IEA Wind Energy
Annual Report 1993

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Swedish National Board for Industrial and
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Foreword

This is the sixteenth Annual Report 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. The Agreement and its programme, which is known as IEA R&D Wind, is a collaborative venture between parties from fourteen IEA countries.

The report is published by Nutek, the Swedish Contracting Party to the Agreement, on behalf of the IEA R&D Wind Executive Committee. It is edited by B Pershagen with contributions from D.F. Ancona (USA), H.J.M. Beurskens (the Netherlands), P.W. Carlin (USA), J. 't Hooft (the Netherlands), H. Matsumiya (Japan), P. Nielsen (Denmark), D. I. Page (UK), R.S. Rangi (Canada), E. Sesto (Italy), E. Solberg (Norway), E. Soria (Spain) and R. Windheim (Germany).

Edinburgh in January 1994

W G Stevenson
Chairman of the
Executive Committee

Contents

Executive Summary

The report reviews the progress during 1993 in the Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind), set up in 1977 under the auspices of the International Energy Agency (IEA).

The purpose of IEA R&D Wind is to carry out cooperative research, development and demonstration projects in wind energy. Since 1991, the activity also includes the exchange of information on the planning and execution of national programmes for the design, construction, operation and evaluation of large-scale wind systems having a rated power of approximately 1 MW or more.

IEA R&D Wind has 15 signatories from 14 countries: Austria, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, the United Kingdom and the United States. The Technical Research Centre of Finland joined the Agreement during the year.

Wind energy continues to stand out as one of the most promising renewable energy sources for the medium to long term. Small and medium-sized wind turbines are commercially available. Present installations are either single units or arrays of units, forming windfarms. Most of the plants are owned by private investors or cooperatives, but utilities are increasingly involved in the deployment of large wind systems.

The combination of a maturing technology and effective market incentives has produced an installed capacity in the member countries of more than 2700 MW by the end of 1993. The rate of increase is about 300 MW per year. Current estimates suggest that by the turn of the century the total capacity worldwide may reach 10 000 MW with 4000 MW in Europe, 4000 MW in the USA and 2000 MW in other countries.

The average rated power of machines in today's windfarms is about 200 kW. The unit size in new installations is increasing - the average unit rating in windfarms installed in 1993 was about 300 kW and in some countries over 400 kW. There is a market pull, led by utilities, for still larger units.

Several manufacturers are marketing small and medium-sized wind turbines. Commercial wind turbines of 500 kW rated power (rotor diameter 35 - 40 m) are now available. The leading manufacturers are developing megawatt-sized machines. The feasibility of designing and operating wind turbines with rotor diameters up to 100 m has been demonstrated, but generation costs have been two to four times higher than from small and medium-sized machines. A reason is that large wind turbines have not yet benefitted from the economies of large-scale production.

Despite the technological advances and a vast resource, wind energy still faces barriers to widespread use. Dropping fuel prices, and planning difficulties due to environmental concerns have conspired to slow the pace of market penetration. Some utilities are simply reluctant to introduce new technology which they perceive as risky and unnecessary. In recognition of this, government-sponsored market incentive programmes are in effect in many countries to encourage wind power developments. The incentives take different forms, such as investment support, generation credits, tax reliefs or guaranteed buy-back rates.

The national wind energy R, D & D programmes are set to continue in the member countries. Funding has increased in recent years and was equivalent to approximately USD 160 million in 1993, as illustrated in the bar chart (see page 14). The programmes are mainly directed to the development and demonstration of large-scale wind turbines.

The national wind energy programmes are the basis for the IEA R&D Wind collaboration. Eleven projects, called Tasks, have been successfully completed since the start of the cooperation. The total level of effort is typically about ten manyears per Task over a period of three years. 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 organisations, to a joint programme coordinated by an Operating Agent.

Two Tasks were completed during the report period: Task XII Universal Wind Turbine for Experiments (UNIWEX) and Task XIII Cooperation in the Development of Large Wind Systems.

Task XII has comprised experimental studies of wind turbine aerodynamics, operational behaviour, load spectra and control strategies, and the validation of computer codes for wind turbine design. Use has been made of the UNIWEX experimental wind turbine at the Ulrich Hütter wind test site near Schnittlingen, Germany. Three countries (Germany, the Netherlands, and Sweden) participated in the project, which included an extensive measurement programme and numerical simulations.

Task XIII consisted of cooperative action and exchange of information on the planning and execution of national R,D&D programmes for the development of large wind turbine systems. A computerized system was established for the collection and dissemination of information on national wind energy installations, design and operation of prototype wind turbines and selected windfarms. The progress in the development of large-scale wind turbines and windfarms as well as information on government funding levels will continue to be reported to the Executive Committee by its members.

The ongoing Tasks include:

Task XI	Basic Technology Information Exchange Operating Agent: Department of Fluid Mechanics, Technical University of Denmark
Task XIV	Field Rotor Aerodynamics Operating Agent: Stichting Energieonderzoek Centrum Nederland (ECN)

Task XI has participants from twelve countries. One subtask is the preparation of Recommended Practices for Wind Turbine Testing and Evaluation. Eight Recommendations have been issued so far. They are continually being reviewed and in some cases re-issued. During 1993, a revised Glossary of Terms was issued. Revised editions of Costing of Wind Turbines, and Acoustical Noise are in preparation, as is a new Recommendation on anemometric issues in power performance testing.

In a second subtask, Joint Actions are set up in specific research areas of current interest, where a periodic exchange of information is considered necessary. The Joint Actions usually take the form of symposia or workshops. A new Joint Action on Wind Condtions/Turbine Loads was initiated during the year.

Task XIV is a relatively new joint research project involving five laboratories in four countries (Denmark, the Netherlands, United Kingdom and United States). The project aims at coordinating measurement programmes on existing experimental wind turbines, equipped with instrumented blades, to measure pressure distributions around the profiles or aerodynamic forces on blade sections. The data will be used to verify aerodynamic models. A first round of data exchange was completed during the year.

Much of the information exchange takes place at Executive Committee meetings twice a year when the activities in the participating countries are reviewed with emphasis on large-scale systems. The highlights of the national R,D&D programmes and the progress of the cooperative Tasks are summarized in the Wind Energy Newsletter, published semi-annually by the Executive Committee. The third and fourth issues of the Newsletter were published during the year.

At its 1993 fall meeting the Executive Committee adopted a five-year strategic plan for 1994-1998. Goals for continued cooperative action were set and areas for collaboration were identified. While joint research and information exchange will remain the prime activities, increased emphasis will be laid on state-of-the-art assessments of wind energy technology, economics and environmental impact. Efforts will be made to identify barriers to deployment and analyse support strategies.

The wind energy activities during 1993 in the member countries are reviewed in the report with emphasis on the large-scale developments, and briefly summarized as follows.

In *Canada*, the large EOLE vertical axis wind turbine, which has operated with high availability for five years, was shut down in April 1993 due to damage of the bottom bearing. Replacement of the bearing is possible but costly, probably marking the end of operations. Hydro-Québec is continuing the development and demonstration of a community-scale wind/diesel system, and is also planning a 5 MW windfarm in Magdalen Islands. In Alberta, one windfarm is in operation and three large windfarms are underway with a total rated power of about 20 MW.

In *Denmark*, about 3 % of the electricity consumption is now generated by wind power. The installed capacity was around 490 MW by the end of 1993. The national goal is 1500 MW by year 2005. Most of the capacity is in small units operated by private investors and cooperatives. Due to local resistance, the utilities are lagging behind the commitments to increase their windfarm capacity. The large prototypes at Nibe and Tjæreborg and the windfarm at Masnedø have operated well during 1993. After a lightning stroke in March 1993, the wooden blades of Nibe B were replaced by new fibreglass blades. The 1MW/50 m prototype at Avedøre, which can be used in both stall and pitch control, is in commissioning. A second offshore windfarm of 5 MW rated power is in the planning stage.

The total wind power in *Germany* is estimated to be about 280 MW at the end of 1993. More than 30 windfarms larger than 1 MW are operational. About 60 % of the capacity is installed under the government-sponsored "250 MW Wind" programme. The government is also supporting research and development on large wind turbines. Several megawatt-sized prototypes are in operation, including the 1,2 MW WKA I and II, the three 640 kW Monopteros, and the 3 MW Aeolus II. The 750 kW HSW 750 was placed into operation during the year. New 500 kW machines are commercially available. Two German manufacturers have started developing 1 MW turbines with innovative components. Under a recent government-sponsored programme, users in southern climatic zones are cooperating with German partners to install wind power in several countries.

The wind energy activities in *Italy* are mainly carried out in cooperation between the ENEL utility, the ENEA research organization, and the Alenia-WEST and Riva Calzoni manufacturers. About 200 wind measuring stations have been set up. Testing of medium-sized wind turbines is conducted at the Alta Nurra test station in Sardinia and at a test station in the Apennines, which is nearly completed. ENEL is building a demonstration windfarm in Sardinia with twenty Medit 320 kW units. Another windfarm will be installed in the Apennines with thirtysix M30-A 250 kW machines. Alenia-WEST is developing an advanced Medit for 400/600 kW, and Riva Calzoni is working on an advanced M30 for 350 kW rated power. Successful tests on the 1,5 MW Gamma 60 prototype at Alta Nurra were completed during the year.

The national wind energy programme in *Japan* is part of the New Sunshine Project. An experimental wind farm of about 1 MW rated power is under construction on Miyako Island, Okinawa. Detailed design of a 500 kW prototype is in progress. The machine will be manufactured by Mitsubishi Heavy Industries Ltd. The programme also includes observation and numerical prediction of wind characteristics, and basic technology research. Five additional 275 kW units will be erected at the first large-scale utility wind farm, erected in 1991 at Cape Tappi, Honshu.

The target in the *Netherlands* is 1000 MW of wind power by the turn of the century. The installed capacity is presently about 125 MW, typically in 1 - 10 MW windfarms with 150 - 500 kW unit rated power. Investment subsidies of the order of NLG 40 million per year are available. Grants corresponding to a total of 60 MW were allocated in 1993. A redesigned version of NedWind's 500 kW turbine has been put on the market. The first prototype of a 1 MW machine will be installed in early 1994. WindMaster has redesigned its 750 kW turbine, and Lagerwey has developed a 250 kW prototype. Technology research on the aerodynamics of stall controlled wind turbines, noise emission, fatigue properties, and turbine design methods is continuing. A feasibility study has started of the industrial development of a stall controlled constant speed wind turbine with elastomeric teetering hub and flexbeam.

The first programme for the introduction of wind power in *Norway* was completed in August 1993 with the installation of two 500 kW Danish wind turbines at the Vikna windfarm which now has a generating capacity of 2200 kW. A second generation wind/diesel system was installed at the test plant on the island of Frøya in the summer, to be followed by a one year test programme, when the system will be serving an autonomous grid with ten domestic consumers. Lightning has caused damage to wind turbines in the coastal zone on several occasions, and a thorough analysis of lightning protection is in progress.

At the end of 1993, the total installed wind power in *Spain* was about 61 MW (up 15,7 MW in 1993) in more than 600 wind turbines, approaching the national goal of 100 MW for 1995. About 33 MW are found in the Tarifa region, about 21 MW in the Canary Islands, and about 5 MW at Cabo Villano, Galicia. The total potential of these areas is estimated at around 650 MW. Two manufacturers, Made and Ecotecnia, have developed several types of wind turbines up to 300 kW rated power, and Made is developing a 500 kW prototype. The research organisation IER of CIEMAT is participating in the testing and evaluation of prototypes, and is performing technology research and wind measurements and modelling.

In *Sweden* about 24 MW (up 8 MW in 1993) of wind power was installed in 121 units at the end of the year, excluding the prototype machines. The installation rate under the government-sponsored market stimulation programme has been slower than expected, in spite of increased subsidies. The 3 MW Näsudden II turbine was connected to the grid in March and has since been in test operation with good availability. A conceptual design study of a third generation Näsudden type machine has started. Successful testing of the Nordic 400 prototype at Lyse was conducted during the year. Detailed design of an upscaled version, Nordic 1000, is near completion. The 3 MW turbine at Maglarp was shut down in June 1993 after twelve years of operation, having generated 36 700 MWh, more than any other single wind turbine so far.

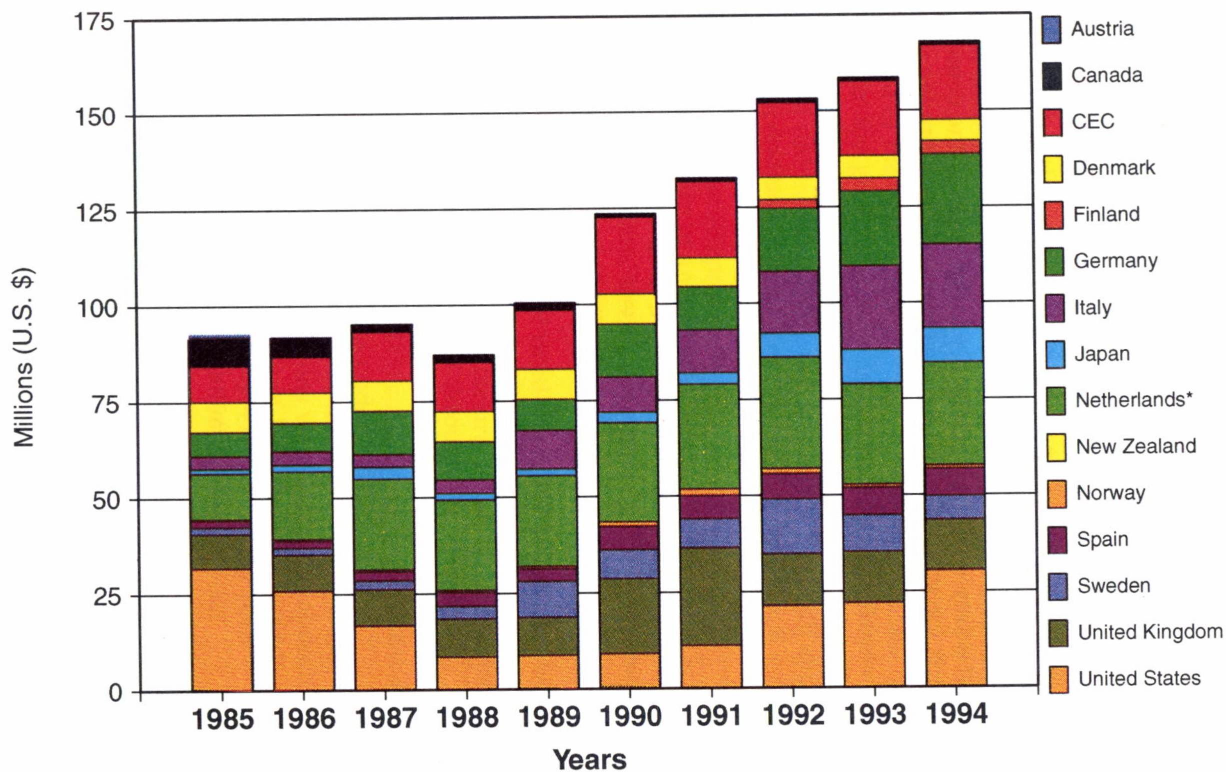
In the *United Kingdom* nearly 120 MW of rated wind power capacity were connected to the grid by the end of the year. About 20 % of the approximately 400 turbines are British manufacture, based on prototype and pre-demonstration machines developed through the national programme. During the year, ten new windfarms were commissioned under the Non Fossil Fuel Obligation (NFFO) subsidy, adding 85 MW of installed capacity. Twenty of the 49 projects under NFFO 2 were operational at the end of the year, and another three windfarms were under construction. Nine planning applications were subject to appeal, the main concerns being noise intrusion, loss of landscape value and electromagnetic radiation. A third round of NFFO for 1994 has been announced, and a Scottish Renewables Obligation (SRO) has been introduced.

In the *United States,* new government incentives and the commercialization of new turbine designs conspire to an expected substantial increase in installations. The completed installations in 1993 were small in capacity but significant in that there was some activity outside California. The first wind power plant in the state of Iowa was dedicated during the year, and construction began on the first 25 MW of Kenetech Windpower's installation of 100 MW of wind turbines in

Minnesota. Work is expected to start soon on plants in the Northwest and in Texas and Maine.

The federal funding of wind technology R&D has nearly tripled since Fiscal Year 1991. The increase in FY 1994 is primarily intended to support the new National Wind Technology Center at Rocky Flats, Colorado, and the Utility Wind Turbine Performance Program. Four prototypes of advanced wind turbines, developed in a collaborative program with utilities and industry, are ready or currently in field testing. Activities for next generation advanced turbines have started. In a new collaborative program, prototype wind turbines will be deployed and evaluated in typical utility environments in diverse regions of the country. Applied research for advanced system development is continuing.

WIND ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION GOVERNMENT FUNDING



Source: International Energy Agency
Wind Energy Systems Agreement
Executive Committee 10/93

*Includes Investment or Operating Subsides

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The IEA R&D Wind Programme

1.1 The Implementing Agreement

The IEA co-operation in wind energy started in 1977. Presently 16 parties, designated by the governments of 14 countries are participating. The co-operation is governed by "The Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems", or IEA R&D Wind for short. The Contracting Parties are:

Austria	The Republic of Austria;
Canada	The Department of Energy, Mines and Resources;
Denmark	The Ministry of Energy;
Finland	The Technical Research Centre of Finland (VTT);
Germany	Forschungszentrum Jülich GmbH;
Italy	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA); and ENEL, Società per Azione;
Japan	The Government of Japan;
Netherlands	The Netherlands Agency for Energy and the Environment (NOVEM);
New Zealand	The Electricity Corporation of New Zealand Ltd.;
Norway	The Norwegian Water Resources and Energy Administration (NVE);
Spain	Instituto de Energias Renovables (IER) of the Centro de Investigación Energetica Medioambiental y Tecnologica (CIEMAT);
Sweden	The National Board for Industrial and Technical Development (NUTEK);

United Kingdom	UK Atomic Energy Authority; Scottish Hydro-Electric plc;
United States	The Department of Energy.

The general objective of IEA R&D Wind is to undertake collaborative R&D projects, called Tasks, and to exchange information on the planning and execution of national large-scale wind systems. Each Task is managed by an Operating Agent, usually one of the Contracting Parties. Overall control of the programme is vested in the Executive Committee, where each Contracting Party is represented.

The Tasks are defined in Annexes to the Implementing Agreement. To-date thirteen Tasks have been initiated. Eight Tasks have been successfully completed. Three Tasks are technically completed but the final reports are pending.

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: US 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 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 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 Decentralised Applications for Wind Energy Operating Agent: UK National Engineering Laboratory Technically completed in 1989. Final report pending.
Task IX	Intensified Study of Wind Turbine Wake Effects Operating Agent: UK National Power plc Completed in 1992
Task X	Systems Interaction Never entered into force
Task XI	Base Technology Information Exchange Operating Agent: Department of Fluid Mechanics, Technical University of Denmark To be completed in 1995
Task XII	Universal Wind Turbine for Experiments (UNIWEX) Operating Agent: Institute for Computer Applications, University of Stuttgart, Germany Technically completed in 1992. Final report pending.
Task XIII	Co-operation in the Development of Large Wind Turbine Systems Operating Agent: National Renewable Energy Laboratory (USA) Technically completed in 1993. Final report pending.
Task XIV	Field Rotor Aerodynamics Operating Agent: Stichting Energieonderzoek Centrum Nederland (ECN) To be completed in 1995

In Tasks VIII and XI, the participants contribute manpower and work - usually in their home countries - to a joint programme coordinated by the Operating Agent. The total level of effort is typically about ten manyears per Task. Tasks XII, XIII and XIV are mixed cost- and task-shared. The participation in current Tasks is shown in Table 1.1.

Table 1.1 Participation per country in current Tasks. OA indicates Operating Agent

Country	Task VIII	Task XI	Task XII	Task XIII	Task XIV
Canada	x	x		x	
Denmark	x	OA		x	x
Finland		x			
Germany		x	OA	x	
Italy	x	x		x	
Japan				x	
Netherlands	x	x	x	x	OA
New Zealand	x	x			
Norway	x	x		x	
Spain	x	x		x	
Sweden	x	x	x	x	
United Kingdom	OA	x		x	x
United States	x	x		OA	x

1.2 Task VIII Decentralised applications for wind energy

This Task was set up in 1985 and has involved ten countries in a task-sharing arrangement, coordinated by the UK National Engineering Laboratory. The overall objectives were to:

- Define cost effective models and techniques suitable for obtaining wind and load data necessary for planning and specifying decentralised wind energy conversion installations;

- Apply and further develop models suitable for analysing the performance of wind-diesel systems.

Nine technical meetings were held during 1985 - 1989, involving about thirty experts from the participating countries. At an early stage a desire was expressed to produce a work of reference which would convey to a wider community the potential difficulties and stage of development of wind-diesel technology. The final report of the Task therefore takes the form of a handbook on the siting and implementation of wind-diesel systems.

A revised draft manuscript of the final report, called *Wind-Diesel Systems*, was distributed to the Executive Committee members and Task participants in September 1991. The authors comprise the foremost experts from the participating countries, who by discussion and information exchange have agreed upon the contents, which include:

1 Wind-diesel options and their applicability
2 Matching the wind-diesel system to the community
3 Assessing the wind resource
4 Designing a system
5 Wind-diesel case studies
6 Modelling techniques
7 Installation and setting up wind-diesel systems
8 Assessing the economics

The Executive Committee has agreed to have the book published on the open market. A contract has been negotiated with Cambridge University Press, who will publish the book and distribute it on the open market. The manuscript was first delivered to the printers in 1992, and has since undergone some editorial changes. The book is expected to be published in early 1994.

Participating organisations

Canada	Department of Energy, Mines and Resources
	Atmospheric Environment Service
Denmark	Risø National Laboratory
Netherlands	ECN Research Centre
New Zealand	NZ Meteorological Service
Norway	Norwegian Electric Power Research Institute
Spain	Instituto de Energias Renovables
Sweden	State Power Board
	Chalmers University of Technology
Switzerland	Federal Office of Energy
	Oekozentrum Langenbruck
	Alpha Real AG
United Kingdom	Rutherford Appleton Laboratory
	National Engineering Laboratory
United States	Department of Energy
	Solar Energy Research Institute
	University of Massachussetts
	Atlantic Orient Corporation

Operating Agent

United Kingdom National Engineering Laboratory

1.3 Task XI Base technology information exchange

The objective of this Task is to promote wind turbine technology by co-operative activities and information exchange on R&D topics of common interest. The Task has two subtasks:

A Development of Recommended Practices for Wind Turbine Testing and Evaluation

B Joint Actions

As part of subtask B, Topical Experts Meetings are arranged, as agreed by the participants, acting in the Executive Committee.

Recommended practices for wind turbine testing and evaluation

The aim of this subtask is to propose recommendations for wind turbine testing to address the development of internationally agreed test procedures. So far, recommendations have been published in eight areas, see Table 1.3.1. The documents are available from the Operating Agent and selected representatives in the participating countries.

A Standing Committee (SC) is reviewing the needs for revising existing recommendations or for preparing new recommendations. The SC takes the necessary steps for setting up ad hoc expert groups, as decided by the Executive Committee, for preparing proposals for revised or new recommendations. The SC met twice during the report period.

A revised edition of Volume 8 Glossary of Terms was published during the year. Work on revised editions of Vol 2 Costing of Wind Turbine Systems and Vol 4 Acoustics made substantial progress. A new document on anemometric issues in power performance testing (power curve) is in preparation.

Joint actions

Joint Actions are set up by the Executive Committee in a specific research area of current interest, where a periodic exchange of information is deemed necessary. The Joint Actions have taken the form of workshops or symposia. Participation is by invitation from the national members of the Executive Committee. So far, four Joint Actions have been initiated:

- Aerodynamics of Wind Turbines
- Fatigue of Wind Turbine Blades
- Offshore Wind Systems
- Wind Conditions/Turbine Loads

In the Joint Action on Aerodynamics, the 7th Symposium was held on 29-30 November at the Technical University of Denmark.

No meetings on Fatigue and Offshore Installations took place during the report period.

The Joint Action on Wind Conditions and Increased Turbine Loads was initiated during the year and will have its first meeting in Spring 1994.

Table 1.3.1 Documents in the series of Recommended Practices for Wind Turbine Testing and Evaluation

Vol	Title	1st Ed	2nd Ed	3rd Ed
1	Power Performance Testing	1982	1990	
2	Estimation of Cost of Energy from Wind Energy Conversion Systems	1983	In prep	
3	Fatigue Characteristics	1984	1989	
4	Acoustics. Measurement of Noise Emission from Wind Turbines	1984	1988	In prep
5	Electromagnetic Interference (Preparatory Information)	1986		
6	Structural Safety (Preparatory Information)	1988		
7	Quality of Power. Single Grid-Connected WECS	1984		
8	Glossary of Terms	1987	1993	
9	Point Wind Speed Measurements	In prep		

Topical expert meetings

Topical expert meetings are arranged once or twice a year, as decided by the Executive Committee. Attendance is by invitation through the national EC member, and the number of participants is limited to a few per country. Proceedings are published by the German Contracting Party, the Forschungszentrum Jülich.

The 24th meeting took place 29-30 April at Risø, Denmark on Wind Conditions for Wind Turbine Design. The 25th meeting was held 3-4 May in Gothenburg, Sweden on Increased Loads in Wind Power Stations (Wind Farms). A complete list of the meetings held so far is shown in Table 1.3.2.

Participating organisations

Canada	Department of Energy, Mines and Resources
Denmark	Department of Fluid Mechanics, Technical University of Denmark
Germany	KFA Jülich
Finland	VTT
Italy	ENEA
Norway	NVE
Netherlands	ECN
New Zealand	ECNZ.
Spain	CIEMAT/IER
Sweden	FFA
United Kingdom	ETSU
United States	Department of Energy

Operating Agent

Department of Fluid Mechanics of the Technical University of Denmark

Table 1.3.2 IEA Wind Energy Expert Meetings

1	Seminar on Structural Dynamics	12 Oct 78	Munich, Germany
2	Control of LS WECS and Adaptation of Wind Electricity to the Network	4 Apr 79	Copenhagen, Denmark
3	Data Acquisition and Analysis for LS WECS	26-27 Sep 79	Blowing Rock, US/
4	Rotor Blade Technology with Special Respect to Fatigue Design	21-22 Apr 80	Stockholm, Sweden
5	Environmental and Safety Aspects of the Present LS WECS	25-26 Sep 80	Munich, Germany
6	Reliability and Maintenance Problems of LS WECS	29-30 Apr 81	Aalborg, Denmark
7	Costing of Wind Turbines	8-19 Nov 81	Copenhagen
8	Safety Assurance and Quality Control of LS WECS during Assembly, Erection and Acceptance Testing	26-27 May 82	Stockholm
9	Structural Design Criteria for LS WECS	7-8 Mar 83	Greenford, UK

Table 1.3.2 Continued

10	Utility and Operational Experience from Major Wind Installations	12-14 Oct 83	Palo Alto, California
11	General Environmental Aspects	7-9 May 84	Munich, Germany
12	Aerodynamic Calculation Methods for WECS	29-30 Oct 84	Copenhagen
13	Economic Aspects of Wind Turbines	30-31 May 85	Petten, Netherlands
14	Modelling of Atmospheric Turbulence for Use in WECS Rotor Loading Calculations	4-5 Dec 85	Stockholm, Sweden
15	General Planning and Environmental Issues of LS WECS Installations	2 Dec 87	Hamburg, Germany
16	Requirements for Safety Systems for LS WECS	17-18 Oct 88	Rome, Italy
17	Integrating Wind Turbines into Utility Power Systems	11-12 Apr 89	Herndon, USA
18	Noise Generating Mechanisms for Wind Turbines	27-28 Nov 89	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

1.4 Task XII Universal wind turbine for experiments (UNIWEX)

UNIWEX is a computer-controlled, two-bladed experimental wind turbine of 16 m rotor diameter installed at the Ulrich Hütter wind test field near Schnittlingen, Germany. The main goals of the project are the experimental study of aerodynamics, operational behaviour, load spectra and control strategies for different hub concepts, as well as the validation of computer codes.

Seven organisations from three countries are participating:

Germany	Forschungszentrum Jülich GmbH (KFA); Institute for Computer Applications (ICA), University of Stuttgart;
Netherlands	Netherlands Energy Research Foundation (ECN); Delft University of Technologie (DUT); Stork Product Engineering (SPE);
Sweden	NUTEK (NE); Aeronautical Research Institute of Sweden (FFA)

Operating Agent: Institute for Computer Applications (ICA), University of Stuttgart.

The work was technically completed in 1992. The main achievements were summarized in the previous Annual Report, which also gives references to the numerous technical reports published. The final report will appear in early 1994.

1.5 Task XIII Cooperation in the development of large-scale wind systems

The purpose of this Annex is to further the development of large wind turbine systems (LWTS) by means of cooperative action and exchange of information on the planning and execution of national LWTS research, development and demonstration programmes. In order to participate in the Annex it is necessary that a country engage in national projects on the development, construction, and operation of at least one LWTS.

A major task under the Annex is the assembly and maintenance of a database of material pertinent to large wind energy systems. The procedure and definitions were agreed upon at a workshop in September 1992. An important component of the organisation for the Task is the network of contact persons in the participating countries, who provide input to the database.

Two Task workshops were convened in 1993. The first meeting was held in conjunction with AWEA Windpower '93 in San Francisco on 14 July. The second meeting was held in Amsterdam on 9 September.

The most important result of the Amsterdam workshop was the unanimous agreement to limit wind farm data to be collected. It was agreed that the EC Member from each participating country together with his one or more contact persons will select a representative sample of wind farms and submit a complete data set for each of them. The meeting recognized that each country works with different constraints, thus each country must be allowed to give its own criteria for the information which it supplies. After choosing the set of representative wind farms, each country will supply an estimate of what fraction of that country's annual wind energy is provided by the chosen sample.

The workshop further agreed on the following particular specifications for the windfarms which shall be selected for reporting:

(a) Total nameplate power of the farm must exceed 1 MW
(b) Only wind farms with turbine diameters 25 meters or more should be selected
(c) The farm must have been brought into operation on or after 1 January 1990.

For the case of prototype machines smaller than one megawatt a special case was made: A new machine of rating less than one megawatt may be described for inclusion if it demonstrates some technical development which is likely to become applicable to large machines.

At the fall meeting of the Excutive Committee it was agreed that the collection, condensation and updating of the extensive data was a large task that need not be continued beyond the present stage. Accordingly, the Task will be terminated at the end of 1993. The final report of the Annex is now in preparation. It is expected that progress in the development of large wind energy systems will continue to be communicated to the regular IEA R&D Wind Executive Committee by its members.

1.6 Task XIV Field rotor aerodynamics

Five parties from four countries are performing aerodynamic field experiments on full scale horizontal axis wind turbines.

The objective of the task is to exchange measured data in order to develop a database for the verification of profile codes, and as a design basis for stall-controlled rotor blades.

The available facilities are the following:

1 **Denmark**
Risø National Laboratory
Rotor diameter 19 m
Measurements of total sectional forces from which aerodynamic forces can be derived at three sections.
Status: operational

2 **The Netherlands**
(a) ECN (Operating Agent)
Rotor diameter 25 m
Pressure tap measurements around profiles at three stations.
Two types of experiments are performed:
* Measurements on a stationary test rig
  Status: operational
* Measurements on a rotating test rig.
  Status: under construction.

(b) Delft University of Technology
Rotor diameter 10 m
Pressure tap measurements at four stations.
Status: operational.

3 **United Kingdom**
Imperial College/Rutherford Appleton Laboratory
Rotor diameter 17 m
Pressure tap measurements at six stations.
Status: under construction

4 **United States**
National Renewable Energy Laboratory (NREL)
Rotor diameter 10 m
Pressure tap measurements around profiles at four stations
Status: operational

Since the start of the project in November 1992, two meetings have taken place between the participating laboratories.

Preparatory meeting on 2 December 1992

The meeting was held at the University of Delft. A workplan was defined. It was agreed that, if possible, three types of experiments will be performed:

(i) Experiments with "constant" (i.e. as constant as possible) angle of attack
(ii) Experiments with a periodic angle of attack variation around a mean value by yaw misalignment
(iii) Experiments with an angle of attack variation by pitch angle variation.

Agreement was also reached on the format and the data which should be supplied.

First meeting on 16-17 September 1993

On the basis of the discussions which took place at the preparatory meeting, a first round of data exchange was defined. The main purpose was to gain experience with the data exchange.

Measurements of the "constant angle of attack" type were supplied to the Operating Agent. The data were then distributed to all participants on MS-DOS floppy discs. The procedure worked satisfactorily, although it turned out that it is difficult to find measurement campaigns where the angle of attack can be considered constant.

The results were discussed at the meeting which took place at Risø National Laboratory. In addition, very useful discussions were held about related subjects, such as the definition and measurement of the angle of attack, corrections which should be applied to the measured data, and possible ways of instrumentation.

As a next step all participants will make a review of measurements which they have available. On the basis of the review, a selection will be made of campaigns, which will be exchanged between the participants. A decision will then also be made about the electronic medium on which the data will be stored.

Conclusions

- Work is underway to generate a database from aerodynamic experiments on horizontal axis turbines.

- A first round of data exchange has been completed.

- The data which have already been distributed are used to verify aerodynamic models

- The Annex serves as a useful forum for the exchange of ideas.

References

J G Schepers; Minutes of the preparatory meeting of the IEA Annex "Field Rotor Aerodynamics", held at the University of Delft on December 2nd, 1992, ECN DE-Memo-92-79, December 1992.

J G Schepers; Minutes of the first meeting of the IEA Annex "Field Rotor Aerodynamics", held at Risø National Laboratory on September 16th and 17th, 1993.

National activities

This chapter reviews the wind energy R&D programmes and the status and prospects of wind energy in the member countries with emphasis on large-scale applications. The review is based on contributions by members of the Executive Committee as indicated in the Foreword.

2.1 Canada

Funding

The Canadian wind energy R&D programme is modest, with annual federal funding of CAD 0,75 million and about 1,5 MCAD from contractors and other sources (approximately 0,57 and 1,15 MCAD, respectively). The programme has four main elements: resource assessment, technology development, test facilities, and technology transfer.

Field trials

Project EOLE

The large EOLE vertical axis turbine operated with high availability (about 94 %) for five years at power levels up to about 2,7 MW, but was shut down in April 1993 when noise was detected from the bottom bearing. Visual inspection showed displacements (sinking) of the bearing and traces of metal in the oil. Replacement of the bottom bearing is possible but the estimated cost is up to 0,5 MCAD, probably marking the end of operations. In its five years of operation, EOLE generated 12 740 MWh of electricity in 18 600 hours.

Christopher Point, British Columbia

The Christopher Point 50 kW VAWT was installed at Christopher Point on Vancouver Island, B.C. in November 1981. Up to 29 October 1003 it had produced 510,6 MWh of energy in about 30 200 generating hours.

Haeckel Hill Project

An 150 kW Bonus was installed on the Haeckel Hill (1450 m height) near Whitehorse in Yukon and was commissioned in August 1993. The turbine has been modified for cold climate and equipped with de-icing devices on the blades to deal with the anticipated icing problems. The machine will be tested for a period of two to three years.

Aerowatts at Igloolik, NWT

Two 10 kW Aerowatt turbines were installed by Public Works of North West Territories (NWT) at Igloolik on the northeast corner of Melville Island (approximately long. 81 W - lat. 69,5 N). These turbines were commissioned in August 1993 and will be monitored for one year by Atlantic Wind Test Site of Prince Edward Islands.

Windfarms

Environmental concerns have raised the interest in wind energy in Canada. In southern Alberta, about 1,5 MW of wind turbines are in operation. Another 9 MW windfarm has been installed and will be connected to the grid by mid-December 1993. Foundations for another 9,9 MW are in place and the turbines will be installed in the spring of 1994.

In Québec, Hydro-Québec has chosen three companies from a long list of companies who have expressed interest to participate. These three have been asked to submit proposals for a 5 MW windfarm on the Magdalen Islands, to be in operation by summer 1995.

High-penetration no-storage wind-diesel

Hydro-Québec is continuing the development and demonstration of a community-scale high-penetration no-storage wind-diesel system at the Atlantic Wind Test Site. Series of tests, which have gone well, have been made with different elements of the system (two diesel units and four different wind turbines), and the ultimate tests with the programmable logic controller (PLC) are underway. The project is scheduled for completion by 31 March 1995.

2.2 Denmark

Introduction

As of 31 December 1992, the total number of grid-connected wind turbines in Denmark, privately as well as utility owned, was 3486 units with a total output capacity of 456 MW. The total 1992 electricity production by wind turbines was 902 GWh which was about 3 % of the annual Danish electricity consumption. Most of the installations are privately owned. About 100 additional privately owned turbines for around 25 MW have been installed during 1993.

The first 100 MW utility programme was fully implemented by the end of 1992. It was expected that a new 100 MW programme would be completed by the end of 1993. This programme is, however, delayed due to serious planning difficulties. Only 10 MW of utility owned turbines will be installed during 1993. Based on 1991 experience, the installation costs, including siting, in the ELSAM area was equivalent to about 1000 USD/kW and the generation costs were about 5 US cents/kWh.

Large scale wind turbines

The Danish programme for the development of large scale wind turbines is sponsored jointly by the national government, the Commission of the European Communities, and the Danish electric utilities. The main achievements have been the installation of large scale prototypes at Nibe, Masnedø and Tjæreborg. Another prototype machine for Avedøre is in the commissioning stage.

The Nibe wind turbines

The two 40 m/630 kW wind turbines at Nibe in northern Jutland, Nibe A and B, were commissioned in 1979/80. Both turbines have three-bladed, upwind rotors with active yawing. The A machine is stall controlled; the B machine has full-span pitch control. In 1988, ownership was transferred from the government to the ELSAM utility.

As of 31 December 1993, the operating statistics were as follows:

Nibe A:	Running time:	9725 hours
	Energy output:	2123 MWh
Nibe B:	Running time:	30 439 hours
	Energy out put	8584 MWh

Nibe A has been in normal operation after refurbishment of the rotor with cantilevered, wooden blades. It is still stall controlled.

Nibe B has been in normal operation since February 1984. At that time the first steel/glassfibre blades were replaced by new wooden blades. On March 1993 one of the blades was struck by lightning, which caused considerable structural damage. Although the two other blades were unaffected, it was decided that the aesiest way to resume operation would be to install a set of new 19 m fibreglass blades from Vestas DWT A/S, identical to those developed for the new generation of 500 kW machines (V 39) from this company. The alternative would be to re-fabricate a wooden blade according to the old specifications, but this solution offered no financial benefit.

The B machine was back in operation by September 1993. It is planned to keep both turbines running for at least another 5-10 years.

The Masnedø windfarm

ELKRAFT Power Company Ltd., the regional power company of Zealand, operates a windfarm, comprising five units of Windane 40, manufactured by Vestas DWT A/S. The site is on Masnedø, a small island close to the southern coast of Zealand.

The main specifications for these machines are similar to those for Nibe B, i.e. 40 m rotor, three-stage gearbox, 750 kW generator, and a 45 m concrete tower. The windfarm was partly funded by the CEC/DG XVII.

As of 31 December 1993, the operating statistics of four of these machines were as follows:

Turbine:	MAV 81	MAV 83	MAV 84	MAV 85
Running time, hrs:	23 111	26 768	28 107	26 376
Energy output, MWh:	6251	6339	7680	7726
Availability, %:	82	95	95	51

The availabilities represent averages for 1993.

The five Masnedø turbines were installed in late 1986, and commissioning progressed well until October 1987, when a fire completely destroyed one of the turbines (MAV 82). It was rebuilt and placed back into operation. In spring 1992 the same turbine experienced an overspeed accident (three times normal rpm), but no serious damage was observed.

Most of the turbines have had gearbox failures, so these components have all been modified. As a safety precaution, the maximum power output of all turbines (reference level) was for a long period limited to 450 kW.

Due to surface cracks in a number of the rotor blades, two of the turbines are now equipped with new wooden blades, and the remaining three machines are provided with new fibreglass blades manufactured by Vestas DWT A/S. (V 39 blades).

The Tjæreborg wind turbine

In 1988, ELSAM, the regional power company of Jutland and Funen, commissioned a 60 m/2 MW wind turbine at Tjæreborg south of Esbjerg on the west coast of Jutland. This machine has a 60 m upwind rotor with three pitch-controlled, cantilevered 30 m fibreglass blades and a 1:68 epicyclic gearbox. The 2 MW generator is of the induction type. The 60 m tower is made of concrete.

As of 31 December 1993, the machine has operated for 16 617 hours and generated 11 610 MWh of electricity. During 1992-1993, outage time has been caused mainly by planned maintenance work. The average availablity for these years has been 84 %, and the operating hours have been about 55 % of time. In the previous years, problems related to the gearbox and control computer had to be solved.

As a condition for CEC/ DG XII funding, ELSAM has agreed to keep the plant in operation at least until the end of 1994.

The Avedøre wind turbine

ELKRAFT has designed a 50 m/1 MW wind turbine with blades that can be used in both pitch and stall control. Hub height is 55 m. The site is at Avedøre power station, 10 km south of Copenhagen. This project is also financially supported by the CEC.

The machine is now (December 1993) in commissioning. The turbine will in the first year be operated in the stall mode. Then some minor mechanical modifications will be made in order to change the operational mode to pitch control. A measurement system will collect all relevant data during both periods.

At an early stage, it was also planned to operate the machine at variable speed, but this idea was later dropped due to the extra costs involved.

The annual electricity generation is estimated to be about 1,5 million kWh.

The Tvind wind turbine

The downwind, three-bladed Tvind wind turbine was inaugurated in 1978. It was built near Ulfborg in the northwestern part of Jutland by pupils and teachers from the Tvind School aided by consultants, subcontractors and voluntary helpers.

The three fibreglass blades are fully pitch controlled and have parachutes in their tips for emergency braking. The rotor diameter is 54 m and the rotor speed varies between 14 and 24 rpm. The machine is equipped with a 2 MW synchronous generator, but for various reasons the maximum output is limited to 900 kW. The tower height is 53 m.

On 31 May 1993 one of the blades suddenly broke and fell to the ground. A later inspection revealed that the fracture was in the fibreglass at the point where the spar is connected to the steel flange at the hub. At the time of the accident, the machine was in normal operation with a rotational speed of 15-16 rpm and a power level of about 200 kW.

The turbine has no hour-meter, but the number of accumulated hours of operation is estimated to be about 50 000. The average energy production has been about 1000 MWh per year. A counter on the main shaft has accumulated 53×10^6 revolutions.

It was soon after decided that the best way to resume operation would be to install a set of new fibreglass blades identical to the old ones as far as the airfoil is concerned.

The machine will, presumably, be back in operation by January 1994.

Small scale wind turbines

Statistics

As of 31 December 1992, the total number of privately owned wind turbines in Denmark was 2982 units totalling 348 MW installed capacity and supplying 715 GWh during the year. The corresponding figures for utility owned turbines were 504 units, 108 MW and 187 GWh per year.

The total increase in 1993 is expected to be about 35 MW. The increase in export during 1993 is assumed to be about 50 % in turnover as compared to 1992 when 506 turbines with a capacity of 121 MW were exported.

The official target for year 2005 is 1500 MW of installed capacity in Denmark.

Technology

The latest development trend shows that the well-known "Danish design" is unchanged: three-bladed, upwind rotors, active yawing and induction generators connected to the low-voltage level of 380 volt. Stall regulation is still the most common means of power limitation, although pitch control is increasing.

The power range is rapidly expanding. Machines with ratings of 400 to 500 kW are now commercially available. The utilities have asked for tenders of 1 MW machines, so this machine size is expected to be included in the range of commercially available machines rather soon. The prototypes are financially supported by the CEC.

Accounting rules

The development of private, small scale wind turbines is no longer promoted by public installation subsidies. Reasonable payback rates and exemption from electricity taxation are now the main economic incentives.

On 1 November 1992, new accounting rules for wind generated electricity came into force. The electric utilities now pay private wind turbine owners about DKK 0,60 (≈ USD 0,088) per kWh delivered to the grid. This amount is calculated as follows: 85 % of pretax selling price to private consumers plus a generation credit of DKK 0,27 per kWh. This credit is considered to be partial reimbursement of the carbon dioxide and general electricity taxes paid by private consumers (DKK 0,10 + 0,17 per kWh, respectively).

The average consumer price for a Danish low-voltage customer consuming about 3000 kWh per year is about DKK 1,00 per kWh (USD 0,147 per kWh), including taxation and VAT.

Utility windfarms

Traditionally, Danish wind turbines were erected as individual units. Since 1984, however, many wind turbines have been installed in windfarms. These windfarms are distributed all over the country, and most of them are owned by the electric utilities.

In 1985, an agreement was reached between the Danish government and the electric utilities, committing the utilities to install 100 MW in windfarms over the next five years. This agreement was fully implemented by the end of 1992, 45 MW in the ELKRAFT area and 55 MW in the ELSAM area.

The 1985 agreement has been followed by another 100 MW agreement (1990 agreement) to be implemented before the end of 1993. As a first step, a joint government and utility committee in cooperation with local authorities has recommended a number of suitable sites. Despite this, the implementation of the 1990 agreement has been delayed at least one or two years due to local opposition to wind turbines. Various means to overcome this obstacle are under consideration.

Main data for both private and utility windfarms are listed in Table 2.2.1, and the locations for the utility farms are indicated in Figure 2.2.1. Only systems with five turbines or more are included. As part of the 1985 agreement, the utilities have also installed a number of prototypes and small clusters of turbines distributed all over the country. This adds about 8 MW to the installed capacity in the ELKRAFT area and about 6 MW to the capacity in the ELSAM area. Vindeby is an offshore windfarm and is described in the next section.

For the ELSAM area, the experience can be described as follows: The cost of energy (per kWh) for windfarms installed in the period 1987-1989 was in the range DKK 0,50-0,60 (USD 0.073-0,088). During 1990-1992 the range was DKK 0,38-0,45 (USD 0,056-0,066). The projected energy cost level for the next generation of windfarms is approximately DKK 0,30-0,40 (USD 0,044-0,059). This projection is based on recent tenders to the utilities and is related to machines with a power capacity of about 500 kW. Figures 2.2.2 and 2.2.3 illustrate the development over recent years for the installation costs and the cost of energy.

Offshore windfarms

The first Danish offshore windfarm was commissioned in mid-1991. The site is in the ELKRAFT area at Vindeby, northwest of Lolland in the Baltic Sea. The windfarm consists of a total of 11 wind turbines in two rows, see cover picture. The water depth varies between two and six meters. The distance from the shoreline ranges from 1200 to 2400 m, and the distance between turbines is approximately 300 m. Each turbine is rated at 450 kW, and the hub height and rotor diameter are respectively 37,5 and 35 m.

Although the specific energy output is expected to be about 60 % higher than for average onshore sites, or about 1130 versus 700 kWh per year and m^2 of swept rotor area, the cost of energy produced by this prototype windfarm (USD 0,092 per kWh) is estimated to be 50 % higher than for average inland sites. The total cost of the project, including a two-year measurement programme, was USD 12,5 million. The reported availability is higher than 96%.

A second offshore windfarm to be built by ELSAM is in the planning phase. The selected site is in the area between Jutland and Samsø.

Installed capacity will be 5 MW, and the projected cost is about USD 13,3 million.

Environmental aspects

Acoustic noise

In Denmark a statutory order was issued by the Ministry of the Environment in 1991. Accordingly, the owner of wind turbines shall prove to the county council that the noise level from the wind turbines shall not exceed present limits. This proof shall be given prior to the installation of one or more wind turbines and shall be based on a prediction of the noise level according to a given, simple propagation model. A simple method for calculation of the noise emission (source strength) of the chosen wind turbine type is also given in the order. If the county has not objected to the development project within four weeks, construction can start, provided that all other permissions have been granted.

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.

Up to now only one wind farm (Kyndby) has given cause for complaints about acoustic noise and, altogether, the authorities have received complaints about noise from less than two percent of the country's 3500 wind turbines. Tonal noise (pure tone noise) from gearboxes is often a source of annoyance, so 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.

Wind turbines and bird life

The impact of wind turbines on bird life has been studied in relation to both the Nibe turbines (1984) and the Tjæreborg wind turbine (1986-1990). In the first study it was concluded that no bird bodies were found which have been attributed to collision with the turbines. In the second study the death of seven birds could with some certainty be said to have been caused by collision with either the turbine itself or one of the two meteorological masts. Radar observations at this site during night hours showed that in general birds are able to detect and avoid the wind turbine.

The general conclusion from the latest study is that compared with other human activities, such as farming and car driving, a wind turbine in a bird sanctuary (Tjæreborg) does not have any especially significant impact on bird life, though it does affect it. The birds in question - not birds of prey - but all kinds of waterfowls, waders, seagulls etc. just seem to move away from the turbine for breeding, staging and foraging. There is some evidence, however, that when construction and commissioning are over, the birds get familiar with the wind turbines and tend to move back.

Conclusions

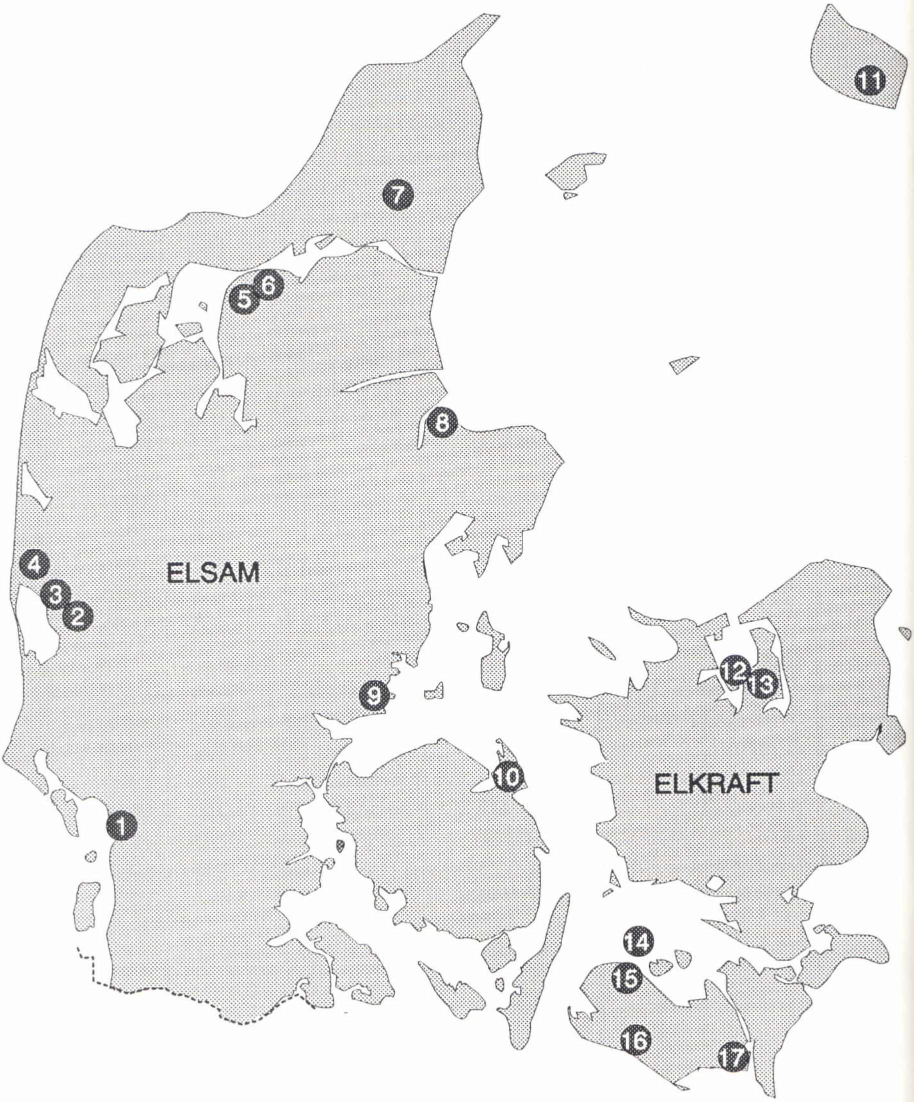
Despite all problems reated to the implementation of the government's "Energy Plan 2000", aiming at 1500 MW of wind power by 2005, efforts are being made to solve them. Much research work is funded, and a combination of agreements with the utilities and production subsidies to private persons and cooperative societies is applied to establish and maintain a Danish home market.

A machine size of about 500 kW is in the commercial stage with the projected cost of energy for planned windfarms close to USD 0,05 per kWh. The installation costs, including siting, will be around 1000 USD per kW.

In two years time it will be of interest to note the cost level of the planned 1 MW prototypes now being designed by the manufacturers as a result of calls for tenders by the utilities.

Table 2.2.1 Windfarms in Denmark 1992

Location	Manufacturer	Number/-Capacity	Total MW	Siting Year
Oddesund Syd	Bonus	25 x 95 kW	2.4	1985
Oddesund Nord	Bonus	10 x 55 kW		
	Vestas	10 x 55 kW	1.1	1985
Sydvestmors	Vestas	10 x 75 kW	0.8	1985
Tændpibe	Vestas	30 x 75 kW	2.3	1986
Fanø	Vestas	13 x 55 kW	0.7	1983
Ærø	Vestas	11 x 55 kW	0.6	1985
Ebeltoft	Nordtank	16 x 55 kW	0.9	1985
Hasle	Blacksm.	10 x 100 kW	1.0	1986
Ranum	Vestas	14 x 75 kW	1.1	1985
Åle	Wind Matic	10 x 75 kW	0.8	1985
PRIVATE WINDFARMS: 11.7 MW				
Syltholm 1-3	Vestas/DWT	25 x 400 kW	10.0	1988/90
Kyndby	Danwin	21 x 180 kW	3.8	1988
Øster Marie	Danwin	7 x 225 kW	1.6	1990
Kappel	Vestas/DWT	24 x 400 kW	9.6	1990
Orø	Micon	5 x 200 kW	1.0	1991
Vindeby	Bonus	11 x 450 kW	5.0	1991
Nøjsomhed	Vestas/DWT	23 x 225 kW	5.2	1992
UTILITY WINDFARMS, ELKRAFT AREA: 36.2 MW				
Hollandsbjerg	Nordtank	30 x 130 kW		
		2 x 300 kW	4.5	1988
Ryå	Wincon	20 x 99 kW		
		3 x 200 kW	2.5	1988
Nørrekær Enge 1	Nordtank	36 x 130 kW	4.7	1988
Nørrekær Enge 2	Nordtank	42 x 300 kW	12.6	1990
Torrild	Bonus	15 x 150 kW	2.3	1989
Velling Mærsk 1	Vestas	34 x 90 kW		
	Vestas	2 x 200 kW	3.5	1987
Velling Mærsk 2	Vestas	29 x 225 kW	6.5	1990
Vedersø Kær	Vestas	27 x 225 kW	6.1	1990
Dræby Fedsodde	Wind World	11 x 220 kW	2.4	1991
Brøns	Micon	8 x 400 kW	3.2	1992
UTILITY WINDFARMS, ELSAM AREA: 48.3 MW				



ELSAM-area:

1. Brøns
2. Velling Mærsk 1
3. Velling Mærsk 2
4. Vedersø Kær
5. Nørrekær Enge 1
6. Nørrekær Enge 2
7. Ryå
8. Hollandsbjerg
9. Torrild
10. Dræby Fed

ELKRAFT-area:

11. Øster Marie
12. Orø
13. Kyndby
14. Vindeby
15. Nøjsomhed
16. Kappel
17. Syltholm

Figure 2.2.1 Location of utility windfarms in Denmark

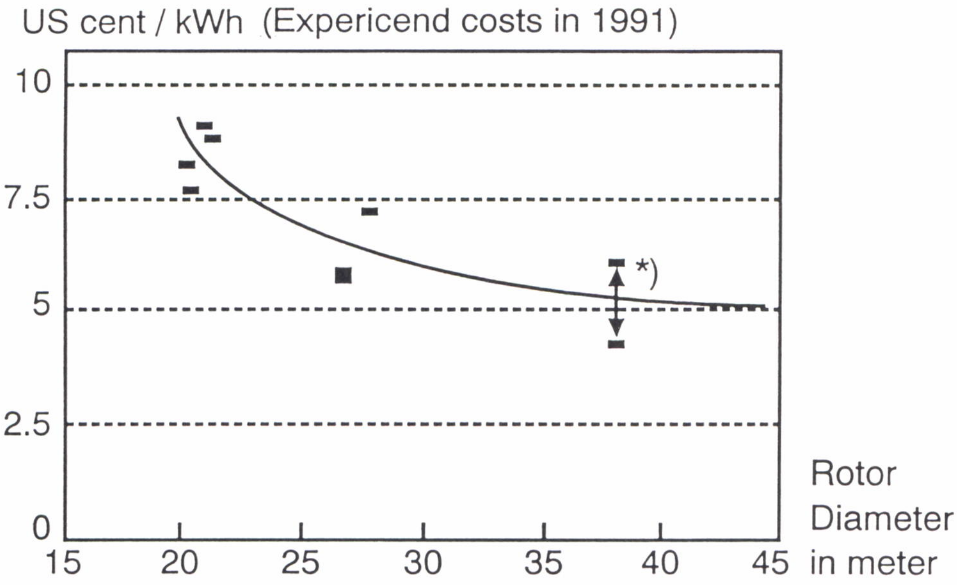


Figure 2.2.2 ELSAM: Development in production costs
* Prices based on recent tenders

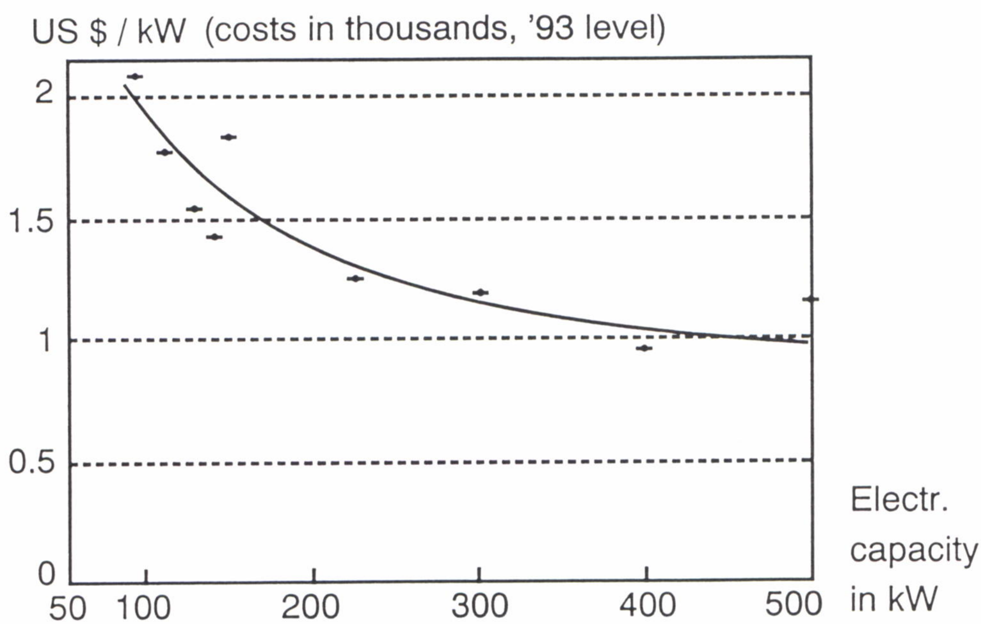


Figure 2.2.3 ELSAM: Development in installation costs

2.3 Germany

Introduction

The Federal Ministry for Research and Technology (BMFT) supports the use of wind energy since 1974. In particular, energy economy goals are being aimed at, i.e. contributing perceptibly to the electricity supply at acceptable costs in the longer run, reducing the energy imports and broadening the basis of energy supply. The goals also include considerable supply of a growing number of people in the Third World. Moreover, particular significance is attached to reducing loads on our environment and climate [1, see reference list p 49].

The goals in energy economy are to be achieved by a further development of wind energy conversion technology. The costs of electricity from wind energy converters (WECs) are to be reduced to such a level that these machines may be competitive by the end of the century. This goal is apparently not easy to achieve, but considerable progress has been made since 1974.

After a phase of basic and applied research and the testing of first generation prototypes, initial demonstration programmes were launched to test technical reliability on a larger scale. A large variety of WEC types, rated between 5 and 300 kW was installed with seven major demonstration projects which included four windfarms. From 1983-1992 a total of 214 WECs was supported, having a total rated power of 14,5 MW (Table 1, p 59).

These demonstration projects formed an adequate basis for the "*250 MW Wind" - Programme* offered since 1989 [2]. This programme is additionally being supported by the German Federal States and in two cases by the CEC. It provides for additional earnings exceeding the legally stipulated payment of currently around 0,17 DEM per kilowatthour of electricity fed into the grid. In the German coastal region, medium-sized WECs can now already achieve an annual electricity production at a cost of approximately 1 DEM/kWh relative to plant price ex works. This is a clear improvement in comparison with the results of earlier demonstration programmes with greatly scattering figures around 2 DEM/kWh and year.

BMFT's support of *R&D* reflects the tendency towards wind energy converters of increasing rated power. It should be pointed out that, in accordance with all predictions, the existing potential in the densely populated country can be best exploited by large WECs. Experts of the advisory committee the "Ad-Hoc Committee on Large Wind Energy Converters" emphasized that the electriciy production costs of future WECs in the MW range may already be comparable to those of current commercial WECs on a medium-term basis, although considerable expenditure on R&D and testing must be involved.

A further support programme, called *ELDORADO,* offers German manufacturers the possibility of implementing WECs in countries with different climatic conditions.

"250 MW Wind" Programme

Interest is currently focused on the "250 MW Wind" programme for wind energy utilization. In conjunction with a scientific measuring and evaluation programme WMEP [4], the data from supported WECs are being recorded and evaluated over a period of ten years. As an incentive and compensation for their participation in the test, the operators receive financial support from the BMFT, which normally depends on the amount of electricity produced. This also motivates operators to keep their machines as long as possible in well operating conditions.

Until 31 October 1993 around 1300 WECs have been approved and 954 units have been installed with a rated capacity of 158,6 MW, see Figure 1, (p 50). The average rated power is 166 kW per unit. In 1992, 197 million kWh were generated with "250 MW Wind" machines.

Figure 2 shows that most of the wind power is produced in two German coastal states with turbines of about 300 kW rated power. Figure 3 shows a result of WMEP's Annual Report 1992 [4]: The regional distribution of annual electricity production as a function of rated power class. The turbine availability was recorded by WMEP to be 98 % in 1992. Examples of failure statistics are given in Figure 4. Figure 5 shows an example of a wind farm operating in the "250 MW Wind" programme.

Research and developemnt

In this activity the BMFT has concentrated on the further development of WECs in the MW range. The development of MW units started in the second half of the eighties and has already led to the second generation of large WECs, see Table 2 (p 60). They comprise the 1,2 MW WKA 60 (three blades, 60 m rotor diameter, on the island of Heligoland), WKA 60 II of the same size at Kaiser-Wilhelm-Koog, the three Monopteros machines (640 kW, 50 m, one blade) in Wilhelshaven, and the HSW 750, erected this autumn, Figure 6. The total energy production of WKA 60 until August 1993 was 5,4 MWh, corresponding to a total running time of 30 491 h with 10 795 h grid-connected. The second generation turbines also include AEOLUS II (80 m, two blades) with 3 MW rated power, erected last year at Wilhelmshaven, Figure 7. None of the large-sized machines has so far been operated other than as a prototype. Other medium-sized machines are now commercially available, se E-36 (now E-40) and TW 500 in Table 2.

Two German companies started developing 1 MW WECs in order to obtain the economy of commercial medium-sized WECs on a relatively short-term basis. This was to be achieved by incorporating innovative concepts and components. One manufacturer intends to use a design with vertical rotation axis (H-rotor). This WEC works with a special generator without gearbox. A similar gearless concept, combined with an advanced electronic control system, is envisaged by the other manufacturer for a horizontal axis converter. Both manufacturers are supported by the JOULE II programme of the CEC, see Table 2.

Besides the development of LS WECs, other R&D projects aim at further development of the knowledge of wind (special measurements with towers, wind in complex terrain), modelling of the power behaviour of windfarms, offshore installations etc. A wind powered seawater desalination plant is being further developed with a new plant of 15 m^3/h capacity drinking water, achieved by a 200 kW stall controlled wind turbine as power source. Altogether 20 R&D projects are funded by BMFT in 1993. A short summary of these projects is given in Table 3.

Use of wind energy under different climatic conditions

According to a study by the World Bank, almost 50 % of the inhabitants in developing and threshold countries do not have access to central supply grids for electricity, oil, gas etc. They may be assisted by decentralized concepts, and renewable energies are considered to be one option for decentralized energy supply. Against this background, BMFT projects are targeted at the following main applications:

- WECs grouped in windfarms and connected to a grid: either for fuel conservation in a weak diesel-based grid, or for additional electricity production in extended grids.

- WECs in stand-alone operation or in combination with diesel units for the supply of individual consumers such as water pumps, drives for agricultural equipment, and village power supply.

Especially worth mentioning is a project, operated from 1984 to 1993, by the Kreditanstalt für Wiederaufbau (KfW) on behalf of the BMFT. Fortynine WECs, each with a rated power of 30 kW, operate in seven windfarms connected to small isolated grids, see Table 4.

Recently BMFT launched the indirect-specific support programme "ELDORADO Wind" which is being carried out jointly with several partner countries [3]. The type of support selected by BMFT is intended to motivate users in southern climatic zones to construct and operate WECs in cooperation with German partners. The aim is to achieve an installed power of 20 MW in these countries within the next five years on the basis of findings derived from domestic measures. Response to the ELDORADO programme is surprisingly positive. Several projects have already been started, see Table 5.

Short statistics: Status and development of wind power in Germany

In the statistics above only the status of the "250 MW Wind" programme is described. By 30 June 1993 altogether in Germany 1436 wind turbines with 233,5 MW rated power are in operation, see DEWI [6]. From these figures an average rated power of 162,6 kW per unit is calculated. DEWI estimates that *280 MW of rated power will be in operation at the end of 1993 in about 1550 turbines.*

A comparison with WMEP data by 30 June 1993 shows that 58 % of the wind power is supported by the "250 MW Wind" programme. The rest is supported by the German "Länder" alone, by the CEC or are without public support.

According to windfarm statistics by 30 June 1993 from DEWI, *30 windfarms with more than 1 MW* were in operation, including the installations "Jade Windpark" and "Kaiser-Wilhelm-Koog". The total rated power was *89,2 MW*, 55 MW of which were supported by "250 MW Wind" [4]. With the figures given above it is estimated that 38 % of German wind power is in windfarms larger than 1 MW. In addition, 32 installation with three or more units and a total rated power of 20,3 MW, which means that 53 % of the installed power, were "stand-alone" turbines with less than three units. Figure 8 shows a further example of a windfarm.

In [6] the shares of the suppliers on the German market are recorded. This analysis as well as that of WMEP shows a great variety with more than 40 different turbines from about 20 different European manufacturers.

New licensing procedure in Germany

The government has passed a law aimed at simplifying and accelerating procedures for major investment and construction. The law covers areas like road construction and other industrial projects and includes wind turbine inatallations. As of June 1993, turbines of more than 300 kW power no longer require a licence under the Federal Law on Protection against Emissions. As a consequence, wind turbines are no longer covered by the Noise Act of this Law. They will instead be subject to another guideline which defines noise limits set according to state-of-the-art technology for installations not covered by the Law. Building permission will be required by local building supervisory boards.

Funds and outlook

The BMFT has so far spent about DEM 300 million for the promotion of wind energy [1]. In addition, several tens of millions DEM have been spent on cooperation with countries of southern climatic zones. Approximately DEM 120 million was spent on large WECs, roughly 100 million on the promotion of small and medium-sized machines, and the remainder on other R&D projects, including the "250 MW Wind" programme. The expenditure for the 250 MW Wind programme is about 51 million up to date.

The BMFT funding for 1993 is:

250 MW Wind programme	DEM 22,8 million
R&D, including WMEP	8,6
Use of wind energy under different climatic zones	5,6
Total	DEM 37,0 million

Additional funding is available from by the German States and the CEC for R&D and demonstration projects. It should be mentioned that the States support wind energy activities of universities and special institutes like DEWI (Lower Saxony). This additional support may be of the same order as that of the BMFT.

The "250 MW Wind" is a long-term programme, since every WEC will be scientifically evaluated over a period of 10 years, including WECs put into operation in 1996 and 1997. When the programme ends, roughly DEM 320 million will probably have been spent, excluding the WMEP measuring programme. The subsidy is 0,06 DEM/kWh if wind energy is fed to the public grid, and 0,08 DEM/kWh for the owner's own consumption. The subsidy ends after ten years or after two times of the investment is regained by the avoided electricity costs, by the income from electricity fed into the public grid (0,166 DEM/kWh by law) and by all public subsidies including state and CEC subsidies. In certain cases, i.e. for non-trade and industry bodies or private individuals, an investment subsidy of at most 60 %, but not more than DEM 90 000 may be obtained.

BMFT funds for separate R&D projects should also be available in the future. For small and medium-sized WECs, however, the level of development is already very advanced, so that further debelopment will generally be financed by the manufacturers themselves. Interest will probably focus on large units with the goal on further reducing the costs of wind power, e.g. by increased service life, improved technical reliability, and reduced plant costs as well as optimum integration into the electricity grid.

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[1] Renewable Energy, The Federal Minister for Research and Technology, D-53170 Bonn.

[2] Full Guideline, published by Bundesanzeiger No 37, 22 Feb. 1991, p 920f.

[3] Full Guideline, published by Bundesanzeiger No198, 23 Oct. 1991. English translation available from BEO, Dept 13, KFA, BEO D-52425 Jülich.

[4] Annual report and monthly reports (also in English), available from ISET, Königstor 59, D-34119 Kassel.

[5] Annual Report "Energieforschung und Energietechnologie". Fachinformationszentrum Karlsruhe, D-76012 Eggenstein-Leopoldshafen.

[6] DEWI-Magazin 3, August, available from Deutsches Windenergie-Institut, Ebertstrasse 96, D-26382 Wilhelmshaven.

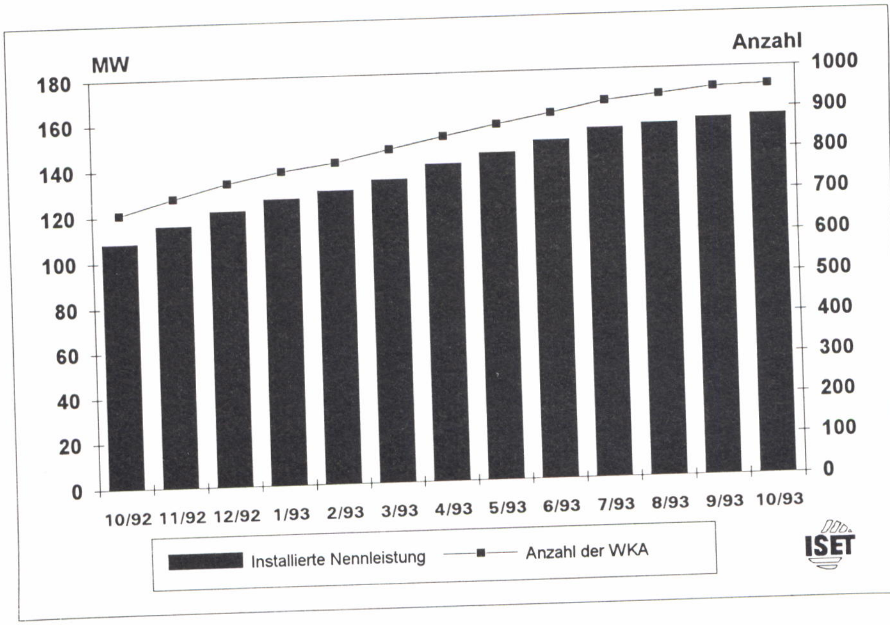


Fig. 1: **"250 MW Wind"-Programme/WMEP. Installed rated power and number of WECs by Oct 31, 1993**

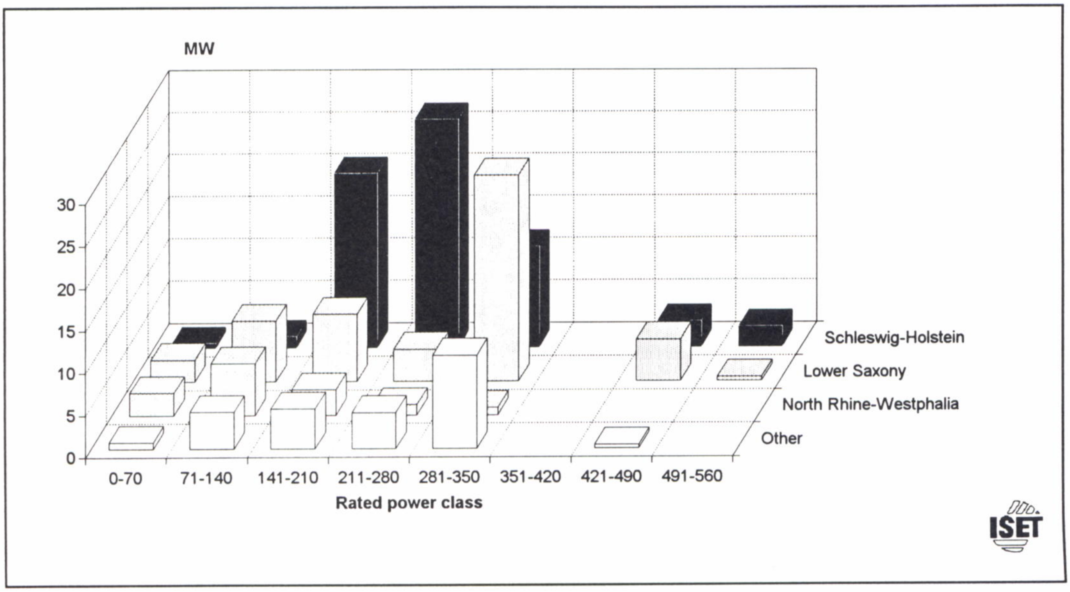


Fig. 2: **"250 MW Wind"-Programme/WMEP. Regional distribution of rated power by Oct. 1993.**

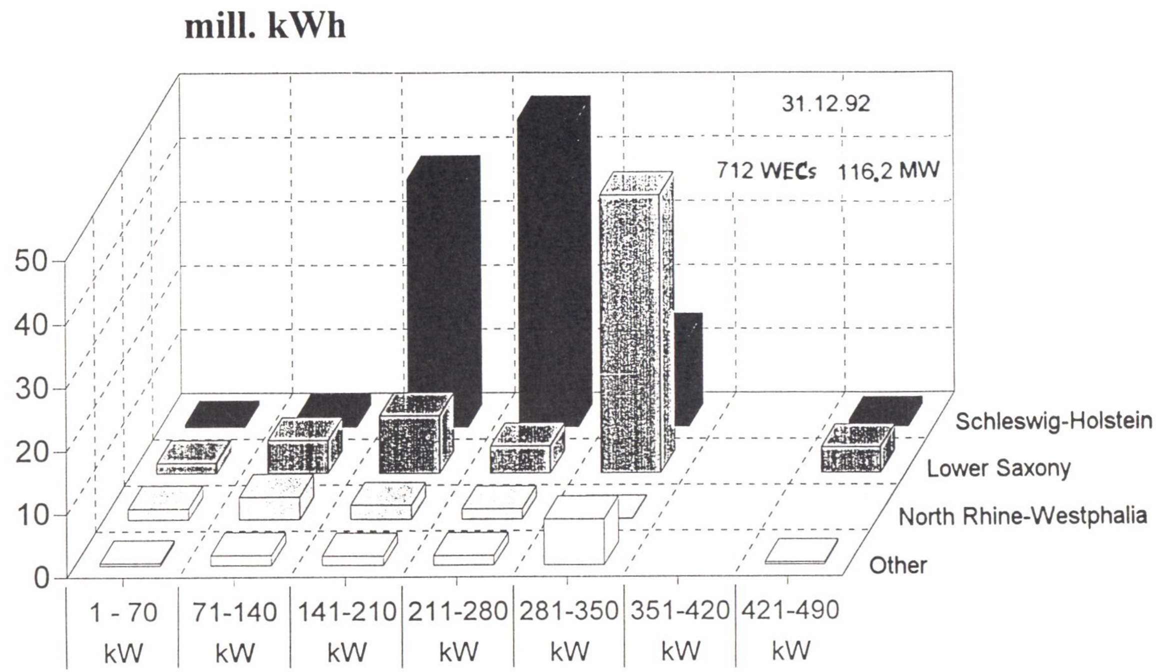
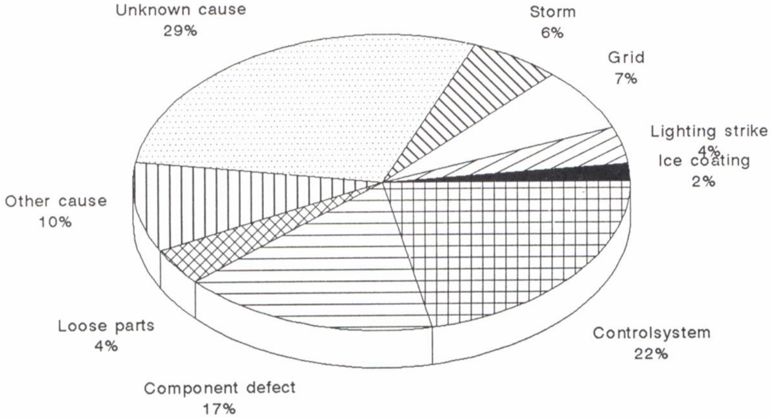
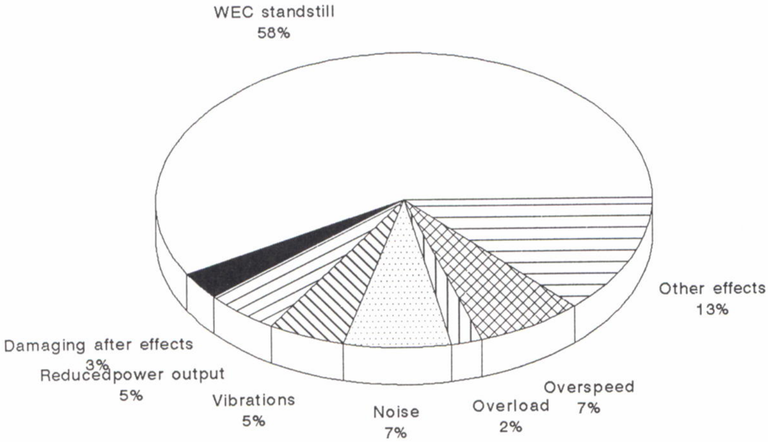


Fig. 3: **"250 MW Wind"-Programme/WMEP. Regional distribution in 1992 of annual electricity production as function of rated power. Total in 1992: 196.665 mill. kWh**



Failure effects



Repared or exchanged components

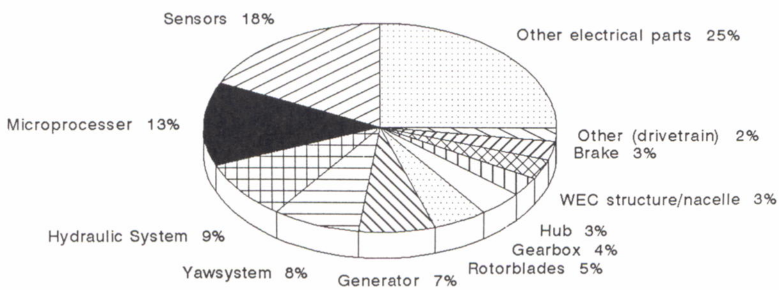


Fig. 4: "250 MW Wind"-Programme/WMEP. Examples of failure statistics 1992.

Repaired or exchange parts	Number
Hub	49
Hub Body	3
Blade Adjustment	36
Blade Bearings	7
Others	3
Rotor Blades	66
Blade joints	4
Blade body	25
Tip Brakes	13
Others	24
Generator	6 2
Winding	8
Collector/Brushes	7
Bearings	19
Others	28
Other electrical	336
Inverter	40
Fuses	94
Contactors/Switches	104
Cables	38
Others	60
Sensors	178
Windspeed & Windirection	69
Vibration	25
Temperatur	16
Oilpressure	18
El. Power	5
RPM	26
Others	19
Other Control & Supervision	248
Microprocessor	170
Relays	27
Wiring/Contacts	15
Others	36
Gear Box	61
Bearings	3
Gearwheels	5
Gear shafts	2
Sealings	28
Others	23
Mechanical Brake	48
Brake Disk	3
Brake Lining	19
Bremssattel	5
Others	21
Other (Drive Train)	25
Rotor Bearings	5
Shafts	4
Coupling	11
Others	5
Hydraulic System	128
Hydraulic pumps	21
Pumpdrive	7
Valves	39
Hydraulic pipes	8
Others	53
Yaw System	115
Azimut Bearing	24
Motor	27
Gear	10
Others	54
WEC Structure	37
Foundation	1
Tower	14
Nacelle structure	5
Nacelle cover	9
Others	8

Fig.

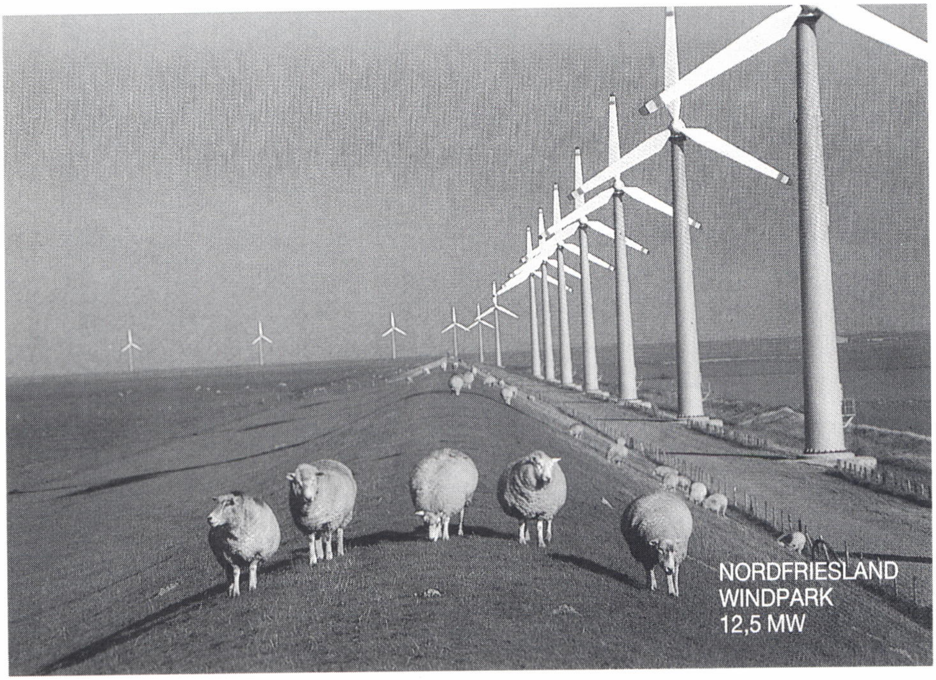


Fig. 5: **12,5 MW "Nordfriesland Windpark" of the owner Nordfriesland Windpark GmbH & Co. KG. 50 HSW-250 wind turbines, erected 1991/91.
The 1992-annual electricity production was 29 mill. kWh. Site is the Friedrich-Wilhelm-Lübke-Koog neer the Danish border with mean anual wind speed at hub height around 8 m/s.**

Fig. 6 HSW 750 at the Kaiser-Wilhelm-Koog test facility. Rotor diameter 40 m, hub height 45 m. Mean anual wind speed at hub height 7,0 - 7,5 m/s.

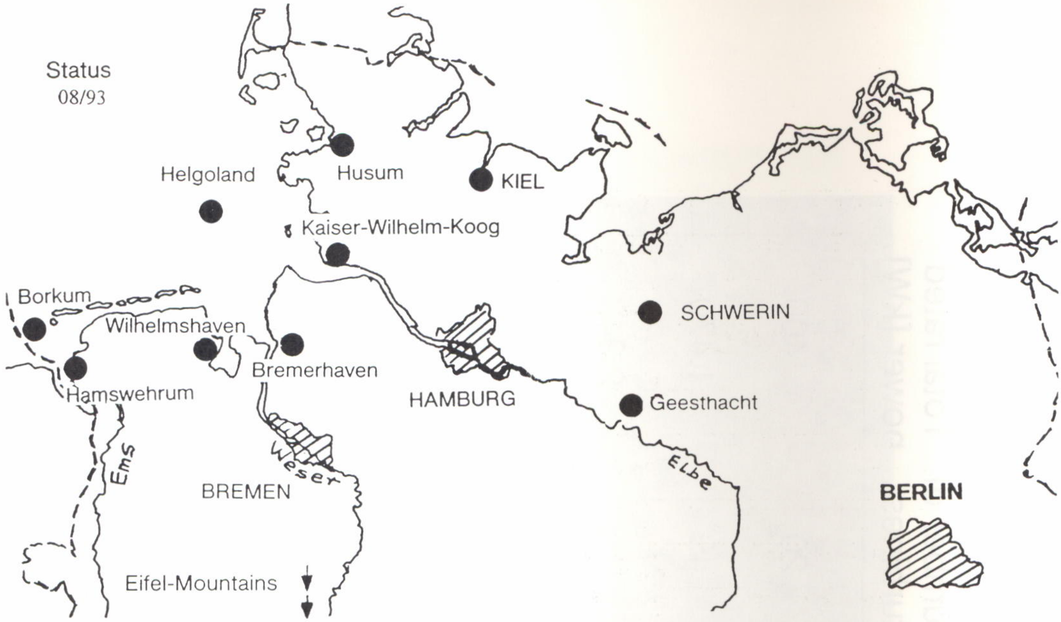
Fig. 7 AEOLUS II, Jade Windpark near Wilhelmshaven. Mean anual wind speed at hub height is around 7,5 m/s.

Fig. 8

3 MW "Windenergiepark Krummhörn-Pilsum" of the owner EWE Aktiengesellschaft. 10 "Enercon 32" wind turbines, erected 1989/90 in two phases. Mean anual wind speed at hub height around 7,5 m/s. With two further wind farms EWE is one of the leading utilities using own wind power. With a total power of 8.4 MW (28 turbines) more than 22 MWh electricity were generated 1992.

Project	Period	Number of turbines	Total rated power [kW]
Application of small WECS in Germany (MAN)	83–86	20	400
Test of WECS in Developing countries (KfW)	84–93	49	1.470
DEMO Program 250 kW (13 manufactures)	86–87	48	2.943
DEMO Program 80–800 kW (5 manufactures)	87–90	25	3.650
Windfarm Westküste (Windf. Westk. GmbH)	86–89	32	1.330
Windfarm Cuxhaven (ÜNH)	87–88	25	1.000
Windfarm Husum (City of Husum)	90–92	15	3.750
		214	14.543

Table 1: **Demonstration projects of small and medium WECs.**



Typ	Location ●	Power	Realization
MON 50	Wilhelmshaven	3 à 640 kW	Summer 89
WKA 60 AWEC 60	Heligoland Cabo Villano (Spain)	1.2 MW 1.2 MW	Antumn 90 Summer 89
AEOLUS II WKA 60 II	Wilhelmshaven Kaiser Wilhelm-Koog	3 MW 1.2 MW	Spring 93 Autumn 91
HSW 750	Kaiser Wilhelm-Koog	750 kW	Autumn 93
E-36	Hamswehrum	400 kW	Spring 92
TW 500	Borkum	500 kW	Summer 92
E-40	Geesthacht	500 kW	94
E-55	Northern Germany	1.0 MW	95
H-1200	Eifel-Mountains	1.2 MW	95

Table 2: Prototypes with rated more than 400 kW in Germany

Title of Project	Contractor	Period	Total Costs in mill. DM	BMFT-Contribution [%]
Wind powered seawater desalination	Rügenwasser GmbH	01.06.93-31.05.97	3.401,8	70
AEOLUS II	PreussenElektra Windkraft NDS	01.09.89-31.12.93	21.375,5	20,51
Wind/solar supported pump storage plant	Hamburger Elektrizi-tätswerke AG	20.02.89-31.12.94	11.801,2	40
Construction, ecrection and test of HSW 750	Husumer Schiffswerft	01.04.89-30.06.94	7.084,8	20,40
Development of advanced aluminium rotor blades	Aerodyn Energiesysteme GmbH	01.10.91-31.12.93	714,5	50
Modelling of the power of wind farms	Universität Oldenburg	01.09.91-31.08.94	312,0	50
Measuring programme of economic factors, AEOLUS II	PreussenElektra Windkraft NDS	01.01.91-31.05.95	577,4	50
Measuring programme of economic factors, WKA 60 II	PreussenElektra Windkraft SH	01.1091-31.05.95	556,7	50
Technical measurement programme of different WEC's	Windenergiepark Westküste GmbH	01.01.93-30.09.95	490,0	50
Evaluation of wind data from 2 towers of 150 m height	Deutscher Wetterdienst	01.04.92-31.03.95	471,0	100
Development, erection and test of 1 MW E-55	Enercon GmbH und Co. KG	01.01.93-30.09.95	7.745,0	14,20
HSW 750 measuring programme	Husumer Schiffswerft	01.06.93-28.02.05	604,7	50
Special wind dates for planning and for complex terrain	Deutscher Wetterdienst	01.07.93-30.06.97	1.641,9	100
WMEP, Phase II	ISET	01.07.92-30.06.96	13.386,9	100
Wind measurement Heligoland for WKA 60	Deutscher Wetterdienst	01.08.87-30.06.93	1.844,0	100
WKA 60 II	PreussenElektra Windkraft SH	01.02.89-30.06.93	14.271,7	25
Measuring programme for 48 turbines of 13 manufactures	Fördergesellschaft Windenergie	01.06.89-31.05.93	573,8	100
Offshore Wind Turbines	Germanischer Lloyd	01.09.90-30.04.93	547,5	30
30 kW-WEC's with diesel back-up	PEB/Südwind	01.02.91-31.08.93	1.018,0	24,71
Measuring programme for MW-turbines	Germanischer Lloyd	01.04.92-30.06.94	560,0	50

Table 3: Wind Energy R & D-Projects, 1992

Country / Locality	Number of WECS à 30 kW	Wind velocity (m/s)	In operation since
Madeira / Porto Santo	8	7.0	5/88
Azores / Santa Maria	8	6.8	8/88
Haiti / Port-de-Paix	5	6.5	10/88
Mauritius/ Rodrigues	4	8.5	12/88
Cape Verde / Mindelo	10	8.9	11/89
Argentina / Rio Mayo	4	7.1	2/90
China / Sijiao Island	10	7.2	6/91

Table 4: **Wind farm project of KfW**

Country/Locality	Application	Total rated power	Typ of WECS
Egypt	Windfarm	1 MW	Ventis 100
Brazil	Windfarm	1 MW	Tacke 250
China	Wind / Diesel	150 kW	Aeroman 33
China / Dalian	Windfarm	1 MW	HSW 250
China / Zhurihe	Windfarm	1 MW	HSW 250
Russia	Windfarm	300 kW	HSW 30

Table 5: **Projects already approved within ELDORADO Programme.**

2.4 Italy

Introduction

The year 1993 saw, in Italy, the continuation of the work that had been in progress since the early eighties on the assessment of exploitable wind resources and development of a domestic wind energy technology. As in previous years these efforts were made mostly in collaboration between some, or all, of the following bodies: the ENEL company (Italy's main utility, entrusted with both generation and distribution of electricity all over the country), the state-owned ENEA (the Italian Energy, New Technologies and Environment Agency), and two wind turbine manufacturers: the WEST company (which has taken over construction of medium and large sized machines from Alenia) and the Riva Calzoni company.

In compliance with the targets set by the 1988 National Energy Plan (PEN) efforts were also made by ENEL to pursue full implementation of the programmes already launched in past years with a view of setting up demonstration windfarms for a total capacity of 20 MW. WEST and Riva Calzoni also continued their own installation activities in cooperaton with local authorities and ENEA. All these activities, along with a number of other projects developed by private installers and local municipalities, led to the installtion of a grid-connected generating capacity totalling over 10 MW in 1993. Installed capacity is expected to grow to at least 20-25 MW before the end of 1994, taking into account only the projects already under way.

Some regulations providing for incentives to wind plant investors are currently in force, although their effects have so far not been as remarkable as in some other countries. The most effective provision, issued in April 1992, allows a premium price of 150-166 ITL/kWh over the first eight years for electricity generated by wind power plants feeding their energy into the ENEL system. Nevertheless, the extent to which windfarms will be set up will mainly depend not only on financial aspects but also on the availability of sites.

For nearly 15 years, wind data have been collected in Italy by various organisations in order to assess the exploitable resources. A total of about 200 measuring stations had been set up by the end of 1993. ENEA and ENEL, together with Alenia/WEST and Riva Calzoni, have also set up, in 1990, a joint "Siting Commission" for compiling information and eventually mapping sites suitable for windfarms of significant capacity.

As a result of the survey, a number of areas, especially in the South and on the Islands, seem to have enough wind resources to make the installation of windfarms a viable option. However, a much more careful approach is required when construction of a large windfarm is envisaged, as most of the areas feature complex terrain.

Generally speaking, most of the wind resources are found either in coastal areas or in mountain regions, mainly in the Apennines 800-1000 m a.s.l., and both types of location bring about specific problems. Coastal areas are rather densely populated and also stricly protected by laws, safeguarding their natural beauties. Mountain areas are also protected by laws, and often have harsh environmental conditions in wintertime when the best wind resource is available. In these areas the medium-voltage distribution networks may be far from candidate sites or not strong enough for direct connection, so that higher costs than usual will be incurred for connecting a windfarm to the grid.

Full information is being gathered on all aspects of a number of identified windy sites, and preliminary windfarm projects are being prepared for possible submission to the physical planning authorities. At the most promising sites with complex terrain, preliminary micrositing acticities are also underway.

In addition to the financial and siting aspects, other major obstacles seem to arise from the very cautious attitudes of the physical planning authorities, and the public in general, towards wind energy plants, and from the length and complexity of the procedures that have to be followed for obtaining construction permits.

Activities of the ENEL Company

During 1993, ENEL S.p.A., set up in mid-1992 as a joint stock company, continued the wind energy activities of the former Italian National Electricity Board. The new company's policy for exploiting renewable energy sources is still in the process of being defined. In addition to wind surveys (a total of 120 wind measuring stations were set up from 1980 to 1993), micrositing studies and preliminary windfarm planning, ENEL's work in 1993 therefore mainly consisted of windfarm testing and activities aimed at building the two demonstration windfarms already decided in the past.

Wind turbine testing

Alta Nurra Test Site

Testing of medium-sized wind turbines continued at the Alta Nurra site in North Sardinia. Four units featuring different technical characteristics were put into continous operation in April 1991, with a view to assessing, at the same site under seaboard environmental conditions, the performance of a few Italian and foreign-made medium-sized models for windfarm applications.

The machines include: the 225 kW, 32m rotor diameter Medit prototype, made by Alenia/WEST; the 200 kW, 33 m M30 prototype by Riva Calzoni; a 300 kW/33 m MS-3 unit by WEG of the UK; and a 400 kW/34 m Windane 34 unit by Vestas-DWT of Denmark. A Medit I (or Medit 320), the 320 kW/33 m industrialized version of Medit, was also put into operation in spring 1992.

The 225 kW Medit prototype was taken out of service in spring 1993, as all relevant activities were considered completed.

The first testing phase, which also included in-field determination of power curves and measurements of noise and telecommunications interference, ended in October 1992. After that, the machines have been kept in continuous operation to check the long-term behaviour with respect to performance and availability. As of 15 December 1993, the energy produced by the medium-sized machines totalled 2500 MWh.

The 1,5 MW/60 m GAMMA 60 prototype (installed in April and first rotation in June 1992) was also tested all through 1993. The unit was designed and constructed by Alenia/WEST in the framework of an agreement between ENEL and ENEA. At the end of 1993 the prototype was still in the commissioning phase, which will be considered as fully completed only after the production of 1000 MWh. As of 15 December the unit had produced 360 MWh in 1190 generating hours.

Acqua Spruzza Test Site

ENEL's programme also provides for high-altitude experiments on medium-sized wind turbines in order to check the viability of windfarms on the ridges of the Apennines, at sites with very hard winter weather, prior to considering the option of building production plants in such areas. This necessitated the construction of a new test site at Acqua Spruzza, located at an average altitude of 1360 m a.s.l. in the commune of Frosolone (Molise Region, Central Italy). The project comprises two wind turbines of each type installed at Alta Nurra, namely two Medit 320, two M30, two MS-3 and two Windane 34, for a total capacity of 2440 kW. The plant is financed by ENEL, with some support from CEC DG XVII.

An application for construction permit was submitted in February 1990, but the subsequent authorization procedure took an unexpectedly long period of 28 months and caused considerable delay in the work schedule. Site work started in July 1992 and was resumed again in late spring 1993 after a long interruption due to adverse weather conditions during the winter months.

At the end of 1993 all wind turbines had been installed and the whole plant completed, except for the centralised measuring, control and monitoring system. Some operating experience is, however, expected already in the winter 1993-1994. A micrositing study is also in progress over a larger area around the test site, using eleven 15 m and one 40 m measuring masts, to look into the possibility of enlarging the plant in the future. The study has been granted funds by the CEC DG XII.

Santa Caterina Test Site

In 1993, ENEL decided to install two hybrid stand-alone systems at the Santa Caterina wind test site, located in the province of Calgiari , Sardinia. The first system will consist of a 25 kW AIT-03 wind turbine made by the Mareco company under licence from Alenia, a 5 kWp photovoltaic field and storage batteries. The second system will comprise a 5 kW M7 wind turbine by Riva Calzoni and a 2 kWp p.v. field plus storage batteries. Installation of these systems will come in ENEL's "Storage Project" and should take place in the first months of 1994.

Demonstration windfarms

Monte Arci windfarm

ENEL's first windfarm is to be built in Sardinia, in a part of of the Monte Arci plateau at an average altitude of about 750 m a.s.l., 8 km from the sea (Gulf of Oristano). The climatic conditions are typical of a seaboard Mediterranean area.

The original project comprised forty Italian-made wind turbines, specifically twenty Medit 320 and twenty M30-A520 units. In September 1991 a preliminary design of the windfarm was submitted to the concerned authorities for the construction permit. At the same time additional wind measurements were undertaken for micrositing purposes by means of five 15 m masts. The THERMIE programme of CEC DGXVII also granted this project some funding.

In the course of 1993, taking into account both the requests of the local authorities and the advantage of having only one machine model at each site, ENEL decided to install 34 Medit 320 units at Monte Arci, shifting all the Riva Calzoni wind turbines to another site. Total capacity at Monte Arci will therefore be nearly 11 MW. The annual energy output is estimated to be 14 000 MWh.

After having obtained all permits, ENEL granted, in October 1993, to WEST a contract for the supply of the wind turbines and relevant foundations and for electrical and monitoring infrastructures. Construction work is expected to be completed by the end of 1994.

Collarmele windfarm

ENEL is also planning to build another windfarm near Collarmele, in the province of L'Aquila in the Abruzzo region (Central Italy). This plant will be located in the Apennines at an altitude of about 1000 m a.s.l. and will consist of 36 wind turbines of the 250 kW M30-A model, supplied by Riva Calzoni. The total installed capacity will be 9 MW. The procedure for getting the relevant construction permits was well in progress at the end of 1993. If the permits are obtained shortly, as expected, the plant will be completed in early 1995.

ENEA activities

Until 1992 most of the ENEA wind energy activities were aimed at promoting the development of new wind turbines by Italian industry. The programme was carried out also by substantial financing of collaborative activities with manufacturers, including the development of prototype wind turbines such as Medit and Gamma 60. From 1993, even though financial participation in particular projects is continuing, for example regarding the design of the second and third Gamma 60 units and an advanced version of Medit, ENEA has been involved more directly in research activities, the product of which will be made available to the manufacturers as a scientific and technological service. The main activities are directed to siting, certification and technological development. In each of these fields, ENEA has been looking for partnerships in the study of new solutions and improving those currently adopted.

Siting

While continuing the efforts to identify suitable windfarm sites in cooperation with ENEL and coordinated by the Siting Commission, priority is given to the establishment of a siting and territorial data bank for the whole of Italy, and the identification of a site for a national test station for wind turbines.

Certification

ENEA, as a government organisation, is considered the most suitable body for the certification of wind turbines. The action of certification will put Italian manufacturers in a better position to compete on the free market of the European community. To this end, ENEA has been studying the feasibility of setting up a national test station. The matter will be discussed in a working group established by the Ministry of Industry and Commerce, including representatives of ENEA, ENEL and manufacturers.

Technological development

With the aim to improve wind turbine performance, ENEA is engaged in studies of:

- Modelling of wind turbine behaviour in diffrent operating situations.
- Structural analysis, both by developing computer codes and by means of experimental tests, simulating load conditions.
- Reliability analysis of the whole machine and of relevant components and subsystems.
- Identification of new control algorithms and systems.
- Studies of rotor aerodynamics, both theoretical and experimental.

In addition to these high-priority activities, ENEA will continue to be involved in the definition of programmes for the exploitation of wind energy in Italy, contributing to the activities of Ministries, regional and local authorities, and cooperating with ENEL. Particular attention is given to economic aspects of windfarm construction, e.g financial problems for private investors wishing to build windfarms.

WEST company

WEST (Wind Energy Systems Taranto) is a company of the Finmeccanica Group. The field of activity is to develop and manufacture wind energy systems, based on the technology acquired from Alenia's multi-year experience. The main objective is to develop windfarms in Italy in order to push the commercialization of Medit 320, in production since 1991, as well as Gamma 60 and the advanced Medit MK3. To achieve the goal, the engineering team has been optimized and the design philosophy has been improved in order to reduce costs and increase the technical reliability. Generic activities include studies of noise reduction, blade technology, advanced components, wind measurements, and improved mechanical design.

Another important goal is to promote wind energy utilization by the utilities, not only in Italy but also in other countries. Several Italian provinces are planning activities as a result of the market stimulation programme. Experience is accumulating from windfarm operation in Italy on issues such as reliability, maintenance, lifetime, annual production, installation cost, and site availability.

In summary, the main activities of WEST are:

- Production and improvement of Medit 320
- Design and production of Medit MK3
- Definition of advanced Gamma 60
- Windfarm installation
- Wind turbine test sites
- Blade technology development.

Medit 320

As of the end of 1993, a total of 66 Medit 320 units have been fabricated, 18 of which during 1993. Some improvements have been introduced as a result of operational experience. Production plans for the coming years are based on an annual production of up to 100 units and an existing backlog corresponding to 15 MW. The main features of Medit 320 are shown in Table 2.4.1.

Table 2.4.1 Main data of Medit 320

Number of blades	2
Rotor diameter	33 m
Rotor position	upwind
Hub height	26 m
Hub	teetered
Gearbox	rigid
Power regulation	pitch control
Pitch system	hydraulic
Yaw system	electromechanical
Rated power	320 kW
Wind speed @ 10 m	
cut-in	4,2 m/s
rated	11,5 m/s
cut-out	17,5 m/s
survival	50 m/s

An improved version is known as "Medit Industrialized", which has an electromechanical pitching system with lower production costs and a better availability. The Medit Industrialized is expected to be installed in 1994 and field tested in 1994-1995.

Medit MK3

WEST is also developing a new model, Medit MK3, the general background of which is derived from the experience in the development of the Gamma 60 prototype and the industrial production of Medit 320.

Medit MK3 will essentially embody the gamma 60 concepts with improvements and simplifications that are expected to allow minimum series production costs, maximum energy capture and adequate availability. The main features are shown in Table 2.4.2.

Table 2.4.2 Main data of Medit MK3

Number of blades	2
Rotor diameter	36 m
Rotor position	upwind
Hub height	36 m
Hub	teetered
Gearbox	rigid
Power regulation	yaw control
Yaw system	hydraulic
Rated power	400 kW
Wind speed @ 10 m	
cut-in	4 m/s
rated	14 m/s
cut-out	26 m/s
survival	56 m/s

The MK3 prototype is foreseen to be installed in 1994 and field tested in 1994/1995.

The series version of MK3 will be named W636 and will have a rated power of 636 kW.

Gamma 60

Gamma 60 is a large-sized wind turbine with innovative features to make a cost-effective machine. The main features (teetered hub, fixed pitch, broad range variable speed, yaw control) have been chosen to increase the annual energy yield and to eliminate all control equipment from the rotating parts, thus allowing for a simpler machine with lower manufacturing and maintenance costs. Assembly took place in April 1992 at ENELs Alta Nurra Test Station in Sardinia and first rotation was in June 1992.

Static and rotation tests were performed under controlled conditions, i.e. below the proper supply limit, in order to check the overall operation of the equipment and of electric, mechanical and control components, and to ensure that the operating parameters were in accordance with the targets laid down during the design stage. Tests were then carried out in various operative conditions in 1993, in order to confirm that the equipment performed according to specifications.

The main features of Gamma 60 are shown in Table 2.4.3.

Table 2.4.3 Main data of Gamma 60

Number of blades	2
Rotor diameter	60 m
Rotor position	upwind
Hub height	66 m
Hub	teetered
Gearbox	rigid
Power regulation	yaw control
Yaw system	hydraulic
Rated power	1500 kW
Wind speed @ 10 m	
cut-in	4,9 m/s
rated	13,5 m/s
cut-out	27 m/s
survival	64 m/s

Windfarm developments

Bisaccia

The first Italian windfarm, made up medium-sized machines, is located at Bisaccia (Campania). It consists of six Medit 320 and sixteen AIT 03 (unit rated power 30 kW). more information on this plant was given in the 1992 Annual Report.

Monte Arci

WEST's first large windfarm will be built for ENEL at Monte Arci in Sardinia. The plant will have 34 Medit 320 units for a total rated capacity of around 11 MW.

Bassa Nurra

In early 1993, WEST and Riva Calzoni were charged by "Consorzio di Bonifica di Nurra" to set up a windfarm with 16 wind turbines in an area located in Bassa Nurra, a part of Northern Sardinia. The plant consists of four machine clusters made up of Medit 320 and M30-A units. The specific sites are: Monte Uccari (5 Medit 320, 1,6 MW), Brunestica (3 Medit 320, 0,96 MW), Campanedda (4 M30-A, 1 MW), and Ottava (4 M30-A, 1 MW).

In this project, WEST has the role of the team leader. Installation was completed in June 1993, see Figure 2.4.1 and 2.4.2.

Roseto

A windfarm of five Medit 320 units will be installed in 1994 at Roseto in Puglia with financial support from the CEC. The site has an annual mean wind speed of 8 m/s at 10 m. The total rated power is 1,6 MW, and the plant will generate 5000 MWh per annum in steady conditions.

Other installations

Other installations were made by WEST during the year in Sardinia (Villagrande, two Medit; Oristano, one Medit; Carloforte, three Medit); in Molise (Sannio, one Medit); and in Abruzzo (Sangro, three Medit).

In the beginning of 1994, a Medit will be installed in the Czech Republic with the cooperation of ESOS.

Riva Calzoni

Riva Calzoni is presently the world leader in single blade technology for wind turbines and has achieved a unique know-how in such advanced technology. Furthermore the company has developed an expertise in siting and site development for complete customer assistance in all phases of a project. Since 1993, the wind energy activities have therefore been divided into two lines: WEC development and manufacture, and site and wind plant development.

WEC development and manufacture

While the production of the M30-A (250 kW, 33 m rotor diameter) is continuing, the prototype of the M30-S1 (250 kW) has been designed and manufactured. This prototype aims at testing a new innovative rotor. At the end of 1993 its possible installation at the Alta Nurra test site was under discussion.

Moreover, the M30-S2 (350 kW) is under realization. Besides the rotor, it has some other substantial innovations in the energy conversion system at semi-variable speed and, thanks to the simplification and re-design of the whole machine, it finally makes the single blade technology really competitive with traditional technologies. The main technical characteristics are shown in Table 2.4.4.

Site and wind plant development

Riva Calzoni has been monitoring over 30 sites in Italy, many of which have good characteristics for the installation of medium-sized windfarms. Some of the sites are located in the central-south Apennines at an altitude between 800 and 1400 m. This area represents an important part of the Italian wind potential, and Riva Calzoni has gained a considerable knowledge about the meteorology and the typical conditions of these sites.

The sites are fairly isolated and without any particular constraints, but there are often some access difficulties and the weather conditions, especially during the winter season, are rather harsh with strong turbulence, frequent precipitation of snow and presence of ice. The sites can certainly be considered among the most difficult sites in Europe, and the operation of wind turbines under these conditions may be critical. Riva Calzoni single-bladed wind turbines are particularly interesting for these kind of sites because of the flexible concept, intrinsically more suitable to work under turbulent conditions.

During 1993, several WECs of the M30-A model were installed, among them two units in the ENEL test field at Acqua Spruzza, eight units in two clusters in northern Sardinia (four at Campanedda, Figure 2.4.3, and four at Ottava, Figure 2.4.4, and also one unit at a test field of the Hokkaido Electric Power Company in Japan. At Alta Nurra and Acqua Spruzza and in Japan, the M30 machines will be compared with other WECs of the three- and two-bladed technology.

Among the several plants under development, the most important is the windfarm at Collarmele (Abruzzo) at 1000 m altitude, where 36 M30-A will be installed for ENEL, see Figure 2.4.5.

Table 2.4.4 Riva Calzoni M30S2 350 kW technical specifications

ROTOR	
Number of blades	1
Diameter	33 m
Rotation speed	51 to 57 rpm
Rotor position	downwind
Drive train tilt angle	8°
Rotation direction	clockwise (seen from upwind)
Type of hub	free teetering
Hub teetering range	-11° to +20°
Aerodynamic control	full span pitch
Variation of pitch angle	0° to 90°
Pitch variation speed	< 8°/s
BLADE	
Weight	800 kg
Chord lenght	0.66 - 2.06 m
Twist angle	11.5°
Profile	series FX84-W
Material	GRP composite
Tip speed	97 m/s
CONTROL	
Type	computer controlled
BUS type	VME
Processor type	68010
Location of control panel	in transformer house
Emergency logic	relays based
NACELLE	
Type of yaw bearing	ball bearing
Positioning	by active yawing
Type of actuators	electric motors
Yawing speed	2°/s
Rotor locking for maintenance	mechanical lock on gearbox
Type of frame	shell
Material	low brittleness high tensile steel
Casing	GRP

Table 2.4.4 continued

DRIVE TRAIN

Type of gearbox	parallel shaft
Ratio	1 : 29.4
Number of stages	2
Generator:	
- type	induction "Kramer" with slip power recovery
- power	350 kW
- number of poles	4
- rated speed	1650 rpm
- rated voltage	380 V - 50 Hz

TOWER AND FOUNDATIONS

Height base - hub	33 m
Shape	conical tubular
Diameter	1.8-1.3 m
Material	hot galvanized high tensile steel
Type of securing	through bolted flange
Foundations	concrete
Erection system	by crane
Access ladder	inside tower, with safety device

OPERATIONAL DATA (wind speeds at hub height)

Cut-in wind speed	4,5 m/s
Rated wind speed	13,5 m/s
Cut-out & park wind speed	25 m/s
Survival windspeed	70 m/s

Figure 2.4.1 The windfarm set up in 1933 in Northern Sardinia for "Consorzio di Bonifica di Nurra: view of the Monte Uccari plant with five WEST Medit 320 machines

Figure 2.4.2 The windfarm set up in 1993 in Northern Sardinia for "Consorzio di Bonifica di Nurra: view of the Brunestica plant with three WEST Medit 320 machines

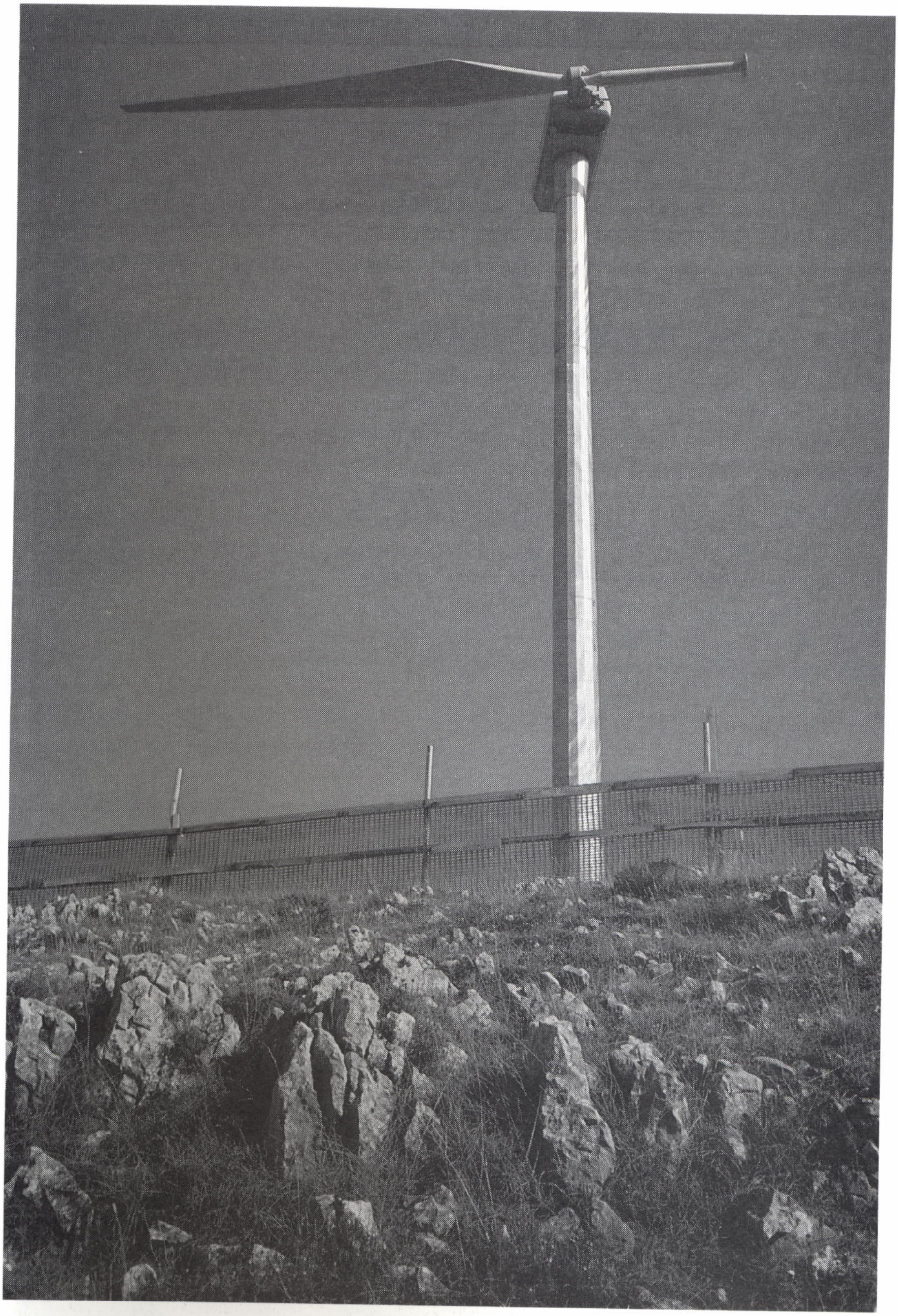


Figure 2.4.3 The Riva Calzoni M30-A wind turbine (250 kW, 33m rotor diameter) set up in 1992 near Collarmele (Abruzzo, Central Italy) for the Marsica Gas Company.

Figure 2.4.4 The wind farm set up in 1933 in Northern Sardinia for "Consorzio di Benifica di Nurra": view of the Campanedda plant with four Riva Calzoni M30-A wind turbines

view of the Campanedda plant with four Riva Calzoni M30-A wind turbines

Figure 2.4.5 The wind farm set up in 1993 in Northern Sardinia for "Consorzio di Bonifica di Nurra": view of the Ottava plant with four Riva Calzoni M30-A wind turbines

2.5 Japan

Introduction

Since 1978, the Japanese wind energy R&D programme has been directed by the New Sunshine Project Promotion Headquarters (NSS H.Q.) in the Agency of Industrial Science and Technology (AIST) of the Ministry of Trade and Industry (MITI). The New Energy and Industrial Technology Development Organization (NEDO) plays the main role in the construction and operation of the large scale tests plants. The Mechanical Engineering Laboratory (MEL) and the National Institute for Resources and Environment (NIRE) are carrying out basic research in wind energy and are supporting the Sunshine Project by evaluating the activities of NEDO. The national programme also includes standardization activities.

The budget for wind energy in the Sunshine Project increased from JPY 370 million in fiscal year 1990 to 549 MJPY for FY 1992 and 982 MJPY for FY 1993.

Utilities and manufacturers are also active in wind energy. The structure of activities is outlined in Table 2.5.1.

Table 2.5.1 Wind energy activities in Japan

National activities	NSS-H.Q.
R&D LS-WECS	
(1) 500 kW WTGS	NEDO-MHI
(2) 1 MW windfarm	NEDO-Okinawa EPC
(3) Wind observation	NEDO
Basic research	
(1) WINDMEL, Wind/Diesel, WINDMEL II , etc.	MEL, MITI
(2) Wind analysis	NIRE, MITI
Standards (IEC, ISO)	MITI, MEL, Manufacturers, Utilities, Universities
Industrial activities	Utilities Local authorities Manufacturers

Development of large scale WECS

After completion of the 100 kW pilot plant in 1986 and studies of large wind systems, a new R&D programme was initiated in 1990. As a result, the basic design of a 500 kW class wind turbine and the construction of a 1 MW experimental windfarm started in FY 1991.

The 500 kW wind turbine prototype

Conceptual design of the 500 kW prototype was completed in FY 1992. It is a three-bladed upwind machine with a rigid hub, 38 m rotor diameter and GFRP blades. In FY 1992, detailed design of the turbine, the trial manufacture of the blades and two planetary gear units, rotor/tower coupled vibration analysis, and structural analysis of the rotor head and and nacelle were undertaken. The specification was slightly changed and is shown in Table 2.5.2 The turbine will be manufactured by Mitsubishi Heavy Industries Ltd. In 1993 some components such as the nacelle, main bearing and generator have been manufactured and tested.

Table 2.5.2 Specification of the 500 kW wind turbine

Operational data	Rated output	500 kW
	Cut-in wind speed	5,8 m/s
	Rated wind speed	12,4 m/s
	Cut-out wind speed	24 m/s
Rotor	Orientation	upwind
	Hub	rigid
	Number of blades	three
	Tilt angle	5 deg
	Corn angle	0 deg
	Diameter	38 m
	Rotational speed	32 rpm
Blade	Airfoil section	NASA LS(1)-04XX
	Length	18,25 m
	Material	GFRP
Transmission	Type	two-stage planetary
	Nominal power	500 kW
	Input speed	32 rpm
	Output speed	1500 rpm
Generator	Type	Induction (4 poles)
	Rated output	55 kW
	Grid connection	AC-link
Pitch control	Mechanism	linkage, hydraulic
Yaw control	Motor type	induction
Tower	Type	rigid, taper monopole

Utilization technology

An experimental windfarm of approximately 1 MW rated power is under construction on Miyako Island, Okinawa. The first 250 kW turbine was installed in FY 1991 and a second turbine in FY 1992.

Wind observation

A number of suitable sites for wind turbines have been identified but most of them are located in complex terrain. This fact has bearing on the R&D for reliable and economical turbine technology.

As a complement to the nation-wide network for local meteorological observations, NEDO has been measuring wind characteristics at selected sites since 1983. The number of sites were 13 in FY 1990, 10 in 1991, 15 in 1992 and 18 in 1993. In 1993 a wind map was created using all wind data obtained. In 1994 the wind energy potential in Japan will be evaluated, based on the wind map and and taking various other conditions into account.

NEDO is also acquiring fine-mesh data in the Rumoi area, Hokkaido, in order to develop a numerical method for predicting wind flow over complex terrain.

Basic research

MEL has been investigating basic aspects of rotor aerodynamics, structural mechanics, vibration, aerodynamic noise etc. since FY 1978. At MEL a two-bladed variable speed 15 kW experimental wind turbine generator system, called WINDMEL, was developed and operated. WINDMEL has a teetered rotor, a soft tower and variable pitch/free yaw control system. In March 1993 WINDMEL was reconstructed to serve in a wind/diesel mechanical hybride system.

A new test machine, WINDMEL II, is being developed. It has a variety of options, such as teetered/rigid hub, constant/variable speed, etc. The basic design is almost the same as WINDMEL.

NIRE is analyzing turbulent wind characteristics over complex terrain.

Industrial activities

The first windfarm with more than 1 MW capacity was built in 1991 at Cape Tappi by Tohoku Electric Power Co. It consists of five 275 kW three-bladed pitch-controlled units with 28 m rotor diameter. In the period from 1 April 1992 to 31 March 1993 the energy production was 2293 MWh with an availability factor of 47,6 % and a capacity factor of and a capacity factor of 21,6 %. Tohoku Electric Power Co. will build five additional units at the Tappi Wind Park by 1995.

Major electric utilities have their own wind projects aiming at a total installed power of around 5 MW by 1995, see Table 2.5.3.

Table 2.5.3 Main wind turbines in Japan

Date of construction	Owner	Location	Machine	Rated power kW	Rotor dia. m	No.of units	Purpose
1982-90	Kyushu EPC	Okinoerabu	MHI-300	300	33	1	Demo
1983-86	NEDO	Miyake Isl.	IHI	100	29	1	R&D*
1985-89	Tokyo EPC	Miyake Isl.	HMZ	80	25	1	Demo
1985-87	MHI	Nagasaki	MHI-250	250	25	1	Research
1987-	MEL	Tsukuba	Yamaha	15	15	1	Research*
1988-91	Tohoku EPC	Cape Shiriya	Yamaha	16,5	15	1	Research
1989-	Suttsu Town	Suttsu	Yamaha	16,5	15	5	Power
1990-	Kyushu EPC	Koshiki Isl.	MHI-250C	250	28	1	Power
1990-	MHI	Nagasaki	MHI-250C	250	28	1	Research
1990-91	Yamaha	Okinawa	Yamaha	100	30	1	Research
1990-	Kansai EPC	Rokko Isl.	Yamaha	16,5	15	2	Research**
1990-	Seto City	Seto	MHI	100	28	1	Power
1991-	NEDO	Miyako Isl.	MHI et al	250	28	2	Demo*
1991-	Tohoku EPC	Cape Tappi	MHI	275	28	5	Windfarm
1991-	Chubu EPC	Hekinan	MHI	250		1	Demo
1993-	Hokkaido EPC	Tomari	MHI et al	275,300,250		4	Demo
1993-	Tokyo EPC	Futtsu	IHI	300		1	Demo
1993-	Hokuriku EPC	Fukui		15		1	Demo
1993-	Tachikawa	Tachikawa	USW	100		3	Demo
1993-	Mattou City	Mattou	Micon	100		1	Demo
1994-	Shikoku EPC	Cape Muroto		300		1	Demo
1994-	Dengen	Wakamatsu		15		1	Demo
1994	Kyushu EPC			250		1	
1995-	NEDO		MHI	500	38	1	R&D*
1995-	Kansai EPC			100		1	
1995-	Chugoku EPC			15		1	
1995-	Tohoku EPC	Cape Tappi	MHI	275	28	5	Windfarm

* S/S project
** NEDO project

2.6 Netherlands

Introduction

In the late eighties the number of wind turbines in the Netherlands started to increase rapidly. In the period 1985-1993 grants for a total capacity of 260 MW were allocated. The operational capacity increased to 125 MW. At the end of 1993 another 15 MW was under construction or in preparation, see Figure 2.6.1. An increase of the installed capacity to approximately 180 MW is foreseen in 1994.

In the Policy Plan on Energy Conservation and Renewables of the Ministry of Economic Affairs (June 1990), the government has set goals with respect to wind energy, implying the installation of 1000 MW by year 2000, growing to 2000 MW in 2010. This would save 17 and 33 PJ, respectively, of primary fuel per year. In comparison, the total annual energy consumption in the Netherlands is 2700 PJ.

National programme

In order to realize the government's objectives a national programme is in place to stimulate the use of wind energy. The National Support Programme for the Application of Wind Energy in the Netherlands 1990-1995 (TWIN) concentrates on removing financial and planning obstacles and on contributing to the development and improvement of wind turbines in the Netherlands. TWIN is managed by the Netherlands Agency for Energy and the Environment (NOVEM).

The general objective has been translated into a number of operational objectives to be met by 1995, as follows.

Implementation

The aim is to implement wind energy in the Netherlands at an average rate of 60 MW per year, thereby realizing an installed capacity of 400 MW in 1995. This component includes investment grants up to 35 % of the total project costs including the physical planning of wind turbines.

Industrial development

The aim is to improve the cost/performance ratio by approximately 30 %. As of 1995, reduction in the cost of turbines and improvement of the reliability and lifetime of turbines should result in an average cost of energy, generated at proper locations, of NLG 0,14 per kWh, compared to the state of technology in 1990 when the average cost level was NLG 0,20 per kWh.

The improvement of safety, the reduction of noise, and the increased size of turbines will contribute to the efficient use of available wind turbine sites. Milestones in this respect are the reduction of the average source noise emission level by 6 dB(A) and the extension of the capacity range up to rotor diameters of 40-55 m.

Technological development

The aim is to provide the technical conditions for a continued industrial product improvement and development of the present generation of turbines. In consultation with the market parties involved, the wind turbine expertise will be used to produce solutions for current and anticipated problems.

Long term market development

The aim of this part of the programme has been extended from offshore development to long term market development. In view of the restricted area available for wind turbines in the Netherlands, the development of a continuous market perspective for the Dutch wind industry will be investigated. Offshore siting will be one of the options considered. The outcome will be used to formulate the Dutch wind energy programme for the period 1995-2000.

Dissemination of know-how and programme support

The aim is to make the available know-how accessible and applicable to the industry and operator/owner of wind turbines, to promote international cooperation and to keep track of the development in other countries.

Other programmes

In addition to the TWIN programme, other activities are important:

• Wind energy programmes financed by the Ministry of Economic Affairs through direct funding of research establishments:

- ECN (Netherlands Energy Research Foundation), 3 MNLG/yr
- TNO (Dutch Organisation for Applied Scientific Research), 0,2 MNLG/yr

• Wind energy research financed by the Ministry of Education through the programme of the Delft University of Technology;

• Research and development by the industry.

The organisation of the joint utilities SEP operates a moderate programme aimed at collecting experience of the interconnection of large amounts of wind power in the national grid. In this programme, the laboratory of the utilities, KEMA, is involved.

The NOVEM and ECN programmes are coordinated. The research activities are mainly aimed at providing know-how to the industry, to future owner/operators of wind turbines and to the development of advanced components to be applied in both medium and large-sized turbines.

Budgets

The wind energy budgets for the period 1990-1995 are given in Table 2.6.1. Some statistics for investment grants is shown in Figures 2.6.2 and 2.6.3. The distribution of the available funds for generic research shows a decreasing trend both in absolute and relative terms.

Table 2.6.1 Average annual government budgets for wind energy development during the period 1990-1995 in million NLG.

	Realized			Planned		
	1991	1992	1993	1994	1995	Total
Market stimulation*	40,0	42,0	45,5	35,0	p.m.	162,5
Implementation support	1,5	1,7	1,1	1,1	1,5	6,9
Industrial development	4,0	3,6	3,5	3,5	1,5	16,1
Technological development	3,0	3,4	3,0	3,0	2,2	14,6
Long term market developm't	0,1	0,2	0,4	0,3	1,5	2,5
Dissemination of know-how	0,4	0,5	0,3	0,3	0,3	1,8
Total TWIN programme	49,0	51,4	53,8	43,1	7,0	204,3
R&D ECN	2,5	2,5	3,0	3,0	3,0	14,0
Research universities (est.)	2,0	2,0	2,0	2,0	2,0	10,0
Research utilities	0,6	0,6	0,6	0,6	0,6	3,0
Total	54,1	56,5	59,4	48,7	12,6	231,3

* The investment grant budget is partly given pro memoria and is published annually by the government.

Main results in 1993 and future activities

Implementation

In 1993, utilities and private investors proposed projects to NOVEM for 180 MW, applying for NLG 185 million investment grants. The available budget was 35 million. After consultation of all applicants it was agreed that the allocation of grants should be ranked on the criterium of stage of preparation. In December the budget was increased by NLG 10,5 million to a total of 45,5 million. Investment grants for a total of 60 MW were allocated.

Present Dutch windfarms typically have a capacity of 1 to 10 MW and consist of wind turbines with a rated power between 150 and 500 kW. Table 2.6.2 lists the largest windfarms in the Netherlands.

Table 2.6.2 Dutch windfarms larger than 4 MW capacity

Name	Location	Manufacturer	Rotor diam.	Units	Installed power (MW)
IJsselmij	Noordoostpolder	WMN	28	50	15,0
Lelystad	Lelystad	WMN	25	35	10,5
EGD	Uithuizermeedum	Micon	26	40	10,0
GEB Rotterdam	Maasvlakte I	Nedwind	35	13	6,5
SEP Proefwindcentr.	Oosterbierum	Holec	30	18	5,4
GEB Rotterdam	Maasvlakte II	Nedwind	35	10	5,0
GEB Rotterdam	Hartelkanaal	Nedwind	35	10	5,0
PEN Ulketocht	Wieringermeer	Nedwind	35	10	5,0
PNEM Volkerak	Volkeraksluis	Nedwind	35	10	5,0
Windpark Nederland	Roggeplaat	Enercon	33	12	4,1

The construction of the the 3 MW demonstration windfarm on the island of Curaçao (the Netherlands Antilles) was completed in June 1993. The twelve 250 kW NedWind turbines owned by the KODELA utility are showing very promising results with regard to their predicted output.

Industrial development

Dutch wind turbine manufacturers are continuously improving their products. Due to these activities the general cost/performance ratio decreased by more than 10 % since 1991.

NedWind's 35 m/500 kW turbine was developed in the early nineties. The first machine was used as a test facility to investigate the phenomena of stall-induced vibrations and stall stability in a CEC JOULE I project. It has been used in many windfarms. In 1992 the turbine was extensively redesigned and upscaled to 40,15 m rotor diameter. It has two 250 kW induction generators. It is essentially a stall controlled machine but with a slow blade pitch control mechanism to adjust to optimum stall conditions at nominal power. In 1993 further value engineering was done on the machine, resulting in an increase of the rotor diameter to 42,1 m.

NedWind is also developing a 52,6 m/1 MW turbine with support from the CEC THERMIE programme. The measuring programme will be carried out in the framework of JOULE II. The turbine has a two-speed conversion system, two blades and stall control. The first of two prototypes will be erected in the beginning of 1994. Two utilities in North Holland (EGD and PEB Friesland) will operate the machines during a period of one year. Depending on the results more machines will be purchased. The machine is expected to be commercial in 1995.

WindMaster has developed a 40 m/750 kW wind turbine. The first prototype has been operating at the windfarm Halsteren since 1991. In 1992 the noise level of this machine was brought down from 103 dB(A) to 98 dB(A) after a research effort to reduce the acoustic noise. During 1993 the machine was extensively redesigned. The rotor diameter was increased to 43,2 m. The first of the new machines will be built in 1994.

Lagerwey is specialized in variable speed turbines with passive blade pitch control. The blades are individually hinged, which gives flexibility in the flapwise direction. After a development period of more than 10 years, this complicated concept has proven to be mature. Lagerwey installed more than a hundred 18 m/80 kW turbines both in the Netherlands and in Germany. Lagerwey has also developed a 25 m/250 kW prototype. Certification of this machine is underway. It will be commercially available in 1994.

In order to be eligible for investment grants in the Netherlands, wind turbines have to be certified according to NEN 6096/2. A complete list of certified turbines is given in Table 2.6.3.

Technical development

Industry involvement in technology research is crucial. In 1991 an industrial platform was formed with representatives of leading industries. The platform advises NOVEM on the planning, progress and results of R&D projects. Increasing commitment of the industry by financial participation in R&D projects will be pursued in order to guarantee the applicability of the results.

In 1993, research was concluded on:

Rotor aerodynamics of stall regulated wind turbines. Results from the ongoing JOULE II project Dynamic Inflow, research on the validation of 3-D effects in stall, and research on stall-induced vibrations were collected in a handbook for industrial designers. A first approximation of a better calculation method for 3-D effects was presented.

Comparison of national standards with regard to IEC and EEC developemnt of standards. The cooperation between certifying bodies and the wind industry was strengthened. The comparison between the Dutch standard and the draft IEC standard was first done on a qualitative and then on a quantitative basis. Results are used to redesign Dutch turbines according to the draft IEC standard.

Long and short term research on aerodynamic noise emission. In the short term part of this project some ideas on the shape of the trailing edge were verified in field tests. The first phase of the long term part of the project was conducted in 1993. Some theories about mechanisms of aerodynamic noise due to turbulent inflow and trailing edge noise were verified in the anechoic wind tunnel of NLR. The results look very promising, especially with regard to reduction of the trailing edge noise. A patent application was filed for a certain trailing edge shape. In 1994 the second phase of this research project will pursue a further refinement of theoretical and experimental models through wind tunnel and field tests.

Fatigue properties of glassfibre reinforced polyester. Partial results, especially with regard to methodology, will be discussed with certifying bodies in early 1994. Final results will be available by mid-1995.

Turbine design. Application of the methods of reliability analysis to the NEWECS-45 wind turbine has started in a JOULE II project. Furthermore a case study will be carried out to transfer the methodology to wind turbine manufacturers. Design tools in the form of the computer codes PHATAS-II and FLEXLAST were modified and transferred to Dutch industries.

After the evaluation in 1992 of the FLEXHAT/VERIFLEX programme it was concluded that:

- the concept of a variable speed turbine with passive pitch control and mechanical damping of vibrations in the drive train through advanced electronic control of the generator did not fit in the development line of Dutch industries;
- the evaluation committee showed some doubts as to the alleged cost reduction of 30 % of this concept;
- it might be possible to incorporate partial results of the research in existing product developments.

Dutch industries showed interest in the development of a stall controlled constant speed wind turbine with elastomeric teetering hub and flexbeam. This concept is named Stall-Flexteeter.

ECN started a measuring programme on the 25 m HAT to evaluate the existing FLEXTEETER rotor in stall operation and to verify the calculated variable loads on the flexbeam.

Stork Product Engineering started a commercial and technical feasibility study with regard to the development and production of the Stall-Flexteeter. This is done in close cooperation with blade manufacturer Aerpac and turbine manufacturer NedWind.

Other programmes

Important elements of the ECN programme are:

- Construction of a 23 m diameter rotor equipped with pressure holes at three radial positions to measure the pressure distribution during operation. The facility will be used for research on dynamic stall and dynamic inflow phenomena (Annex XIV) and in a JOULE-II project;
- Research in fatigue properties and evaluation methods to determine the fatigue life for for large blades. The determination of so-called stress reserve factors gives vital information for optimizing the use of blade materials;
- Development of variable speed electrical conversion systems with appropriate control systems;
- Computational programmes for wind field description, aerodynamic and structural dynamic response, lifetime and stress calculations. A series of programmes, which form an integrated package, has been completed with a description of the model manuals and verification procedures;
- Development of improved field measurements methods for acoustic noise emission, power performance and mechanical loads;
- Development and application of probabilistic reliability and safety analysis methods and failure mode analysis for wind turbines;
- Development of evaluation and certification methods.

Table 2.6.3 Certified wind turbines in the Netherlands per 17 Dec.1993.

Manufacturer	Type	Rotor diameter (m)	Rated power (kW)	Noise emission dB(A)	Date of certification
NedWind	NedWind 25	25,47	250	94,9 2)	93-03-09
	NedWind 40	40,15	500	97,5 1)	93-03-23
	23 PI 250	23,1	250	98	87-08-12
	35 PI 500	35	500	103	89-10-13
Lagerwey	LW 15/75	15,4	75	92	87-06-10
	LW 18/80	18	80	91,0 1)	91-03-27
Micon	M 450	24	250	96	87-12-08
	M 530	26	250	93,6 1)	89-12-20
	M 750	31	400	99,7 2)	93-11-05
WindMaster	WM 450	24	250	103,0 1)	87-12-08
	WM 500	32,9	500	107,0 1)	89-12-18
	WM 750	40,18	750	101,0 3)	93-06-22
Enercon	Ener 32/330	33	330	97,7 1)	90-12-27
	Ener 33/400	33	400	97,7 1)	90-12-27
Nordtank	NTK 300	31	300	98,6 2)	93-03-11
Vestas	V39-500/NL	39,4	500	97,8 2)	93-07-08
	V27-225	27	225	97	93-11-30
Bonus	Bonus 500	37	500	96,7 2)	93-06-28
	Bonus 300/NL	31	300	95,8 2)	93-10-26

1) measured at 7 m/s
2) measured at 8 m/s
3) measured at 7,5 m/s

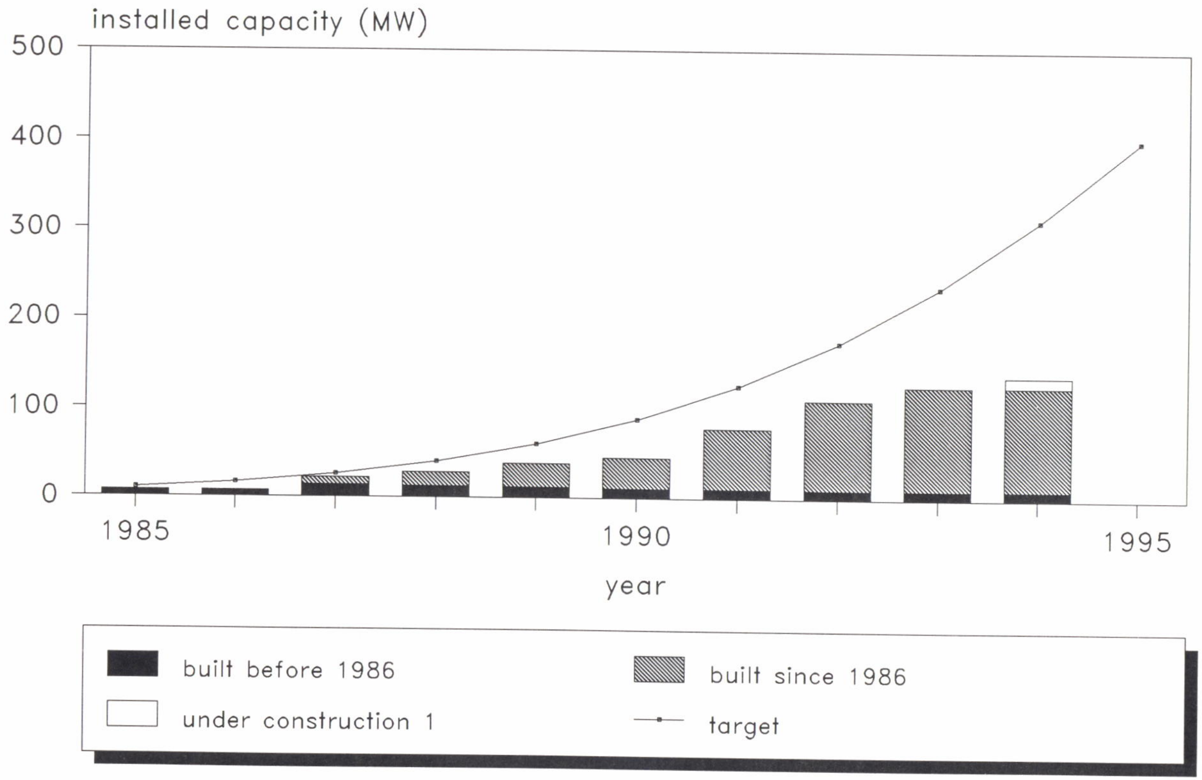


Figure 2.6.1 Installed wind power in the Netherlands

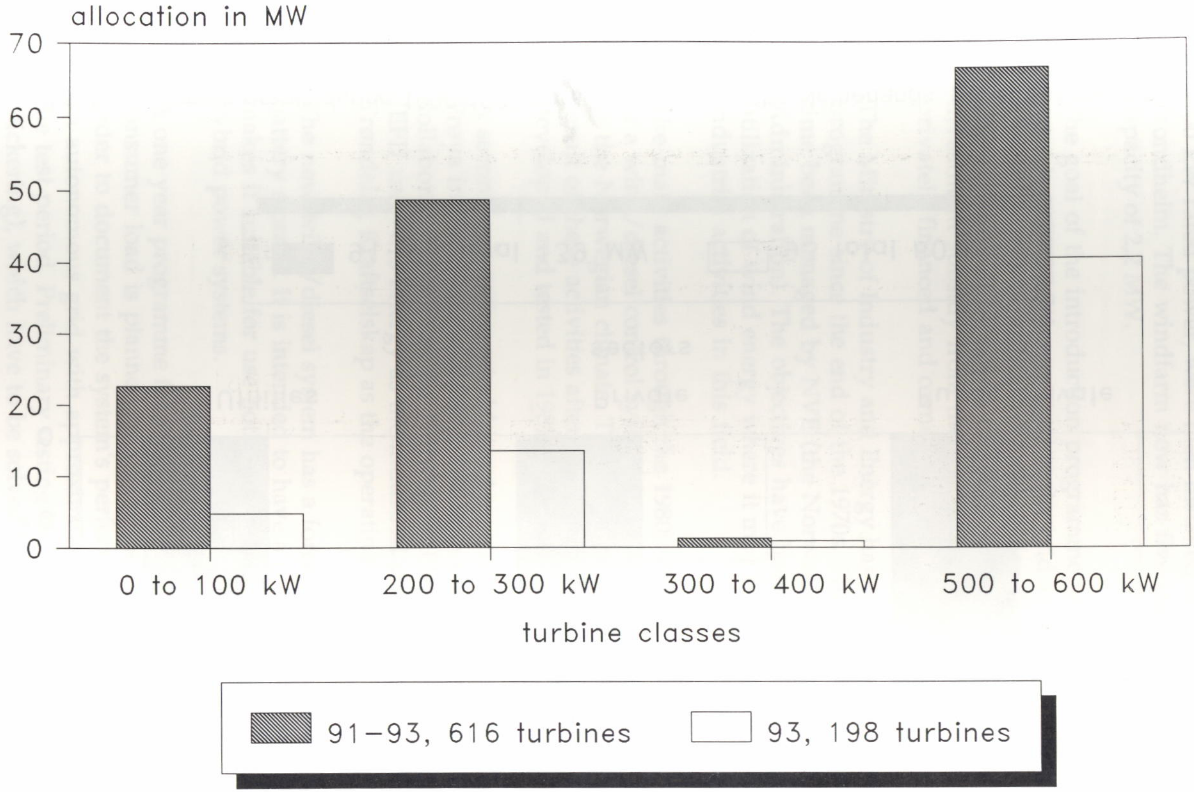


Figure 2.6.2 Investment grants during 1990-1993 for wind turbines in the Netherlands per unit rated power range

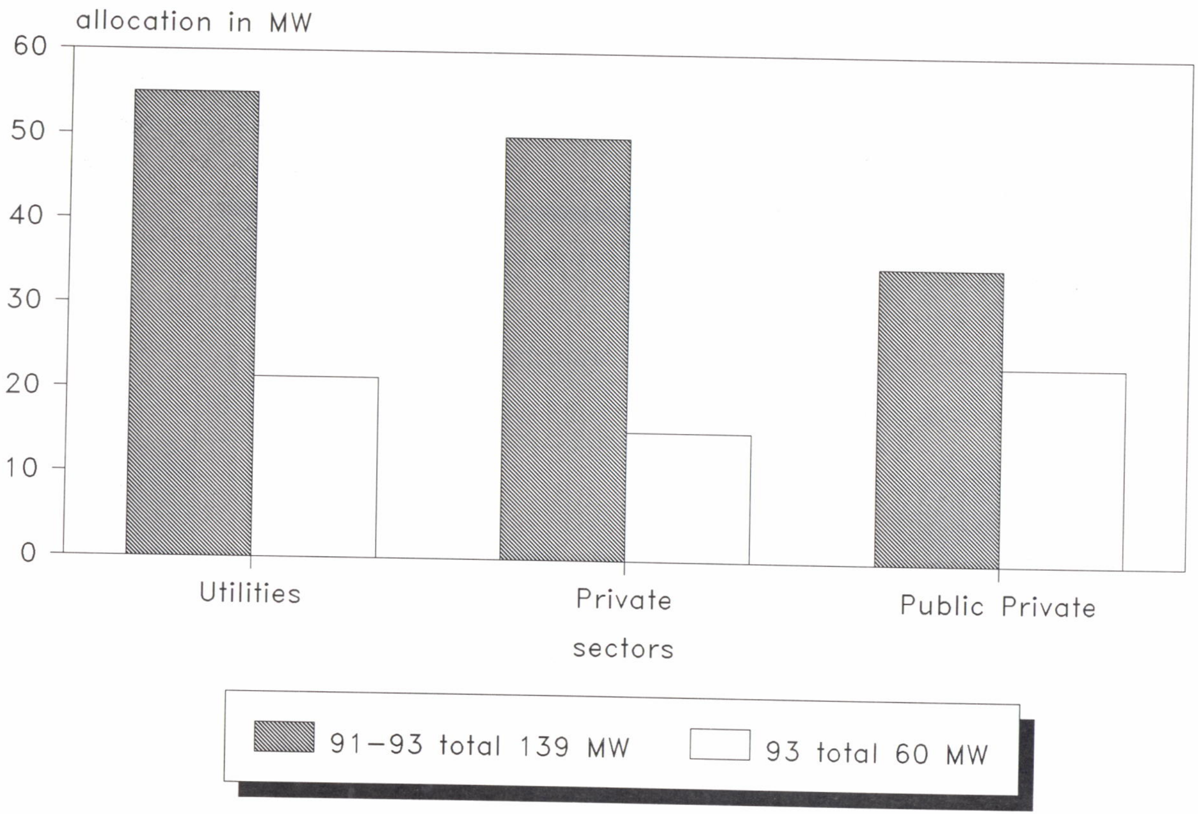


Figure 2.6.3 Investment grants during 1990-1993 for wind turbines in the Netherlands, per owner/operator sector

2.7 Norway

The first national programme for the introduction of wind power was completed in August 1993. Two additional wind turbines, each with 500 kW rated power, were then installed at the Vikna windfarm north of Trondheim. The windfarm now has five units for a total generating capacity of 2,2 MW.

The goal of the introduction programme was to install wind turbines for a capacity of 3-4 MW connected to the grid system by the end of 1992. At present twelve Danish wind turbines for 3885 kW are installed. Ten of them are owned by power companies. They were installed with a 50 % investment subsidy from the national programme. The two others are privately financed and owned.

The Ministry of Industry and Energy has supported the wind energy programme since the end of the 1970s. The activities have for most of the time been managed by NVE (the Norwegian Water Resources and Energy Administration). The objectives have been to form a basis for the utilization of wind energy where it may be profitable, and to promote industrial activities in this field.

The main activities through the 1980s were focussed on the development of a wind/diesel control system and the testing of Danish wind turbines in the Norwegian climate. The introduction programme was initiated as a result of these activities after the first geenration wind/diesel system was developed and tested in 1989.

A second generation wind/diesel system was installed at the test plant at Frøya in the summer of 1993. The new system has been developed in collaboration between the Norwegian Electric Power Research Institute (EFI) and ABB Energy as the industrial partner with the utility Sør-Trøndelag Kraftselskap as the operating manager of the system.

The new wind/diesel system has a forced commutated converter with battery storage. It is intended to have a control system with properties that makes it suitable for use both in wind/diesel and other autonomous hybrid power systems.

A one year programme for testing of the new wind/diesel system against consumer load is planned to follow the completion of the installation in order to document the system's performance. The system will be serving an autonomous grid with approximately 10 domestic consumers during the test period. Preliminary testing has disclosed som voltage problems (flickering), which have to be solved before the one year test programme can start.

To protect the wind turbines against lightning in the Norwegian coastal climate seems to be a problem. One wind turbine, a 400 kW unit at Vesterålen, was struck by lightning last winter. Two of the rotor blades were damaged. The turbine has been rebladed and put into operation again. A thorough analysis of the lightning problems will be carried out by the firm Transinor Technology A/S with the view to give some recommendations on how to protect the wind turbines against lightning.

The Norwegian wind energy programme will be reorganized from January 1994. The research programme will be managed by the Research Council of Norway, whereas NVE will be responsible for the introduction programme. The priorities in the new programme will probably be directed more towards finding appropriate market niches and options for profitable use of wind energy. Less attention will be paid to attaining certain installation capacities.

2.8 Spain

Introduction

The progressive wind development in Spain since 1986 has been consolidated in the last years. The 38 MW installed during 1992 together with the 15,7 MW installed in 1993 brings the capacity closer to the target of 100 MW in 1995.

The development of new prototypes and the identification of the best wind areas in the Canary Islands, the Gibraltar Straights and the North-West Corner, the support of the Public Administration and the utilities in windfarms conspire to an interesting future for wind energy in Spain. Main data for the installed and planned windfarms are shown in Tables 2.8.1 to 2.8.4.

Installations

Tarifa continues to be the most important wind turbine concentration in Spain with 259 aerogenerators of a rated unit power larger than 100 kW and a total installed capacity of 33 MW. The wind data in the Tarifa area are very promising. The results obtained at the Experimental Windpark, supported by CIEMAT, show an annual average wind speed of 8,7 m/s at 30 m height with prevailing winds from the east.

The total investment for the Tarifa windfarms is about ESP 5400 million (≈ 40 MUSD) with an external support of 14 % private funds, and 25 % of public funds through the FEDER (VALOREN programme), the Spanish Ministry of Industry and Energy and the Regional Government. The remaining 61 % of the total cost is obtained from long term loans. The estimated wind potential for the whole area corresponds to nearly 250 MW of wind power capacity. Several projects are being considered in order to increase the current installed capacity.

At the northwest coast, in the Galicia region, the windfarm of Cabo Villano is located, which includes the AWEC-60 wind turbine (prototype of 1,2 MW rated power and 60 m rotor diameter, which is part of the WEGA programme of the CEC), and 20 wind turbines of 180 kW, developed by a Spanish company. A new 15 MW windfarm is being considered close to the existing windfarm. The most conservative estimates show a potential capacity of 300 MW for the Galicia region.

The Canary Islands, located in the trade wind regime, is the other interesting area of Spain. At present there are 20,6 MW of wind turbine capacity installed in several windfarms along the island coasts. Views of the Granadilla and Jandía windfarms are shown in Figures 2.8.1 and 2.8.2. The last estimates show a potential capacity of around 100 MW. However, the small insular grid requires some studies of the penetration of wind energy.

An important future development is foreseen also in Cataluña: The "Valle de Ebro" windfarm with 4 MW installed capacity will come into operation in 1994. The participants are ECOTECNIA, ENDESA-MADE, FECSA and the local administration.

Industrial activities

The public utility ENDESA is engaged in the major wind energy projects in Spain through its subsidiary manufacturing company MADE. MADE has developed several types of wind turbines from the first 24 kW model. The most used model has a rated power of 180 kW, three stall-controlled blades and 23 m rotor diameter. A 300 kW model has been tested at the Granadilla windfarm. Three new 300 kW prototypes will be erected in the Tarifa region. The new commercial plants installed by ENDESA are based on this model. The next step of MADE is the developemnt of a 500 kW unit.

The other Spanish manufacturer is the ECOTECNIA company. This is a cooperative of specialists in renewable energies, which has centered its main activity on wind energy. The work has been oriented to the development of independent technology. In 1983, ECOTECNIA developed a 30 kW wind turbine. Then a 180 kW, 20 m rotor diameter model was manufactured and tested, of which 52 units with a total capacity of 11,75 MW are now in operation in several windfarms. A new 24 m/200 kW wind turbine is operating at Tarifa. Since January 1993, other activities have focussed on decentralised applications and wind resource studies, and on developing new site evaluation models for complex terrains, which are common in the Tarifa and Ebro Valley regions.

Two other companies are also involved in wind turbine fabrication, but in joint ventures with foreign manufacturers. One of them is located in the Canary Islands, and has an agreement with the Vestas company. This is the Aerogeneradores Canarios (ACSA), which is engaged in the windfarms in the islands. The other company is Abengoa Wind Power (AWP) which has cooperated with U.S. Windpower in the manufacture of 100 kW wind turbines.

R&D projects

The main areas of R&D activity in the Instituto de Energias Renovables (IER) of CIEMAT in 1993 are:

- Testing and evaluation of the new MADE AE-26 prototype with 26 m rotor diameter and 300 kW rated power. The prototype was installed at Granadilla (Tenerife - Canary Islands) in August 1992. The tests were carried out during the first three months of 1993.

- In the framework of the JOULE II programme of the CEC, the Wind Division of CIEMAT is involved in two main projects:

  - A load and power measurement programme on wind turbines operating in complex mountaineous regions.
  - The S & FAT project for blade rotor testing.

- Development and testing of the 300 and 500 kW prototypes in collaboration with ENDESA and MADE.

- Wind resource assessment
  - Wind measurement and modelling in complex terrain, in the framework of the JOULE programmes of the CEC, in order to estimate the site climatology and evaluate the model predictions of promising zones for wind energy exploitation in Spain and Portugal.
  - Development of a short-term prediction model of energy production in windfarms, in collaboration with several utilities.
  - Site selection for windfarms. Several projects contracted by ENDESA in order to select windfarm sites in some potential areas.

Since 1989 CIEMAT is working together with the Universidad Politécnica de Las Palmas on the wind-diesel plant at Pájara (Fuerteventura - Canary Islands). This autonomous system, with a 225 kW wind turbine and two 60 HP diesel engines, is financed by the CEC through the VALOREN programme.

WINDFARM			WINDTURBINES			MACHINES Nº	YEAR	TOWER (m)	SWEEPT (m^2)
NAME	LOCATION	TOTAL POWER (MW)	MANUFACTURER	MODEL	RATED POWER (kW)				SINGLE WIND TURBINE
LA MUELA	LA MUELA (ZARAGOZA)	0,55	GESA GESA	10/3 AE15 AE18	30 75 110	12 1 1	1987 1988 1988	12 18.4 21.5	85 183.8 273.5
ESTACA DE BARES	MAÑON (LA CORUÑA)	0,36	GESA	10/3	30	12	1987	12	85
ONTALAFIA	ALBACETE	0,30	ECOTECNIA	12/30	30	10	1988	14	113
TARIFA	TARIFA (CADIZ)	0,65	ECOTECNIA ECOTECNIA ECOTECNIA	12/30 20/150 24/200	30 150 200	10 1 1	1988 1989 1992	14 29 30	113 314.2 452.4
CABO DE ROSES	GERONA	0,59	GESA GESA	AE 15 AE 18	75 110	2 4	1990 1990	18.4 21.5	183.8 273.5

Table 2.8.1 Windfarms of rated power less than 1 MW in operation in Spain

WINDFARM			WINDTURBINES						SWEEPT (m^2)
NAME	**LOCATION**	**TOTAL POWER (MW)**	**MANUFACTURER**	**MODEL**	**RATED POWER (kW)**	**MACHINES Nº**	**YEAR**	**TOWER (m)**	**SINGLE WIND TURBINE**
GRANADILLA	GRANADILLA TENERIFE (CANARY ISLANDS)	1,68	MADE	AE-20	150	1	1990	21.7	314.2
			ECOTECNIA	20/150	150	1	1990	29	314.2
			W.E.G.	25/250	250	1	1990	25	491
			CENEMESA	FL-19	300	1	1990	25.3	
			VESTAS	V25	200	1	1990	28.7	491
			ENERCON	33	330	1	1991	34	855.3
			MADE	AE-26	300	1	1992	29	531
MONTE AHUMADA	TARIFA (CADIZ)	1,05	MADE	AE-20	150	7	1989	21.7	314.2
CABO VILLANO (Phase 1st y 2nd)	CAMARIÑAS (LA CORUÑA)	3,9	VESTAS	V25	200	1	1990	28.7	491
			VESTAS	V20	100	1	1990	23.40	314.2
			MADE	AE-20M	180	20	1992	21/28	314.2

Table 2.8.2 Windfarms of rated power over 1 MW in operation in Spain

WINDFARM			WINDTURBINES			MACHINES Nº	YEAR	TOWER (m)	SWEEPT (m²)
NAME	**LOCATION**	**TOTAL POWER (MW)**	**MANUFACTURER**	**MODEL**	**RATED POWER (kW)**				**SINGLE WIND TURBINE**
COSTA CALMA	FUERTEVENTURA (CANARY ISLANDS)	1.1	ACSA-VESTAS	V 27	225	5	1992	31.5	572.6
TENEFE	GRAN CANARIA (CANARY ISLANDS)	1.1	ACSA-VESTAS	V 27	225	5	1992	31.5	572.6
MONTAÑA MINA	LANZAROTE (CANARY ISLANDS)	1.1	ACSA-VESTAS	V 27	225	5	1992	31.5	572.6
PESUR	TARIFA (CADIZ)	21.1	MADE A.W.P.	AE-23 AWP-100	180 100	34 150	1993 1993	21.7 18/36	415.5 254.5
EEE	TARIFA (CADIZ)	10.3	MADE ECOTECNIA	AE-20M 20/150	180 150	16 50	1993 1993	21.7 29	415.5 314.2
DE LOS VALLES	LANZAROTE (CANARY ISLANDS)	5.3	MADE A.W.P.	AE-23 AWP-100	180 100	6 42	1993 1993	21.7 18	415.5 254.5

Table 2.8.2 Continued

WINDFARM			WINDTURBINES					
NAME	**LOCATION**	**TOTAL POWER (MW)**	**MANUFACTURER**	**MODEL**	**RATED POWER (kW)**	**MACHINES Nº**	**YEAR**	**ENERGY OUTPUT PREDICTED (MWH/year)**
JANDIA	FUERTEVENTURA (CANARY ISLANDS)	10,2	MADE MADE	AE-23 AE-30	180 300	27 18	1993 1993	
BAJO EBRO	TORTOSA (TARRAGONA)	4	ECOTECNIA MADE	20/150 AE-20M	150 180	16 9	1993 1993	8.000
CABO VILLANO (Phase 3rd)	CAMARIÑAS (LA CORUÑA)	15	MADE	AE-26	300	50	1993	30.000
BARRANCO TIRAJANA	GRAN CANARIA (CANARY ISLANDS)	1.3	MADE	AE-23	180	7	1993	3.000

Table 2.8.3 Windfarms in planning stage

Figure 2.8.1 Wind turbines at Granadilla in Tenerife (Canary Islands)

Figure 2.8.2 The Jandía windfarm in Fuerteventura (Canary Islands)

2.9 Sweden

Wind energy programmes

The government is supporting the development and installation of wind turbines in three programmes, managed by the National Board for Industrial and Technical Development (NUTEK):

- A fully financed research programme with a three-year budget of SEK 27 million for 1994-1996;

- A development and demonstration programme for large wind systems, with a maximum of 50 % support;

- A market stimulation programme where the installation of commercial wind turbines is subsidized at 35 % of the investment costs.

The utilities are engaged in studies, demonstration and evaluation projects. From 1994, the research and development activities of the utilities are coordinated in a jointly owned company, ELFORSK, which initiates and finds sponsors for projects in the field of electricity generation. In addition to the activities of ELFORSK, the largest utility, Vattenfall AB, has a substantial wind energy development programme of its own.

Basic research

The allocation for wind energy research in fiscal year 1994 (1 July 1993 - 30 June 1994) is SEK 9 million. Due to an agreement with the European Community, Sweden is increasingly involved in the wind energy activities of the CEC.

The research is mainly carried out at universities and national research institutes. Studies in aerodynamics, structural mechanics, materials, advanced design methods, acoustic noise, control technology, and safety and standards are performed at the Aeronautical Research Institute (FFA) in Stockholm.

Basic atmospheric research is carried out at the Department of Meteorology, University of Uppsala, for example on wake effects and boundary layer phenomena. Wind measurements and resource assessments are performed by the Swedish Meteorological and Hydrological Institute, Norrköping.

Electric machinery and control technology for wind systems are studied at the Chalmers University of Technology, Gothenburg, who also operate the Wind Turbine Test Station on the island of Hönö, off the west coast near Gothenburg. A small wind turbine is operated at Hönö, mainly for testing power electronics.

Integration of wind power into electric grids is studied at the Department of Electrical Energy Systems, Royal University of Technology, Stockholm.

Development projects

Maglarp

The 3 MW/78 m wind turbine, installed in 1982, has operated with an availability of around 82 % since the repair of the gearbox in 1991. The turbine was finally shut down in June 1993 by the operator, the Sydkraft utility. It was taken down, after removal of the generator and liquid oils from the nacelle, by cutting a wedge-shaped notch near the base of the turbine and allowing it to fall to the ground. According to Sydkraft the main reason for decommissioning was poor economic performance. At the end of life, the turbine had generated 36 700 MWh of electricity, so far more than any other single wind turbine, during 27 893 hours of operation, connected to the grid.

Näsudden II

The 3 MW/1 MW Näsudden II wind turbine was connected to the grid in March 1993. Testing has been going on during the spring and summer, including a full scale test of the emergency brake. By December 1993, 2331 operating hours had been obtained. The prescribed acceptance test for 500 hours of continuous grid-connected operation has been split into two periods of 200 and 300 hours. The first period was successfully completed during the summer. The second period which must include 50 hours at rated power, is easier to achieve during the autumn and winter when the wind speeds are higher. The availability of the turbine has been high and reached 91 % during December. Total production during 1993 was 2397 MWh; 1913 MWh from the 3 MW generator and 484 MWh from the 1MW generator.

When the acceptance tests are completed and the machine is taken over by the operator, Vattenfall, a two-year evaluation programme will follow. This will include comparisons with the performance of the sister unit Aeolus II in Germany. The evaluation is also coordinated within the WEGA-II project of the CEC JOULE II programme.

Risholmen

Following the accident in June 1992 when a blade tip was lost, the 750 kW Howden turbine, installed in 1988, has been out of service and was disassembled in the summer of 1993. It has been replaced by a 450 kW Bonus machine, erected with support from the investment subsidy programme.

Nogersund

In early November, an accident occurred at the 200 kW offshore demonstration turbine (Windworld). When the unit was remotely restarted after an automatic stop due to phase instability, the turbine caught fire and was destroyed. The cause of the accident has not yet been established. The operator Sydkraft has announced that a new turbine will be erected.

Advanced wind turbines

Zephyr

The three 250 kW Zephyr wind turbines at Falkenberg on the west coast are two-bladed, passively pitch-controlled with individually flapping blades, see Figure 2.9.1. The project is funded by the local utility, and the installation of two of the turbines have been supported by the government-sponsored market stimulation programme. After the loss of a rotor blade in 1992 in one of the turbines, the machine was rebladed and has since operated well.

Lyse

The Lyse wind power station, at Basteviksholmarna near Lysekil on the west coast, has a Swedish prototype (Nordic 400) and a Danish standard machine (Bonus 450 Mk2) for reference, as well as an advanced data acquisition system and a meteorological mast.

Bonus 450 was erected in June 1992 and Nordic 400 in September 1992. The prototype, which has been certified by Det Norske Veritas, is still in commissioning. The wind measurements have indicated severe wind conditions with high wind shear and turbulence, due to the rugged coastline.

The Nordic 400 has shown a stable dynamic behaviour during most wind conditions. Some corrections in the control system are still needed to meet the requirements of the operator. Preliminary noise measurements indicate a lower aerodynamic noise and higher mechanical noise for the Nordic 400 as compared to the Bonus.

Näsudden III

Phase 1 of Vattenfall's Development Study of third generation large wind turbines was completed in December 1992. General technical specifications, safety requirements, and target costs were established. The target cost is set at 1/3 of the cost of the present Näsudden II machine, at the same location. Critical parts for cost reduction have been identified as the blades and the machinery, for which a 50-75 % lower cost is needed.

Phase 2 of the Development Study, which includes a conceptual design study based on phase 1 and the experiences of Näsudden II and Aeolus II, has started and is expected to be completed in the summer of 1994.

Nordic 1000

Vattenfall and Nordic Windpower are developing an upscaled version of Nordic 400, see Figure 2.9.2. The project is part of the CEC JOULE II programme. At the end of the year, the detailed design is in the final stage of completion. The machine will have a rated power of 1000 kW, a rotor diameter of 52 m and a hub height of 56 m. The basic features will be the same as for Nordic 400 with a teetered hub, variable speed and an advanced yaw damping system. The weight of the machine is estimated at only around 75 tonnes, including tower but excluding foundation and electrical systems at ground level.

The turbine will be erected at Näsudden in late 1994 - early 1995. After take-over, an evaluation period will follow. The evaluation is coordinated in the WEGA-II programme of the CEC.

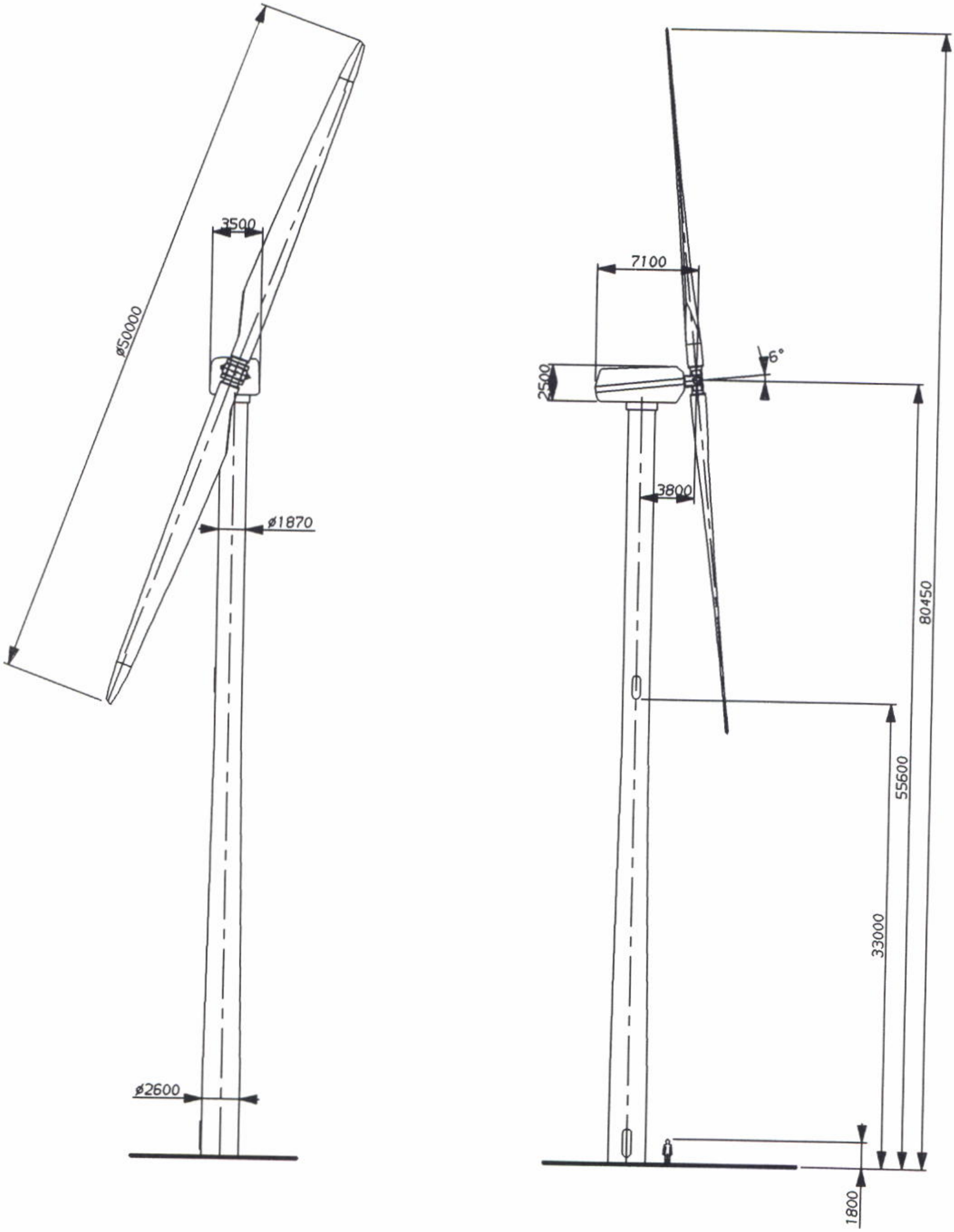
Market stimulation

The government has allocated SEK 250 million over a five year period from 1 July 1991, for supporting the installation of wind power plants larger than 60 kW rated power. The main interest in the programme has been by private investors who can use the produced electricity for their own consumption. This is commonly done either by holding stocks in private wind energy companies or by forming cooperatives. Local distributors have also shown interest in investing in wind turbines.

By 1 January 1993 the subsidy was increased from 25 to 35 % of the investment cost. The increase had, however, little effect for the purchase of foreign-made machines due to the depreciation of the Swedish Krona which occurred in the fall of 1992. Accordingly, the installation rate has been less than expected, and only about half of the amount available for 1991-1993 has been made use of. The main reason for the low interest is the low cost of electricity in Sweden.

By the end of November, about 24 MW of wind power was installed in 121 units, excluding the development projects. More than 50 000 MWh were produced during 1993. Most wind power is generated on the island of Gotland, about 8000 MWh in 1992, which corresponds to slightly more than 1 % of the island's electricity consumption.


ZEPHYR



WIND TURBINE NWP 1000	
Diameter of rotor:	50m
Height of hub:	56m
Rated Power:	1MW
Power limitation:	Stall
Rated wind speed:	14.5m/s
Weight excl. foundation:	72000kg

Figure 2.9.2 Drawing of Nordic 1000

2.11 United Kingdom

Government funded R, D&D programme

Introduction

During the year the Department's programme was reviewed, aims and objectives were defined and a strategy to achieve these during the coming years was developed. These will be incorporated in an Energy Paper shortly to be published. The main line in the strategy to achieve the programme's aims is to use the demonstration projects made possible by the NFFO (Non-Fossil Fuel Obligation), firstly to demonstrate the technology and secondly to gain experience of the environmental and other non-technical barriers to deployment. From the knowledge arising, work can be initiated to improve the technology, to overcome the barriers and to disseminate information to allow full, cost effective exploitation of the resource. The Department will also seek to encourage UK industry to develop capabilities for the domestic and export markets.

As a result of the demonstration of the technology under the first two tranches of the Non-Fossil Fuel Obligation (NFFO 1 and 2), about 120 MW of rated wind power capacity are currently connected to the grid. About 20 % of the approximately 400 turbines are of British manufacture, based on prototype and pre-demonstration machines developed through the Government programme. These developments have done much to demonstrate the potential and performance of the technology in the UK. The announcement of NFFO 3 of 300-400 MW DNC (Declared Net Capacity) for 1994 with possibly two or more tranches for 1996 an 1998 should allow sufficient wind energy capacity to be installed to allow the programme to achieve its objectives.

The demonstrations acted as a stimulus to the market related activities in the programme. As the work became increasingly focussed to market requirements, less generic technical work, fully funded by Government was required. There was increased commitment and financial support from the industry. During the year manufacturers and developers have been more able to contribute to the cost of the new work as a result of contracts under NFFO. Specifically, the jointly funded Joint Windfarm Programme with National Wind Power Ltd is progressing well with all three farms (Cemmaes, Cold Northcott and Llangwyryfon) being commissioned in the course of the year, and most of the projects are in place in the jointly funded wind turbine development programme with the Wind Energy Group.

Programme management

The cash allocation for the Financial Year was GBP 7,2 million, which was supplemented by contributions from external sources, estimated to be 6 MGBP. Of these 6 MGBP, approximately 3 MGBP realted to cost-shared projects (1 MGBP from the CEC) and 3 MGBP related to NFFO projects. Almost 200 individual projects were managed during the year.

Programme planning

Following the review of the programme strategy, programme plans for the next three to five years have been drawn up and agreed with the Department. On the technical side, these plans reflect the growing maturity of the industry and its increasing financial involvement - more demonstration, monitoring and information dissemination is envisaged, and less generic R&D work. Based on the experience of windfarms in NFFO 1 and 2, the non-technical barriers to deployment are seen to be increasing in importance, and additional effort is being focussed on this area.

Promotion and technology transfer

Targets for publication were largely met, up-to-date windfarm bulletins and technical reviews were completed to replace existing material. Several Best Practice Case Studies were prepared. One workshop was organised in collaboration with the BWEA, on Prospects for Offshore Wind Energy. It brought together a wide spectrum of disciplines with offshore interest (from planning through offshore construction to resource assessment) and achieved its aim in disseminating information which allowed the cost of siting wind turbines offshore into perspective and identified the large development programme which will be needed to exploit the resource at reasonable cost. Another workshop was jointly sponsored with BWEA and Royal Agricultural Society of England on Wind Energy on Your Farm.

External assistance

The main effort has been on Regional Planning and Resource Assessment studies in collaboration with County Councils and the Regional Electricity Companies, where members of the wind team headed three of the ETSU studies (involving NORWEB, MANWEB and Scottish Power) and contributed to several others. Presentations were also made by members of the wind team in the series of planning and financial seminars. A wind energy technology module summarising the current status of the technology was completed for the Technology Rview of the new Energy Paper and for the Reappraisal of the Renewable Energy Technologies taking place during 1993-1994.

International liaison

Collaboration has continued in the CEC MW-rated wind turbine project (WEGA) through monitoring data of the Richborough 1 MW machine and Orkney 3 MW LS-1. This will assist development of plans for future MW-rated machines under the CEC JOULE II initiative.

Participation in several Annexes of the IEA R&D Wind Implementing Agreement has enabled a good exchange of information among member countries and an awareness of the international progress in developing wind energy.

Second tranche of the Non-Fossil Fuel Obligation

Contracted projects (NFFO 2)

The second Order included 49 wind projects totalling 82,4 MW DNC (192 MW rated). A "bid-in" system was used with each developer having to state the price at which he was prepared to supply his nominated capacity. The proposals with the lowest bid-in price were offered contracts but a single price, the highest accepted bid, was applied to all contracts. This was 11 p/kWh for wind energy, which to a large extent reflects the short period of the contracts due to the 1998 constraints.

By the end of September 1993, eight of the nine NFFO 1 projects (27,7 MW total rated capacity) were generating, NPWL having withdrawn Carmarthen Bay from the NFFO. Twenty of the 49 NFFO 2 projects (91,9 MW rated capacity) were generating power with another three projects (16,0 MW rated capacity) under construction.

Technical performance of turbines to date has been good with most developers reporting high levels of availability and energy production matching or exceeding predictions.

Reactions to 2nd tranche planning applications

The response of local authorities to planning applications for 2nd tranche projects were much more positive than those in the 1st tranche, probably due to greater awareness and understanding of the problems. Even so, nine applications were the subject to appeals or called in by or referred to the Secretary of State, and five Public Inquiries were held.

The conventional conditions of the planning consents such as highway alterations and ancillary buildings caused little difficulty. However the main concerns of the planners were still noise intrusion, loss of landscape, being largely subjective and non-quantifiable, and noise levels, although quantifiable, caused particular difficulties. Although noise level agreements had common elements (e.g. tonal noise), planners and developers arrived at different details (e.g. noise levels and distances) depending on their own judgements and the particular character and sensitivity of each site.

Scottish Renewables Obligation

A Scottish Renewables Obligation (SRO) was announced in July 1993. The first order under the SRO is expected to be for some 30-40 MW of new capacity to run for 15-20 years from November 1994. Wind power is likely to be the dominant factor in the first SRO.

2.12 United States

U.S. energy policy

The U.S. has developed and issued a Climate Change Action Plan (CCAP). Among its primary objectives is the reduction of U.S. emissions of greenhouse gases to their 1990 levels by the year 2000. The plan contains nearly 50 initiatives, covering all sections of the economy. An example of one that will help the wind industry is the establishment of market mobilization collaboratives between DOE and industry. In another initiative, called the U.S. initiative on Joint Implementation, pilot programmes are planned to implement voluntary projects between the U.S. and foreign partners that reduce net emissions of greenhouse gases. Wind energy projects could be structured under this initiative so as to yield credit for reduction of emissions for both the host country and other participating countries.

The implications of the Clean Air Act Amendments of 1990 continue to be discussed, as 1993 is the first year in which some areas of the U.S. are required to meet national ambient air quality standards. Under the Amendments, utilities exceeding certain levels of emissions will have to purchase "allowances". A single allowance permits a utility to produce one ton of SO_2 beyond the limits specified by the amendments. The trading of allowances has begun this year, and is expected to give renewables, and wind energy in particular, an added edge over fossil fuel-fired generation. Through the use of renewable generation, utilities may bank or sell allowances to other utilities, thus increasing the value of the generators to the utility.

The state of the U.S. industry

The wind industry is poised for a substantial increase in installations as the Renewable Energy Production Incentive takes effect for wind plants coming on line after 1 January 1994. The activation of the incentive coincides with the commercialization of several new wind turbine designs, and the anticipated new installations are of particular interest as they will be some of the first of significant size in areas of the U.S. other than California and Hawaii.

Completed installations in 1993 were small in capacity but significant in that there was some activity outside of California: the first wind power plant in the state of Iowa in the midwestern U.S. was dedicated this year. Current total wind turbine installations inthe U.S. remain approximately the same as 1992, about 1600 MW. Generation from the approximately 16 000 turbines is estimated to be slightly higher than prior years.

Site construction began in September on the first 25 MW of Kenetech Windpower's installation of 100 MW of wind turbines in Minnesota in the upper midwestern U.S. The 73 Kenetech 33M-VS turbines are being installed along the area known as Buffalo Ridge, and are expected to be on line by May 1994. Work is expected to start soon on plants in the Northwest, for the Bonneville Power Administration, and on two demonstration wind installations in Texas. In the eastern U.S., construction could begin as early as the spring of 1994 on the installation of up to 15 MW of turbines in Maine.

Two U.S. wind energy companies, New World Power Corporation and Kenetech Windpower (formerly U.S. Windpower) issued public stock offerings to raise capital for new domestic and international projects this year. The moves show a need for working capital in an industry that has been research intensive in the last few years. Heavy investor response to the two offerings indicates the public expectations of substantial industry growth. The offerings and resulting positive responses from major brokers are important milestones in the perceived maturity of the technology within the financial community.

Federally-funded research and development

This past year has seen the start-up of several new initiatives intended to complement the U.S. Department of Energy's existing R&D peogram, as well as new stages in existing programs such as the Advanced Wind Turbine Program. After a near doubling of funding from USD 11,1 million in Fiscal Year (FY) 1991 to 21,4 MUSD in FY 1992, the funding level rose again to 24 MUSD in FY 1993 and in FY 1994 to 30,4 MUSD. The increase in FY 1994 is primarily intended to support work in two areas: the National Wind Technology Center (3,3 MUSD) and the Utility Wind Turbine Performance Verification Program (3,0 MUSD). The new National Wind Technology Center at Rocky Flats, Colorado, will include full scale turbine testing facilities and will provide the U.S. with an improved wind energy research and development center. Commercial Certification Testing may also be done at the site.

Advanced wind turbines

The Advanced Wind Turbine (AWT) program is a collaborative venture with utilities and industry having the objective of bringing wind-generated electricity costs to levels competitive with those of fossil-fired generators in most regions of the U.S. The Near-term Product Development phase of the AWT program is currently underway, with four contracts awarded with the goal of developing turbines that produce electricity for less than 5 cents/kWh at 5,8 m/s wind sites. R. Lynette and Associates, Inc., Atlantic Orient Corporation, Northern Power Systems and Carter Wind Turbines, Inc. are the participants. Prototype machines from these companies' development efforts are ready or currently in field testing. Characteristics of the turbines are in Table 2.11.1.

Table 2.11.1 Wind turbine generator system data

Machine data		AOC 15/50	AWT-26	CWT 300
Type		Utility interface	Utility interface	Utility interface
Rotation axis		Horizontal	Horizontal	Horizontal
Orientation		Downwind	Downwind	Downwind
No. of blades		3	2	2
Rotor hub		Rigid	Teetered	Teetered
Hub height	m	15,2	26,2	24,1
Rated power	kW	50	275	300
Swept area	sq.m	181	539	455
Rotor speed	rpm	64	57	65
Blade material		Wood/epoxy laminate	Wood/epoxy laminate	Glass/epoxy laminate
Gearbox		Planetary	Planetary	Planetary
Generator		Induction	Induction	Induction
Yaw system		Free	Free	Free

Next Generation AWT activities were started with a request for proposals for innovative subsystems development early this year. Contracts are being negotiated with several companies. The Next Generation phase consists of this innovative subsystems project and a subsequent turbine development project. Full scale turbine development will begin in 1994.

Both near-term and next generation technologies will incorpoarte multiple advanced concepts. For instance, the near-term advanced turbines will use blades with advanced airfoils designed specifically for the turbines, based on aerodynamics research performed at the DOE's Renewable Energy Laboratory. In field testing, these airfoil families have demonstrated energy capture 30 % greater than that of commonly used blades. Two of the near-term designs are using two-bladed teetered rotors in a lightweight turbine architecture.

In the near-term designs, among the improvements of the AWT-26, Figure 2.11.1, is a simplified blade/hub connection design to reduce loads, thereby increasing fatigue life and allowing the use of lighter components elsewhere in the design. In the AOC 15/20, Figure 2.11.2, single piece castings for the hub, gearbox housing, and an innovative split-core rotary transformer allows the control of tip brakes without the use of brushes or other high maintenance components. The North Wind 250, Figure 2.11.3, also features a flow-through rotor structure, in which a one-piece rotor structure eliminates the blade root/hub attachment stress concentrations found in most current rotors. The design also employs ailerons for use in rotor speed control. The CWT 300 will incorporate new airfoils, use of a substantially higher tower and an enhanced controller, and will test advanced data management systems.

The Next Generation designs show a variety of improvements. Although power electronics, with associated variable speed operation, is being proposed, an alternative hydraulic coupling between the rotor and generator to allow variable speed operation is also being considered. There is a trend in the designs toward lighter weight, two-bladed turbines, using tall guyed towers.

Utility integration program

The U.S. DOE has initiated a series of activities addressing issues regarding the integration of wind systems into electric utility operations. An important mechanism for providing guidance for program efforts in this area is the cooperation with the utility industry through the Utility Wind Interest Group (UWIG), a joint effort of the Electric Power Research Institute (EPRI) and DOE. This effort has brought together members of the utility community who support the integration of wind technology for utility application.

One new collaborative effort is the Utility Performance Verification program. This program will deploy and evaluate prototype wind turbines in typical utility operating environments in diverse regions of the country. The first three host utilities were selected because of factors such as geographical and meteorological diversity (differences in turbulence and weather conditions) and differing utility grid conditions. Under the program, Green Mountain Power in the state of Vermont will be building and testing an 8 MW wind plant, Central and South West Corporation in Texas will be building a 6 MW facility, and Central Maine Power will be operating a facility in Maine whose size is not yet finalized. Two more projects are expected to be selected in 1994.

Cooperative wind technology program

The Cooperative Wind Technology Applications activity assists the wind industry in seeking near-term commercial opportunities, both domestic and international, for wind energy. The activity's primary objectives are: 1) to enhance the performance, efficiency, and reliability of current windfarms, 2) to encourage regional diversification, and 3) to define new applications. Seven companies received awards under the initial round of this activity. These cooperative cost-shared research activities are assisting the industry in the design, development, testing, and analysis of solutions to current operational problems. Specific problems being addressed include, but are not limited to, verification testing of existing, new, or improved wind turbines; design, development, and testing to verify new technology components or subsystems; site engineering optimization;

control and utility interconnection; and application demonstrations in new operational environments (for example hybrid systems using small machines).

A Value Engineered Turbine (VET) program was initiated in 1992 to assist the U.S. wind turbine operators in improving the performance and reliability of existing commercial wind installations. Contracts have been negotiated that will support, on a cost-shared basis, value analyses, manufacturing, and commercialization of re-engineered turbines.

Establishment of the new National Wind Technology Test Center is well underway, with several million dollars in funding dedicated to its establishment in 1994. This world-class wind energy research and development center will be located at Rocky Flats, Colorado, and will include facilities for the NREL wind technology R&D staff. It will provide specialized component test facilities, computer modelling facilities, and a turbine test capability for use both by DOE and by industry on a user facility basis. The facility will support a wide variety of activities, including performance testing to meet domestic and international standards.

Applied Research Program

The Applied Research Program is continuing to provide a solid foundation for advanced system development through work in aerodynamics, structural dynamics, mechanics, electrical power systems, and advanced concepts. Transfer of technical knowledge gained to the industry is being accomplished in several ways, including the use of hands-on workshops in such areas as fatigue analysis and wind resource modelling.

Research is continuing on the effect of wind turbines on operational control and power quality in utility grids, electrical utility interconnection, and wind/hybrid systems. Electrical power systems issues being studied include induced harmonics, reactive power demand, and control and isolation, especially local effects on an isolated feeder due to high wind system penetration. Because wind turbines usually operate in clusters, research on controls and adaptive controls will take a systems approach to all operational control issues. The goal of activities in this area is to define electrical characteristics and controls that will minimize undesirable power fluctuations and maximize the energy contribution that wind turbines can make to a utility grid.

Work is also continuing on development of advanced airfoils and blade designs, variable speed generators and advanced drive train research, advanced tower concept development, and the evaluation of aerodynamic rotor brakes. In the rotor control area, program researchers are studying adaptive and semi-adaptive control techniques. Tests include wind tunnel and field tests of advanced airfoils and aerodynamic controls, dynamometer tests of advanced generators and drive trains, and laboratory simulation tests and analyses of control algorithms. This work will find direct application in improving current and future generation of wind turbines.

NREL is also conducting field tests on an experimental turbine to determine pressure distributions along the blades under a variety of atmospheric conditions. Data from this test will be exchanged with other IEA member countries participating in Annex XIV, Field Rotor Aerodynamics. Test results from the four participating countries will be used for aerodynamic flow model verification.

Cooperative studies on avian mortality are being started. This will be an expanding program. Concern over bird deaths in northern California, particularly the possible effects on protected species, has caused DOE, the wind industry, the California Energy Commission and local governments to commit to research to define possible problems and to explore mitigation measures. Mitigation efforts are already underway, with notable success in reducing electrocuting deaths. However, further research into collisions will be pursued, with attention to regions outside California.

Figure 2.11.1 The 275 kW/26 m rotor diameter AWT-26, manufactured by Advanced Wind Turbines, Inc.

Figure 2.11.2 The 50 kW/ 15 m rotor diameter AOC 15/50, manufactured by Atlantic Orient Wind Systems, Inc.

Figure 2.11.3 The North Wind 250 wind turbine

Executive Committee activities

The 31st meeting of the Executive Committee (EC) was held on 5 and 6 May 1993 at Chalmers University of Technology, Gothenburg, Sweden. The meeting was attended by 19 persons, including representatives from 11 of 13 member states, Operating Agents and observers. Visits were made to the Hönö Wind Test Station and to the Lyse and Näsudden Wind Power Stations.

The 32nd meeting took place on 19 and 20 October 1993 at Morrison House, Alexandria, Virginia, USA, see Figure 3.1.1. The attendance was 20, and all member countries except Austria, Finland, New Zealand, Spain and the United Kingdom were represented. A visit to the Paul E. Garber Preservation, Restoration and Storgae facility, operated by the National Air and Space Museum of the Smithsonian Institution, was made on 21 October.

Mr W.G. Stevenson (UK) and Dr E. Sesto (Italy) served as Chairman and Vice-Chairman during the year. At the fall meeting, Dr Sesto and Mr D.F. Ancona (USA) were elected Chairman and Vice-Chairman for 1994.

At the fall meeting Mr B. Pershagen retired as EC Secretary. Mrs Karine Steer-Diederen (USA) was contracted to serve as new Secretary as of 1 January 1994.

The Technical Research Institute of Finland (VTT) joined the Agreement during the year, thereby increasing the number of member countries to fourteen.

New Zealand cancelled its preliminary notice of withdrawal. The Electricity Corporation of New Zealand Ltd. (ECNZ) replaced the New Zealand Meteorological Service as the Contracting Party.

The UK National Power plc withdraw from the Agreement during the year, and Scottish Hydro-Electric plc gave notice of withdrawal. The United Kingdom Atomic Energy Authority remains as the UK Contracting Party.

Some changes in EC membership were announced during the year. The updated list of Members and Alternate Members is attached.

During the EC meetings the progress of the ongoing Tasks was reviewed and the necessary administrative decisions were taken. Proposals for new cooperative actions were discussed. Information was exchanged on the national wind energy R&D programmes and the large-scale wind system activities in the member countries.

The third and fourth Wind Energy Newsletter were issued in July and December, reviewing the progress of the joint Tasks and the wind energy activities in the member countries. The EC acts as editorial board for the Newsletter, which is edited by R.J. Templin and produced in Canada.

An Ad Hoc Group of the EC prepared a five-year Strategic Plan for 1994-1998 during the year. The Plan was adopted by the EC at its fall meeting. It defines objectives and identifies topics for continued cooperative action. Joint research tasks and information exchange will remain prime activities, but assessments of the technology, economics, and environmental impact of wind energy will receive increased emphasis. Efforts will be made to improve the dissemination of information and the involvement of industry. Attempts to extend the cooperation to non-participating countries and to improve the cooperation with the CEC will be intensified.

The Strategic Plan provides a multiyear rolling programme of activities. At the fall meeting, the Ad Hoc Group was established as a permanent Planning Group to assist the EC in reviewing and updating the Strategic Plan and in suggesting topics and outlining projects for state-of-the-art assessments.

During the year an external review of the achievements of the IEA R&D Wind collaboration was initiated. The EC Chairman and Secretary provided input for the reviewer.

Papers on the IEA R&D Wind activities were presented at the European Community Wind Energy Conference (ECWEC'93) in Travemünde, Germany and at the American Wind Energy Association Wind Energy Conference (Windpower'93) in San Francisco, California, USA. A paper was also given at the ISES Solar World Congress in Budapest, Hungary, and a report was prepared for the High-Level Expert Meeting of the World Solar Summit Process, sponsored by UNESCO.

Figure 3.1.1 The 32nd Executive Committee Meeting at Morrison House, Alexandria, Virginia, USA, 19-20 October 1993

Appendix

IEA R&D Wind Executive Committee 1993

(M = Member, A = Alternate Member)

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R 1992:59	Report of the International Evaluation Committee - Conducting Polymers and Polymer Electric Properties, Polymer Chemistry and Polymer Physics.
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R 1993:4	Biomedical Measurements
R 1993:7	Computational Methods for Super and Parallel Computer system.
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R 1993:14	The Balance Principle.
R 1993:17	Consequences on energy and environment associated with electric and hybrid vehicles.
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IEA Wind Energy Annual Report 1993

Wind energy stands out as one of the most promising renewable energy sources in the near term. The deployment of wind energy is promoted by national programmes for advanced technology research and market incentives in many countries.

Parties from fourteen countries collaborate in wind energy research and development under the auspices of the International Energy Agency. The programme includes joint research projects and information exchange on large wind systems.

The report reviews the progress of the joint projects during 1993 and highlights the national wind energy activities in the member countries.

By the end of the report period more than 23,000 grid-connected wind turbines were operational in the member countries, representing a rated power of around 2700 MW. The rate of increase is presently about 300 MW per year.

The average rated power is approaching 300 kW in new units. Commercial machines in the 500 kW range are marketed. Prototype megawatt-sized wind turbines are in operation in the lead countries.

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