Other industrial service enterprises have created important businesses in servicing the wind power industry. For example, companies are specialized in such fields as 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.

9.4 ECONOMICS

9.4.1 Electricity Prices

The 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, including a 25% VAT. In 1998, the average consumer price for Danish low voltage customers was between 1.2 DKK/kWh and 1.35 DKK/kWh.

9.4.2 Turbine/Project Costs

Ex factory cost of wind turbines has decreased significantly with the latest 750-kW generation (44B48 m rotor diameter). For new 750-kW machines the ex factory cost is typically 4.2 million DKK.

Additional costs depend on local circumstances, such as condition of the soil, road conditions, proximity to electrical grid sub-stations, etc. Additional costs on typical sites can be estimated as 20% of total project costs. Only the cost of land has increased during recent years. See Table 9.4.

Table 9.4 Cost of a 750-kW 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

9.4.3 Production Costs

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 produced from a new coal-fired power station based on condensation. The estimated costs are shown in Figure 9.1.

9.5 MARKET DEVELOPMENT

9.5.1 Market Stimulation Instruments

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 connect one turbine to the grid, and this turbine must be placed on the owner's land. Similarly each shareholder in private co-operatives is limited to ownership of 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.

Buy-back rates are related to the utilities' production costs (tariffs). A law requires power utilities to pay wind turbine owners a kWh rate of 85% of the utility's production costs. Average production cost 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. The taxation schemes have changed over time. Today, income from wind turbines, by and large, is taxed as other income.

Private persons and companies can choose between two models for taxation of their income from wind turbines or shares in wind turbines. Owners of individually-owned or company-owned turbines often choose to pay income taxes in the same way as they pay on income from other investments. That is, full tax on the income, but with deductions from

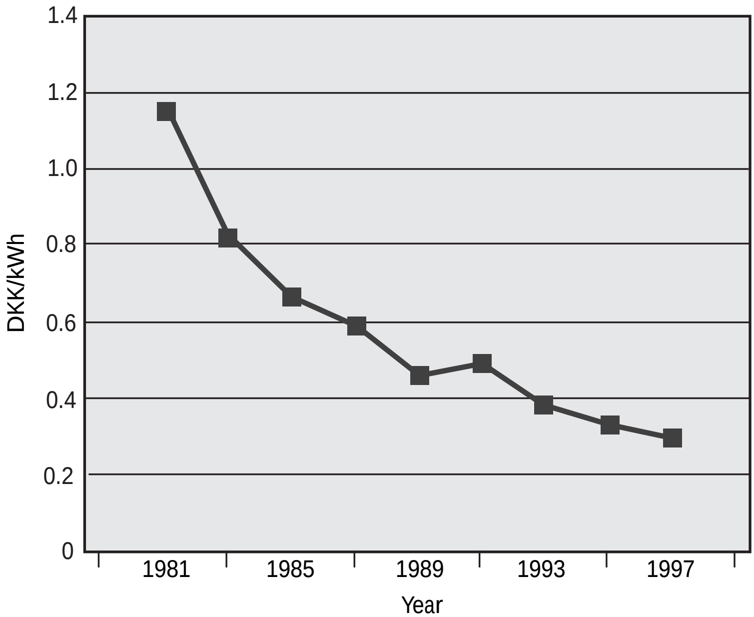


Figure 9.1 Estimated Costs of Wind-Generated Electricity in Denmark, Based on 20-Year Depreciation, 5% Interest Rates, and Siting Roughness Class 1

the annual depreciation of the investment and expenditures to operations and maintenance costs, according to the usual tax regulation. Shareholders in private co-operatives can chose a "simplified model," according to which the first 3,000 DKK of income from sale of wind power is tax free and 60% of the rest is taxed with the usual marginal income tax percentage; usually 60%. No deductions are allowed with this scheme. The simplified income tax model gives a tax incentive for owners of small shares in a wind turbine. The smaller the share, the larger the relative incentive. Thus this instrument spreads the ownership of wind turbines to as many citizens as possible. For owners of turbines acquired before the present taxation rules, a number of other rules exist.

All wind turbines with an annual turnover of more than 20,000 DKK must have a VAT-number. The wind turbine owner or the co-operative charges a 25% VAT on the electricity sold to the utility, but not on the 0.27 DKK subsidy. The wind turbine owners transfer this collected amount to the government.

9.5.2 Planning and Grid Issues

Spatial (or land-use) planning establishes a framework for siting wind turbines on open land and balances the interest of wind energy against other interests, including how existing urban features and landscapes can best be protected. Tasks related to environmental protection are increasingly integrated in the work of spatial planning. Spatial planning in Denmark is carried out at three levels: local and municipal planning in the municipalities, regional planning in the counties, and national planning co-ordinated by the Ministry of Environment and Energy.

The Ministry can influence planning through regulation, national planning directives, and the dissemination of information. The location of wind turbines and high-voltage transmission lines in rural landscapes are two examples in which the Spatial Planning Department influences planning.

All counties have prepared guidelines for regional planning. These guidelines lay down the overall conditions for wind turbine deployment in each particular region / county.

Municipalities (local planning authority) prepare local wind turbine plans and issue both zoning permits and installation permits according to the law on spatial planning. Local wind turbine plans typically prescribe where turbines are to be installed (distances to roads, dwellings, etc.), how they are to be installed (individual machines, clusters, parks), and their appearance (tower type and color).

In 1998, there has been discussion of requiring specific environmental assessments for wind turbine developments. Balancing the interests of wind energy utilization against other interests in open land are usually contained in the legislation on each area.

A wind turbine's noise emission must be verified according to the rules in the Ministry of Environment and Energy's statutory order no. 304. According to this order, noise from wind turbines must not exceed 45 dB(A) outdoors at the nearest habitation in rural areas, and 40 dB(A) in residential areas and other noise sensitive areas. As tonal noise is often a source of annoyance 5 dB(A) is added to the measured broadband noise if tonal noise is clearly audible at the location where the noise level is being measured. A simple method for calculating the noise emission of a wind turbine is specified in the statutory order.

According to a statutory order, the costs of grid connection of wind turbines are split between the wind turbine owner and the power utility. The wind turbine owner must bear the costs of low voltage connections, whereas utilities must carry the costs for reinforcement of the 10-20-kV power lines when such is needed.

9.5.3 Impact of Wind Turbines on the Environment

Utilizing wind power is one of the cheapest methods of reducing CO_2 emissions from electricity production. Production from the 750-MW large-scale offshore wind farms will be approximately 2.5 million MWh of CO_2- free power per year. Replacing other generation with this wind-generated electricity will reduce CO_2 emissions by 2.1 million tons per year or 17.5% of the total national reduction objective for 2005.

Although modern wind turbines conform to current noise requirements, their size alone means that it is not appropriate to install them too close to inhabited areas. As there are very few open areas in Denmark without dwellings, utilizing the open sea has great advantages.

The possible impact on wildlife is one important consideration. Studies on land-based wind farms conclude that wind turbines do not pose any substantial threat to birds and other wildlife. All of the appointed areas for offshore wind farms lie outside of EU bird sanctuaries but there are also important areas for birds in several of the sites. Studies have already been conducted on possible impact on sea birds at the Tunø Knob installation. Although the final result of the studies is not yet available, the studies reveal that the eider ducks have not been frightened away from the Tunø Knob area by the establishment of an offshore wind farm. The eider ducks that winter there are much more influenced by the presence of food than by the presence of the wind turbines.

9.5.4 Financing

Availability of capital for wind power projects is not a problem. Financial institutions compete efficiently in this market and different financial packages have been developed.

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

9.5.5 Institutional Factors

The Danish approval scheme for wind turbines has been established to fulfill the common desire of wind turbine manufacturers, owners and authorities for a coherent set of rules for approval of turbines installed in Denmark. An approval is based partly 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 with 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.

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. To assist the Danish Energy Agency, an advisory committee is formed with representatives from the wind turbine manufacturers' association, the wind turbine owners' association, insurance companies and the power utilities. For discussion of technical and administrative matters regarding the approval scheme, a technical committee is formed consisting of the authorized

Table 9.5 Bodies Authorized by the Danish Energy Agency to Provide Services under the Danish Scheme for Certification and Type-Approvals for Wind Turbines (by end of 1998)

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

bodies. As several authorized bodies are non-Danish enterprises, the technical committee's meetings are held in English. Minutes and other communications from the committee are primarily distributed in Danish. A separate technical committee is set up for household turbines.

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 9.5.

9.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

9.6.1 Funding Levels

The Danish governmental sponsored programs consist of two programs.

9.6.1.1 Ministry of Environment and Energy's Energy Research Program (EFP).

During recent years, a part of the research program has been allocated to energy issues in Eastern Europe and the former Soviet Union. The Energy Agency 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 cost. In the 1998 round (processed in 1997), nine projects were initiated with a total support from the Danish Energy Agency of 15.11 million DKK.

9.6.1.2 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 at the regular meetings of the Technical Advisory Committee. Projects are always shorter than three years. In 1998, projects were supported by the Danish Energy Agency with a total of 14.45 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 7.9 million DKK in 1998.

The total budget for the Danish Energy Agency's wind energy activities amounted to 38.3 million DKK. This is a little smaller than in 1997.

9.6.2 Priorities

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

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 Eastern Europe.

At least one-third of the resources of the energy research program must be aimed at long-term perspectives (beyond year 2005). Project titles in the 1998 round of the research program were the following.

1. Rotor investigations,
2. Program for research in aeroelasticity (98–99),
3. Modeling the damping for edgewise vibrations,
4 Investigation of wind climate in connection with double-stall,
5. Validation of Gaussian turbulence,
6. KAMM / WAsP engineering— a numerical wind resource atlas,
7. Power quality and connection of wind farms in weak grids,
8. DC connections for wind farms,
9. Simplified assembling of offshore foundations.

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

The overall aims of the wind part of the renewable energy development program 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 cooperation,
5. To stimulate Danish industrial development and export.

The list of project titles is very long, and contains very different projects such as development projects, demonstration projects of small household turbines, information activities, economy surveys, 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 included the following.

1. Information activities,
2. International cooperation with other test stations for wind turbines,
3. Secretariat for the Danish certification and type-approval scheme,
4. Spot-check of type approved turbines,
5. Inspections of major break-down of turbines,
6. International standardization,
7. Development of test methods for wind turbines,
8. Development of test methods for blades,
9. Participation on the IEA annex on Round Robin test of a wind turbine.

9.6.3 New Concepts

During recent years, a development and demonstration program for so-called "household" turbines in the range 5 to 25 kW has been a part of the Danish Energy Agency's development program (UVE). A number of concepts different from the traditional "Danish concept" have been developed including a multi-bladed turbine, a two-bladed teeter hub design, and a two-bladed stiff hub design for a heat producing machine. Almost 100 such small turbines have been installed both within and outside the demonstration program.

9.6.4 Offshore Projects

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 offshore projects: 56% reduction compared to Vindeby. More accurate assessment of the offshore wind climate and prediction of wind loads are important research issues.

In 1998, the power companies and the Danish Energy Agency have started the implementation of the first phase of the Plan of Action for offshore Wind Power in Danish Waters. According to the agreement, 750 MW in five large offshore farms will be erected between 2001 and 2008. The turbines will be the newest commercial technology in the coming years. For the first offshore farm, 1.5 to 2.0-MW turbines will be used.

9.6.5 International Collaboration

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

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

CHAPTER 10

EUROPEAN COMMISSION

The Non-Nuclear Energy Programme of the Fourth Framework Programme (1994-1998) is one of the main means by which the European Commission has been supporting scientists, developers, manufacturers, and users. The European Commission supports research, development, and demonstration of renewable energy technologies aiming at safe, reliable, efficient, and environmentally friendly alternative energy sources.

This program came to an end in December 1998, and the cumulative results of the calls for proposals can be summarized as follows. One hundred and twenty-three proposals out of the 381 received from the wind energy sector were accepted for funding totaling Euro 75.4 million. The project funding was subject to the successful conclusion of the contract negotiation.

JOULE, the R&D part of the Non-Nuclear Energy Programme, allocated financial support of Euro 43.3 million to 79 wind energy projects during the period 1995–98. This represents 26% of the total number of renewable energy projects and 19.6% of the total support of Euro 220.7 million allocated to them.

THERMIE, the demonstration part of the Non-Nuclear Energy Programme, allocated financial support of Euro 32.1 million to 44 wind energy projects during the period 1995–98. This represents 21% of the total number of 213 renewable energy projects and 22% of the total support of Euro 148.7 million allocated to them.

The Figure 10.1 presents the number of the wind energy projects supported by the Non-Nuclear Energy Programme during the period 1995–98, compared to the number of projects for the other renewable energy sectors.

Figure 10.2 presents the distribution of funds between the RES sectors.

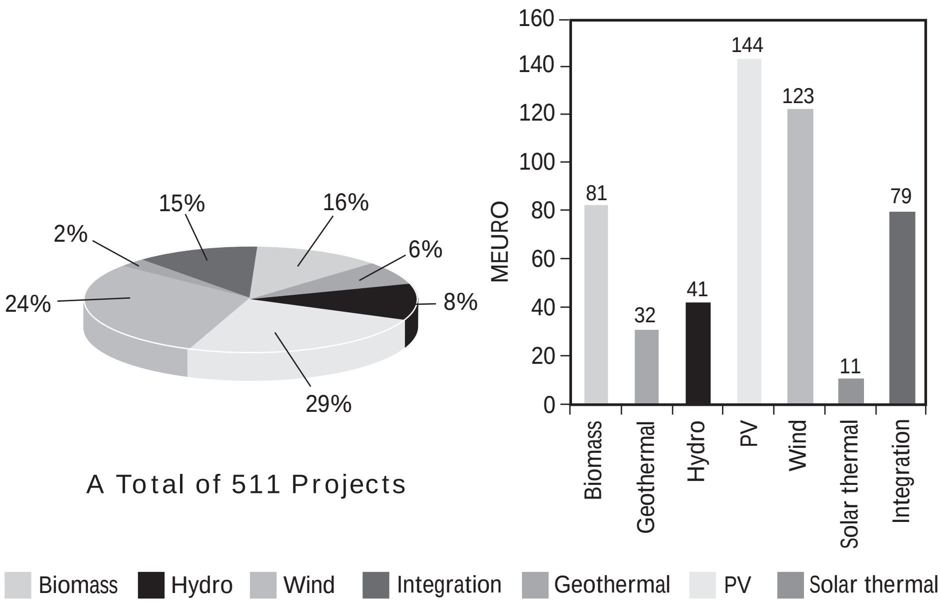


Figure 10.1 Number of Supported Non-Nuclear Energy Projects per Sector in RES under the Fourth Framework Program (1995-1998)

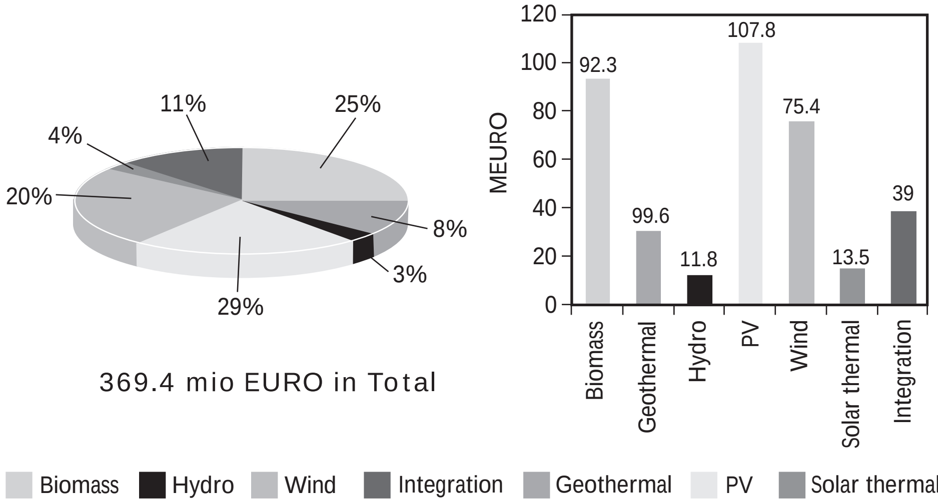


Figure 10.2 Distribution of funds for Supported Non-Nuclear Projects per Sector in RES under the Fourth Framework Program (1995-1998)

The general objective of the program was to encourage market penetration and greater utilization of wind energy in Europe. Therefore the calls for demonstration proposals sought projects to provide innovative solutions to well-known technical and non-technical barriers facing the sector. For example, given the scarcity of sites available for wind farming, support was allocated to projects which allowed for the operation of the wind turbines on sites with specific environmental characteristics outside the normal conditions which are presently being commercially exploited. Another of the calls for proposals explored the innovative integration of wind turbines and their operation in weak electricity grids while avoiding possible negative interactions. In addition, given that the reduction of both installation and operation costs will make the wind energy production more competitive, projects aiming to demonstrate such a reduction through innovative techniques were also supported.

Throughout the years, priority has been given to new wind turbines of larger sizes. It is worthwhile mentioning that 20 out of the 122 projects are using wind turbines larger than 750 kW, with 12 of them using wind turbines of capacity larger than 1 MW. In terms of commercial applications of large wind turbines, their share of installed capacity has increased from less than 1% in 1994 to above 6% by the end of 1998.

Some of the representative and successful projects supported by the Non-Nuclear Energy Programme during the above period include the following.

1. The OPTI-OWECS study on the structural and economic optimization of bottom-mounted offshore wind energy converters,
2. MEASNET, Network of European Measuring Institutes, is a result of the co-operation among different national test centers involved in developing measurement standards to ensure that measurements are performed to a high quality. It is an offspring of the project on “European Wind Turbine Standards II.” Harmonized anemometer calibration, power performance, noise, and power quality measurement procedures which take into

account the existing standards supplemented by MEASNET recommendations will be performed in future publicly funded plants,

3. Wind Energy for Cold Climates (WECO) including studies of icing of wind turbines is another research area which is investigated with the participation of interested members of the industry. Initial project results show an emerging market with interesting applications,

4. A 3-MW wind farm in a remote area of Ireland incorporating innovative control systems for its connection to the weak electricity grid,

5. A comparatively low cost 2.5-MW offshore wind farm in Sweden (one of the three offshore projects supported during the period 1995–1998),

6. The prototype innovative, gearless, variable speed, stall-regulated, direct drive and modular generator of 750 kW, connected directly to the rotor and, through an inverter, to the electrical grid,

7. A 3 x 750-kW wind farm in a mountainous turbulent remote site with annual mean wind speed of 12.5 m/s.

The Fifth Framework Programme (FPV) sets strategic guidelines for the European Union in the areas of science and technology for the period 1998–2002. It was adopted on December 22, 1998 with an overall budget of Euro14.96 billion. The specific programs were adopted on January 1, 1999. Details about the FPV, 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 developing countries can be found on the CORDIS website http://www.cordis.lu/fp5/src/programmes.htm).

Wind energy RTD, being part of the renewable energies, is found under the activities for Promoting Competitive and Sustainable Growth (first activity), Theme IV- Energy, Environment and Sustainable Development, under the key actions: Cleaner energy systems, including renewable energies (key action 5) and Economic and efficient energy for a competitive Europe (key action 6).

The first calls for proposals for RTD projects on the basis of the specific work program are expected to be launched by mid-March 1999.

EU-funded research and the awarding of projects will become more selective and more demanding in terms of results and achievements. In addition, the benefits of EU-supported R&D should be visible to both the industry involved and the participating researchers and should serve European citizens.

The EU-15 wind energy installed capacity at the end of 1998 exceeded 6.6 GW. It is expected that the goal of 8 GW installed capacity by 2000 will be reached. However, if the target of 40 GW installed power is to be achieved by 2010, the present annual rate of installation should increase from 1 GW/year in 1998 to at least 2 GW/year by the end of 2002.

FIGURE 10.3 Combining Pleasure with Energy Production Offshore.