

Chapter 3

Twenty-Five Years of International Cooperation

3.1 INTRODUCTION

Many government research programs were exploring the use of wind energy to generate electricity in the early 1970s. However, communication among people working on technology for wind turbines was limited, because few mechanisms were available to share results. Several countries were building prototype machines and performing tests, but research and development budgets were limited, and the results of these activities were slow to reach other researchers. Relying mostly on scholarly journals, those working on wind turbine technology received information months or even years after the fact, and each country set research priorities based on its own budget limitations.

This situation was soon to change. Pressure to accelerate the development of alternative energy sources mounted after the oil embargo of 1973. In March 1978, after months of planning and effort, two groups of experts from ten countries met to begin the work we now call the International Energy Agency Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA Wind).

In the beginning, there were two groups, working on Implementing Agreements, to advance wind energy technology. One agreement, The IEA Programme for Research and Development on Wind Energy Conversion Systems (R&D WECS), began with four research tasks addressing wind

energy development in general. The R&D WECS group held its first meeting in Paris on 7 March 1978. The original nine members were Austria, Canada, Denmark, Germany, Ireland, the Netherlands, New Zealand, Sweden, and the United States. Soon after, Japan, Norway, and the United Kingdom joined the R&D WECS agreement. The group began work on four research tasks identified by the participants—Task I, Environmental and Meteorological Aspects of WECS; Task II, Evaluation of Models for Wind Energy Siting; Task III, Integration of Wind Power into National Electricity Supply Systems; and Task IV, Investigation of Rotor Stressing and Smoothness of Operation of LS WECS.

The other agreement, the IEA Co-operation in the Development of Large-Scale Wind Energy Conversion Systems (LS WECS), focused on the design of megawatt-scale wind turbine systems. The LS WECS agreement was signed on 6 October 1977. Original members of LS WECS were Denmark, Germany, Sweden, and the United States. Soon after, Canada, Italy, the Netherlands, Spain, and the United Kingdom joined the LS WECS Agreement. The objectives were to further development of wind energy by cooperative R&D within the IEA framework and to coordinate the planning and execution of their national LS-WECS research, development, and demonstration programs. They worked to develop national activities that were mutually supportive and complementary while meeting national needs and requirements.



Credit: Courtesy Lou Divone

Figure 3.1 Meetings of the Executive Committee representatives from each country have played a continuing role in information exchange. The ExCos of both wind agreements are pictured here in 1984, Edinburgh.

In 1991, the two wind agreements were combined under the title “Implementing Agreement for Co-operation in the Research and Development of Wind Energy Systems.” The information-gathering work being carried out under the LS WECS agreement was continued under a new Annex to the combined IEA Wind agreement, Task XIII, Co-operation in the Development of Large Wind Turbine Systems.

By the end of 2002, the IEA R&D Wind agreement had 21 contracting parties from 19 countries and the European Commission. In addition to a continuing Task XI that sponsors Topical Experts Meetings, Joint Action Symposia, and an Experts Group on Recommended Practices, there are four other active task groups exploring issues of current interest to members: Task XVII, Database on Wind Characteristics; Task XIX, Wind Energy in Cold Climates; Task XX, Horizontal Axis Wind Turbine Aerodynamics and Models From Wind Tunnel Measurements; and Task XXI, Dynamic Models of Wind Farms for Power System Studies.

Since the IEA Wind groups began their co-operation, wind turbine technology has advanced from a few prototype machines at government test sites to an important commercial industry with installed generating capacity exceeding 31 GW worldwide. Over the years, the IEA Wind agreements

“Collectively the member countries of the LS WECS agreement developed some 20 different turbine configurations of large-scale turbines. No single country could have afforded such a comprehensive R&D program. Each country learned from the successes and mistakes of the others.” – *Ezio Sesto, former Chair and member, Italy, 2002.*

CHAIRS OF THE IEA R&D WIND EXECUTIVE COMMITTEE

1978-1979	Lars Rey (Sweden)
1980-1981	Louis Divone (USA)
1982-1983	Emon Kinsella (Ireland)
1984-1985	B. Maribo Pedersen (Denmark)
1986-1987	Daniel F. Ancona (USA)
1988-1989	Steffan Engström (Sweden)
1990-1991	H. Jos M. Beurskens (Netherlands)
1992-1993	William.G. Stevenson (UK)
1994-1995	Ezio Sesto (Italy)
1996	Daniel F. Ancona (USA)
1997-1998	Raj Rangi (Canada)
1999-2001	Jaap 't Hooft (Netherlands)
2002-2003	Jrrgen Lemming (Denmark)

CHAIRS OF THE LS WECS EXECUTIVE COMMITTEE

1978-1979	R. Neumann (Germany)
1980	Lars Rey (Sweden)
1981	Leif Brandels (Denmark)
1982-1983	Louis Divone (United States)
1984-1985	Marc Chappell (Canada)
1986-1987	B. Maribo Pedersen (Denmark)
1988-1989	Daniel F. Ancona (USA)
1990	William Stevenson (Scotland)

Secretaries of the Executive Committees

1978-1993	Bengt. Pershagen
1993-1996	Karine Steer-Diederer
1997-present	Patricia Weis-Taylor

Newsletter Editors

1992-1998	Jack Templin
1999-2001	Marc Chappell

facilitated international cooperation that accelerated development of advanced technologies, avoided costly duplication of effort in national research programs, and increased the research labor hours available to any single national program.

3.2 TOOLS OF COOPERATION

As the participants in the agreement worked together, they developed several important mechanisms to enhance information ex-

change and cooperative R&D. Over time, these tools have evolved to accommodate changing research and development interests.

Executive Committee Meetings, Minutes, Newsletters, and Annual Reports

The regular meetings of the Executive Committees (ExCo) have always been an important vehicle for managing work conducted under the Agreement and for information exchange among participants. The ExCo of an agreement consists of a member and alternate member from each contracting party to the agreement, usually one per country. The ExCo meets two times per year to conduct business and examine facilities in the host country. Until the two agreement groups merged, they met at the



Caption: Credit: Rolf Windheim

Figure 3.2 During technical tours that follow ExCo meetings, members view test facilities, factories, and commercial wind farms. This 1979 tour of the Risø National Laboratory showcased a vertical axis machine undergoing tests.

same place and conducted their meetings on two consecutive days. By the close of 2002, there had been 50 meetings of the Executive Committees.

For the R&D WECS agreement, meeting presentations revolved around cooperative research tasks. Research results were shared freely at the meetings, even though not all countries worked on each task. For the LS WECS agreement, participants shared detailed research results from their national programs for development of large-scale wind turbines and planned meetings of experts on topics of common interest.

Minutes of each meeting of both agreements were circulated to all members of the ExCos. IEA Wind also published and distributed a newsletter twice each year between 1992 and 2001.

In addition, since 1978, each agreement has published an annual report every year. These reports contain detailed technical and organizational information to keep participants informed of progress in the member countries and in the cooperative research. In 2000, the ExCo of IEA R&D Wind agreed to make the annual report a public document and it was posted on IEA's public Web site.

“This is more than an annual report; it is a significant information resource for anyone interested in the progress of wind energy.” –

Judge's comment, Society for Technical Communication distinguished award to IEA Wind Annual Report 2001.

Cooperative Research

Cooperative research tasks have been a vital tool for advancing wind technology. Four tasks were included in the original implementing agreement text for R&D WECS, and many more have been added over the years. Originally, tasks were cost-shared, and participants paid an operating agent organization to perform most of the work. All participants shared the results. Tasks then evolved from cost-shared to task-shared; participants contributed labor and facilities, usually in their home countries, to a joint program coordinated by the operating agent. Up to 10 labor-years of effort in each country would be applied per task. The return to each country has been those labor-years multiplied by the number of organizations working on the task. For some tasks, participants received a ten-fold increase of their labor efforts. Over the years, some research has been conducted in combined cost- and task-shared activities in which participants have paid an operating agent to synthesize data generated with labor within participants' own research laboratories. By the close of 2002, 21 official tasks had been adopted as Annexes to the R&D Wind implementing agreement. (See Table 1.2 in Chapter 1)

Topical Expert Meetings

Meetings of experts on narrow topics of interest to wind turbine researchers have been a key feature of the agreements beginning in October 1978 with the Seminar on Structural Dynamics held in Munich, Germany. Members of the ExCo invite experts from universities, research institutes, government laboratories, and industry to attend these Topical Expert Meetings (TEMs). Attendees return home with a broadened perspective. Countries that invite experts from industry pass this benefit directly into the private sector. When personnel from government and university research

“Technical Expert Meetings are important because in each country only one or two people are working on each of these problems. When they go to an experts meeting and talk to others who are working on the problem, it is a reality check for them about problems they may have thought were huge, but find out others don’t think so. This kind of interaction with a wider group of experts has helped guide individual countries to set better research goals, take realistic approaches, and identify important areas that are not being explored.” – *Dr. Robert Thresher, Alternate Member, the United States, 2002.*

groups move into industry, this broadened perspective helps improve commercial machines. The operating agent keeps a library of documents (proceedings and recommended practices) from the meetings and distributes them on request within participating countries.

Topical Expert Meetings also serve to review the state of the art and identify areas for international cooperation. Many of the tasks completed under IEA Wind began with TEMs.

Recommended Practices

In 1980, the R&D WECS ExCo recognized the need for standardized testing procedures designed especially for wind turbine systems, because standards bodies of the day were operating with other objectives. So the ExCo organized an experts group, a standing committee for recommending

test procedures for the evaluation of WECS performance. The aim was to propose wind turbine testing to address the development of internationally agreed-to test procedures. In 1987, the standing committee’s activity was formalized as Annex XI to the agreement.

The approved recommended practices issued by IEA R&D Wind showed the research and industrial community proper testing and operation procedures well before the International Electro-technical Commission started activities related to wind energy. IEA R&D Wind has published recommended practices approved by the member countries on power performance testing, fatigue loads testing, acoustics measurement, structural safety, power quality of single turbines, lightning protection, and wind speed measurement. Several of these recommended practices

“In the Netherlands where noise is an important issue in building and environmental permits for wind farms, the Recommended Practice number 10, Measurements of Noise Immission from Wind Turbines at Noise Receptor Locations, first edition 1997 and number 4, Acoustic Measurements of Noise Emission from Wind Turbines, 3rd edition 1994, form an integral part of the regulations to perform measurements and evaluations. These documents contain detailed information that experts in the field agree upon and would be very expensive for each separate country to generate.”– *J.L. ’t Hooft, Former Chair, Alternate member, the Netherlands, 2002.*

have been revised and published as 2nd or 3rd editions as new information became available. Many of these provided input to the IEC standards of the 1990s. Practices of cost estimation, electromagnetic interference, noise measurement, and anemometry recommended by IEA Wind were still the accepted standards in 2002. (See Table 2.1.1 in Chapter 2.1.)

Joint Action Symposia

The ExCo decided in 1985 that certain topics deserved regular meetings, to keep experts from member countries up to date. Joint actions are set up in a specific research area of current interest for which a periodic exchange of information among experts is deemed necessary. This activity demands less time and money than an official task activity, but it results in steady advancement in the state of the art. As with Topical Expert Meetings, participation is by invitation from the national members of the ExCo. By 2002, multiple joint action meetings had taken place on Aerodynamics of Wind Turbines (15), Wind Turbine Fatigue (5), Wind Characteristics (2), Offshore Wind Systems (1), and Wind Forecasting Techniques (1).

“This is the place to meet the real experts in aerodynamics.” – *Alois Peter Schaffarczyk, Germany, participant in Joint Action Symposium on Aerodynamics, 2002.*

Internet

With the advent of the Internet, IEA Wind offered information to the public at a Web site hosted by the Danish Technical University, initiated password-protected pages for ExCo members, and made information available on special Web pages for participants in tasks. In 2002, a unified

approach was taken and a common public homepage, www.ieawind.org, was created. This central location included descriptions of IEA Wind objectives, activities, organizational structure, accomplishments, and active tasks. It also provided links to specialized information on wind energy within the member countries.

Special Planning Documents and Publications

Throughout the 25-year history of the IEA Wind agreements, members have paused every five years or so to develop planning documents to guide the near-term and long-term research strategy of the agreement. Written by ad hoc committees and approved by consensus, these documents have titles such as Five-Year Plans, End-of-Term Reports, Strategic Plans, and Long-Term R&D Strategy Reports.

Management of the Agreement

Management for efficient progress toward objectives has been an important characteristic of the IEA Wind agreements. For example, after a 1986 comprehensive review of the first 10 years of activities, the ExCo's of the two Agreements determined that many of the functions of the Agreements overlapped. To proceed more efficiently, the agreements merged in 1991. The 10-year review also pointed out the need for multi-year planning. The first Five-Year Strategic Plan was published in 1993. Such plans continue to guide the work of the IEA R&D Wind agreement. The ExCo has overseen work performed by hundreds of participating organizations in the 19 member countries. Tasks are planned and monitored to ensure that the work is done on schedule and within budgets. Results of the work are widely published and help to encourage the development and deployment of wind energy.

3.3 CONTRIBUTIONS TO SELECTED TOPICS

In addition to the benefit to national research programs of people interacting with their counterparts in other countries, the tools described above have advanced the science behind wind turbine technology. Over the first 25 years of the agreement, continuing work in technical areas deemed important by the members has yielded significant results. These long-term efforts, often building on previous tasks within the agreement and always building on the work of the participants, have accelerated the advancement of wind turbine development. The following three topic areas are only a sample of the issues addressed by the Wind Agreement. However, they illustrate the ways progress has been made over the years and provide insight into how work can continue to advance wind energy development.

Increasing Understanding of Wind Turbine Behavior

One of the key issues facing people trying to revive the use of wind energy was an understanding of the behavior of wind turbines in response to the wind. This required integrating information from several disciplines that had not previously interacted. The early studies conducted in these programs pointed out that knowledge in meteorology, electrical machinery, and aeronautical fields could be applied in wind engineering. Initially, the wind energy research organizations were located within meteorological and aeronautical research institutes and universities. Over time, the researchers moved beyond narrow scientific disciplines and focused on specific questions relevant for wind technology, such as wind modeling, resource assessment, aerodynamics, and structural dynamics.

The new LS WECS agreement began by International Energy Agency

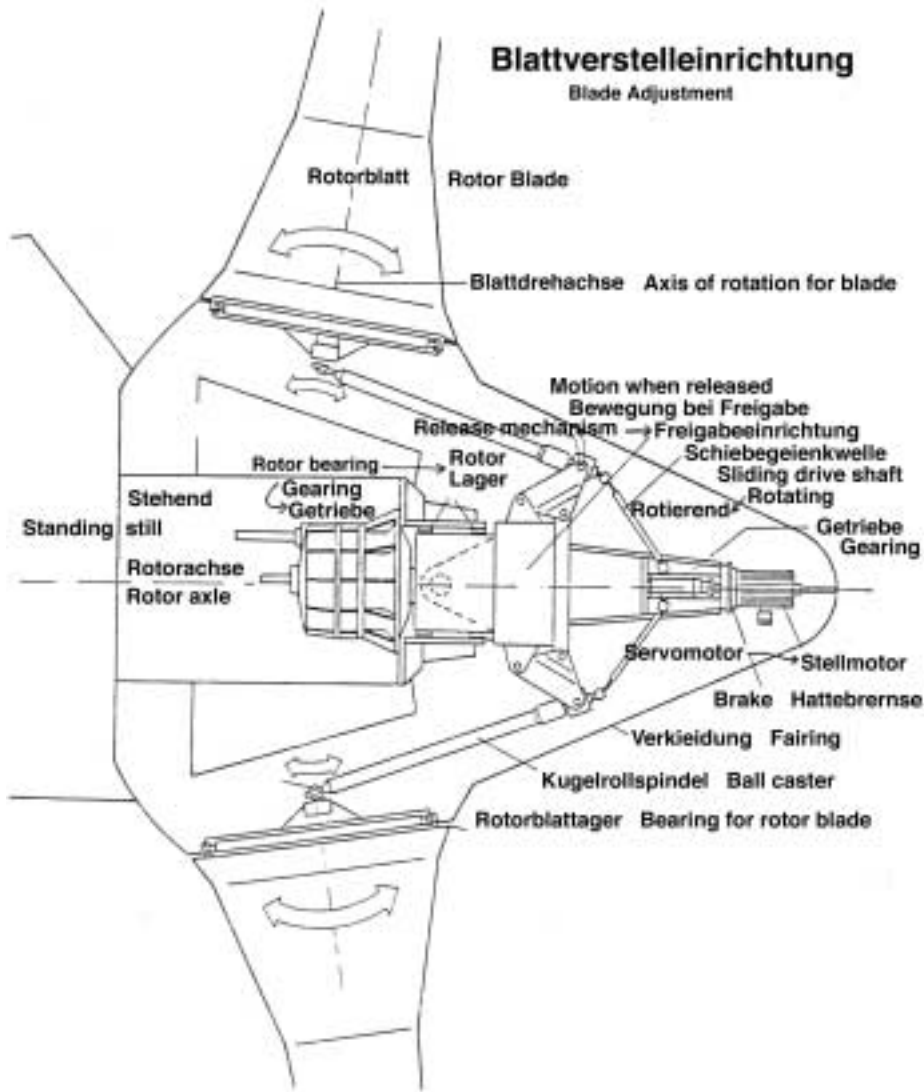
holding a Topical Expert Meeting (TEM) on structural dynamics on 12 October 1978, in Munich. A key presentation at the 1978 meeting described work in Denmark with the Gedser 200-kW wind turbine. This turbine, which operated from 1958 to 1967 in automatic mode and had avoided major mechanical problems, was refurbished in 1975 with funds from Denmark and the United States. These countries wanted measurements from the turbine to validate models for designing large wind turbines for their new wind energy programs. Measurements of power output characteristics and efficiency were taken,



Figure 3.3 The refurbished 200-kW Gedser machine operated for 650 hours between November 1977 and April 1979, when it was taken out of service. Total power production was 39,890 kWh.

and power train oscillations were measured using strain gauges. This information was correlated to anemometer data from the 48-m-tall meteorological tower installed at the site. This work provided a foundation of data for commercial development of wind power in the four countries participating in the LS WECS agreement.

At about the same time, the R&D WECS agreement authorized a cost-shared task to improve understanding of wind turbine behavior. R&D WECS Task IV, Investigation of Rotor Stressing and Smoothness of Operation of LS WECS, was carried out by the University of Stuttgart to help designers of large wind turbines. The work was or-



Source: First Annual Report, IEA LS WECS, 1978.

Figure 3.3 While developing the 3-MW Growian turbine, the German wind energy program worked with participants in IEA Wind task IV to explore rotor control strategies.



Source: UNIWEX: A Universal Wind Turbine for Experiments Summary Report, 1995

Figure 3.4 The UNIWEX project conducted an extensive measurement campaign, revised the ARLIS program for aeroelastic simulation, and documented operating responses during good weather and bad from May 1988 to February 1992.

ganized into 12 subtasks to study control of the rotor blades of a proposed 3-MW WECS (Growian) to reduce loads “from wind profiles, gusts, and gravity and thereby to minimize loads not required to produce the output power of the plant.” The work included modeling and experiments in wind tunnels with a 7.4-m rotor model. The results of this work, completed in 1980, were publicized at ExCo meetings, Topical Expert Meetings, and in numerous papers.

Over the next few years, TEMs brought together experts working to understand the interactions of aerodynamics and loads on wind turbine structures. Structural design criteria for LS WECS were discussed at a TEM held in 1983 in Greenford, the United Kingdom. Methods of aerodynamic

calculation for WECS were the topic of a 1984 TEM in Copenhagen, Denmark. Participants agreed that this topic required regular meetings to share developments, and a Joint Action Symposium on Wind Turbine Aerodynamics was set up in 1986.

Meanwhile, the government demonstration programs of megawatt-class machines in the United States, Sweden, Germany, and Denmark had problems mainly related to structural fatigue. These prototype turbines provided useful information of system behavior shared at TEMs and Joint Action Symposia and applied in industry in later years.

In 1984, the R&D WECS agreement recognized a need to apply the accumulated data on fatigue and measurement techniques to the research and commercial design of wind turbines. The Recommended Practices for Wind Turbine Testing and Evaluation group submitted a Recommended Practice for the evaluation of fatigue loads by means of measurement to the ExCo. Each participating country approved the practice, which was updated in 1990 and has become part of IEC 61400-13 TS, Measurement of Mechanical Loads.

In 1985, a TEM on Modeling of Atmospheric Turbulence for Use in WECS Rotor Loading Calculations was held in Stockholm, Sweden. This topic became the focus of the Joint Action Symposium on Fatigue Testing in 1987.

In 1987, the R&D WECS agreement group was ready to sponsor a task to address some of the issues of aerodynamics, loads, and control strategies that had been discussed in the TEMs and Joint Action Symposia. To supplement and multiply the efforts of national research programs, the ExCo approved Task XII, Universal Wind Turbine for Experiments (UNIWEX); the Institute for



Courtesy NREL

Figure 3.5 The costs and benefits of full-scale fatigue testing of wind turbine blades was discussed at the 23rd TEM in Golden, Colorado, 1992.

Computer Applications, Stuttgart, Germany acted as Operating Agent. In this cost-shared work, a computer-controlled, two-bladed experimental wind turbine at the Ulrich Hütter Wind Test Field at Schnittlingen, Germany, was modified and named UNIWEX. The project included experimental study of aerodynamics, operational behavior, load spectra, and control strategies, as well as validation of computer codes. Results were widely publicized in presentations at ExCo meetings, TEMs, and conferences.

After the work was completed in 1994, the UNIWEX turbine became integrated into several research projects of the Commission of European Communities, resulting in further benefit for resources invested. The experimental data and code validation activities of this project contributed to development of commercial wind turbines in the participating countries. For example, the software developed for aeroelasticity

was successfully applied to seven different commercial wind turbines.

Attention focused on wind turbine blades in 1992, when a TEM on Fatigue of Wind Turbines and Full-Scale Blade Testing was held in Golden, Colorado, the United States. Later that year, work began on a task to improve the design basis for stall-controlled rotor blades. The combined cost- and task-shared work of Task XIV, Field Rotor Aerodynamics Database, was designed so that the operating agent coordinated the measurement programs of the participants and integrated their data into a functional database. All participants were operating experimental wind turbines equipped with instrumented blades to measure pressure distributions around the profiles or aerodynamic forces on blade sections. The data were used to verify aerodynamic design codes. Four years of work resulted in a well-documented database available

to wind turbine designers on CD-ROM and accessible on an ftp site at ECN, Netherlands.

After more discussion of loads and blade fatigue at meetings in Sweden and the Netherlands, the ExCo followed recommendations made at the completion of Task XIV and approved Task XVIII, Enhanced Field Rotor Aerodynamics Database in 1998. Completed in 2002, this task group extended the database developed in Task XIV and disseminated the results; extensive use of this database can be expected for years to come. In 2004, a meeting will be held to discuss beginning another task to continue this important work.

By the close of 2002, the IEA Wind agreement groups had conducted 15 Joint Action Symposia on wind turbine aerodynamics and five on fatigue in wind turbines. As more test data become available and as wind turbines increase in size, Topical Experts Meetings and Joint Action Symposia are addressing the latest issues of wind turbine aerodynamics and structural response.

Out of these meetings came the request for an IEA R&D Wind task on aerodynamic modeling. After several meetings and rounds of discussion, the ExCo approved Task XX, Horizontal Axis Wind Turbine Aerodynamics and Models from Wind Tunnel Tests in 2002. Participants will use data from a full-scale wind tunnel experiment conducted in 2000 at NASA to develop and validate model subcomponents that can then be used to improve comprehensive aerodynamic models. Improving models in all the participating countries will continue the contributions of IEA R&D Wind work to an increased understanding of wind turbine behavior.

“To determine at which distance windmills have to be placed for optimum energy output from a group of windmills.” – *Objective of Task I Subtask A3, Study of wind wake effects, 1978.*

Studying Wind Turbine Siting Issues

One of the important issues at the beginning of the cooperation was the proper placement of wind turbines for maximum energy output and operating lifetime. Identifying high-wind areas and avoiding damaging turbulence were key objectives for all countries with wind turbine research programs.

Two of the first four tasks that began with the IEA Wind agreement in 1977 provided a way for participants to multiply the benefits of the individual efforts of each country. Task I, Environmental and Meteorological Aspects of Wind Energy Conversion Systems, was a cost-shared activity, with the Swedish Board for Energy Source Development as operating agent. The work included a study of wake effects in wind tunnel tests. The results for a model of a vertical axis wind turbine were presented at the 2nd International Symposium on Wind Energy Systems, Amsterdam, October 1978. This presentation began another tradition of the IEA Wind Agreement: presenting results to the wider research community.

Completed in 1983, Task II, Evaluation of Wind Models for Wind Energy Siting was operated by the U.S. Department of Energy's Battelle Pacific Northwest Laboratories. The participants compared selected atmospheric boundary layer numerical models with each other and with observed data to evaluate the



Credit: Lou Divone

Figure 3.5 ExCo members gained first-hand experience with the prototypes that would evolve into the elements of today's wind farms. Here members inspect the nacelle of the 750-kW Nibe turbine in Denmark in 1980.

usefulness of the models for wind turbine siting. Participants completed cases using their own models—a way of organizing work that would be used successfully in many IEA Wind tasks. The study showed that such models can be useful at the initial stage of siting when a large area is screened for places with the best wind energy potential.

Following on the work of Task I on wake effects, IEA Wind initiated work on Task V, Study of Wake Effects Behind Single Turbines and in Wind Turbine Parks, operating agent, Stichting Energionderzoek Centrum (ECN), the Netherlands. By taking measurements at wind farms, doing experiments in wind tunnels, and refining theoretical models, participants hoped to estimate the power output efficiency as a function of spacing of turbines and number and type of machines. Starting in 1980 with field measurements on a 5-m experimental WECS, participants also

measured wakes at their own installations and shared information. Each country benefited from four additional sources of data. At task completion in 1983, the participants concluded that data from wind tunnel tests and small-scale field experiments helped in developing predictive methods for single wakes, small clusters, and large clusters. However, evaluation of these methods required data from full-scale experiments. Participants recommended another task to collect these data.

In response to the recommendations from Task I participants, Task VI, Study of Local Wind Flow at Potential WECS Hill Sites, began in 1982 with an experiment carried out on Askervein, Scotland. The project participants collected field data on local variations in wind speed and turbulence produced by the 125-m-high, treeless, “ideal” hill and compared these data with

model predictions. This project was a god one for cooperation because no one country had sufficient instruments to cover a full-scale hill. Results from this Task helped scientists predict the atmospheric flow and wind acceleration effects in complex terrain.

Consideration of siting issues continued under Task VIII, Decentralised Applications for Wind Energy, which began in 1984 and was completed in 1989. The many working documents that resulted from this task were circulated among member countries. A subtask on site assessment defined models and techniques for obtaining wind and load data for decentralized wind diesel systems. This work was included in the book *Wind-Diesel Systems: a guide to the technology and its implementation*, edited by Ray Hunter and George Elliot, published by Cambridge University Press in 1994. Royalties from the book sales are returned to the ExCo.

As a follow-on from the Task V study of wake and cluster effects, Task IX, Intensified Study of Wind Turbine Wake Effects, began work in 1985. The objective was to improve the knowledge of aerodynamic interactions

between wind turbines operating in a windfarm. The task, completed in 1991, collected data from single turbines, pairs of interacting turbines, and full-size wind farms. The experimental data and theoretical techniques were brought together in a benchmark exercise based around the Näsudden turbine (Sweden) for the evaluation of single wakes and the Taendpipe group of turbines (Denmark) for the evaluation of wind farm models.

An activity related to wind turbine siting decisions began in 1999 with Task XVII, Database of Wind Characteristics. This task was formulated as a continuation of a European Commission project EU-DG XII (Joule), which concluded with a unique database of quality-controlled, documented wind field time series measurements supplemented with tools for easy access and simple analysis on the Web. IEA R&D Wind Task XVII provides wind energy planners, designers, researchers, and the international engineering community a source of actual wind field data (time series and resource data) from a wide range of wind climates and terrain types.



Figure 3.6 To evaluate how wind farms affect the dynamic and transient stability of utility power systems, participants in Task XXI are developing and validating models of wind farm output.



Credit: R. Hinrichs

Figure 3.6 Information from IEA Wind tasks helped guide the layout of wind parks like this one in Spain for improved energy production and increased turbine operating life. Continuing tasks will allow forecasting the output and electrical characteristics of electricity from wind farms thereby increasing its value.

Determining Power Performance and Effects of Wind Turbines on Power Networks

From the beginning in 1977, all IEA Wind members had an interest in using wind energy for the national electricity grid. The first measurements of the refurbished Gedser turbine in Denmark generated data on the quality of power for use in the utility grid.

In 1978, Task III, Integration of Wind Power into National Electricity Supply Systems, used models of wind energy production and models of conventional energy production for the northern German coastal area to calculate the maximum admissible investment costs for wind power plants compared to the investment and fuel costs of conventional power plants. This work was then extended to Japan, the Netherlands, Sweden, and the United States. The positive conclusions of this report helped gain

support for continued R&D to bring this technology to commercial status.

With the advent of commercial wind installations in the early 1980s, an important issue for developers was the accurate determination of power curves for competing wind turbines. Power curves needed to be based on standard tests and measurements so that the energy production characteristics of wind turbines available on the market could be compared. Responding to this need, the R&D WECS agreement established an Expert Group Study on Recommended Practices for Wind Turbine Testing and Evaluation. In 1982, the group issued its first recommended practice: Power Performance Testing.

Continuing to fill a need for performance testing standards, the R&D WECS agreement, in 1984, issued a recommended practice, Quality of Power for Single Grid-Connected WECS.

**“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 analyze support strategies.” – IEA
*Wind Energy Annual Report, 1993.***

As the size and number of wind plants increased, researchers worried that power quality, voltage profiles, controls, system protection, operating strategies, and personnel safety could be adversely affected. In 1989, the LS WECS agreement sponsored an Expert Meeting on Integrating Wind Turbines into Utility Power Systems. Participants recommended further work on wind energy forecasting and on electrical performance of wind farms.

In 1990, the Recommended Practices for Wind Turbine Testing and Evaluation group issued a revised practice for power performance testing that incorporated the improved information from experts meetings. Continuing the information exchange, a Topical Expert Meeting on wind turbine control systems also addressed the issue of power quality and wind turbines. At another TEM in 1991, Electrical Systems for Wind Turbines with Constant or Variable Speed, the special issues surrounding these two approaches were discussed.

In 1995, interest in the consistency of measurements prompted the design of Task XVI, Wind Turbine Round Robin Test Program. To ensure that turbines

are tested and certified to common criteria, participants tested identical machines at their own facilities using comparable test instrumentation and data acquisition. A meeting of experts in 1997 assessed the state-of-the-art on power performance assessments for WECS. The experts concluded that dominant issues of system integration, cost-effectiveness, and certification all depend on power performance verification. In 1999, information from Task XVI and the experts meeting contributed to the 11th recommended practice issued by the R&D Wind agreement, Wind Speed Measurement and Use of Cup Anemometry. This document on wind speed measurement is used by IEC MT 13 to update the power performance measurement standard IEC TC88, Wind Turbine Systems.

As wind power contributes larger percentages of electricity to a grid, the influence of large fluctuations of power becomes important. A Topical Expert Meeting in 2001 explored the Danish and German experience with integrating large-scale wind generation facilities into their grids. The meeting concluded that it is essential to have good simulation tools and reliable dynamic electrical models of wind turbines to perform simulations of wind farm contributions to the electric system. For example, the Netherlands expects to have 6,000 MW of offshore wind power installed by 2020. Joining about 15,000 MW of conventional power, this offshore capacity will affect the dynamic stability of the grid, so it is very important to have accurate, reliable, and verified models of the detailed dynamic electrical behavior of wind farms larger than 500 MW. Given that more than 35,000 MW offshore power is foreseen in other northern European countries and the United States, it makes sense to combine these efforts under IEA R&D Wind.

In response to these conclusions, the R&D Wind signatories in 2002 approved Task XXI, Dynamic Models of Wind Farms for Power System Studies. Participants in this task will assist the planning and design of wind farms by facilitating a coordinated effort to develop wind farm dynamic electrical models suitable for evaluating the dynamic and transient stability of power systems.

Several presentations at Topical Expert Meetings have pointed out that predicting the time and amount of output from wind farms is vital. Predicting output a few hours to a few days ahead of time is important to the value of the electricity that wind farms generate and for scheduling conventional power to balance the supply and demand in the grid.

In response to this conclusion, the R&D Wind agreement established a Joint Action Symposium for (short-term) wind energy forecasting and will sponsor regular meetings on the subject. The first such symposium, in 2002, concluded that current models are inaccurate in complex terrain, that there is much room for improvement, and that discussions of progress should continue.

3.4 COMMON ELEMENTS OF SUCCESSFUL ACTIVITIES

A key factor in the success of the wind agreements over the past quarter century is the variety of mechanisms available to explore issues cooperatively. For example, after wind energy forecasting techniques were identified as important, the agreement held a TEM in 2000 and determined there was interest. An ad hoc committee drafted an annex proposal to the ExCo, but there were concerns about proprietary issues. A Joint Action Symposium was approved instead to hold regular meetings on advances in the topic beginning in 2002. If common research work is identified

at one of these meetings, then a task can be approved; otherwise, interested experts will continue to meet each year.

Some essential features of successful collaborations have included the following.

1. Interested and active participants. Participants send information to the operating agent and/or perform tests and measurements as set out in the task agreement text.
 2. Involvement of users. Representatives from industry, utilities, research institutes, universities, and government organizations participate in the planning and execution of tasks.
 3. Well-defined scope. The number and variety of subtask topics are limited. The work of participants is defined clearly.
 4. Multidisciplinary approach. Participants take work from other fields and apply it to wind.
 5. Multi-national approach. Participants take a model or tool developed in one country and apply it in other countries.
 6. Dissemination of results. Results are published or presented at international conferences, Topical Expert Meetings, in annual reports and on special Web pages for members and the public.
- Twenty-five years ago, when the IEA Wind Agreements were initiated, technical information or data were fundamental and rudimentary at best, and there were no design guidelines or validated experimental data. Today, there is a large repository of data and experience available to assist designers and builders around the world, in large part due to the efforts of participants in the IEA Wind Agreements.

Twenty-five years ago, there was essentially no wind industry. Today, commercial developers are designing, building, and installing wind turbines around the world by the thousands. Commercially available wind turbines have grown in size from ratings under 100 kilowatts to more than four megawatts. The designs and experience behind today's large machines rests largely on pioneering efforts of the participants in the IEA Wind agreements.

At times a delicate balance was maintained between the desire of participants for cooperation and the constraints of proprietary, commercial, and national interests. Over the long run, however, the benefit of the agreements to the participants is summed up nicely by Louis Divone, original member from the United States and director of his government's research program for more than a decade.

"The leverage we got from the relatively little we spent on the IEA agreements was phenomenal. By pooling our resources, we carried out R&D projects that we could not afford individually and validated approaches that we see today in our national wind industries."

The current participants in IEA wind reinforced this sentiment in the ad hoc group report to the IEA Wind Executive Committee in 2001 by setting out an ambitious research agenda. The active program of cooperative research scheduled for 2003 and beyond promises to continue the tradition of multiplying the contributions of individual participants to advance the development of wind energy for all.

"For the mid-term time frame, areas of major importance for the future deployment of wind energy are forecasting techniques, grid integration, public attitudes, and visual impact. ...For the long-term time frame, it is of vital importance to perform the R&D necessary to take large and unconventional steps in order to make the wind turbine and its infrastructure interact in close co-operation." – *Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020, ad hoc group report to IEA Wind Executive Committee, 2001.*

Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020, ad hoc group report to IEA Wind Executive Committee, 2001.

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