

**International Energy Agency
Implementing Agreement
for
Co-operation in the Research and Development
of Wind Turbine Systems**

WIND ENERGY

End-of Term Report 1993-1998
and
Plans for 1999-2003

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This document is prepared following the “Guidelines and Questionnaire” issued 10 December 1997 by the International Energy Agency (IEA), End Use Working Party and adopted by the Renewable Energy Working Party (REWP). It is prepared for review and approval at the Wind Energy Agreement Executive Committee (ExCo) planned for the second calendar quarter of 1998. This report will then be forwarded to the REWP as an End-of-Term report. Format for this report follows the guidelines including the question numbers that are identified by the numbers in brackets.

The current term of the IEA Implementing Agreement for Cooperation in the Research and Development of Wind Turbine Systems ends 31 October 1998. The Agreement began in 1977. However, when the IEA Committee on Energy Research and Technology (CERT) established five year term limits on Implementing Agreements, the ExCo of the Wind Agreement was in the process of updating its strategic plan. The “IEA Wind Energy Strategic Plan 1994-1998” was subsequently completed by an ad hoc group and submitted to the ExCo for consideration. After incorporating input from the ExCo members, the Plan was completed in August 1993. It was then submitted to the REWP in autumn 1993 for comments. No changes were suggested by the REWP, so the plan was formally adopted by the ExCo in October 1993. The Wind Energy Implementing Agreement was reviewed by the REWP again in November 1995 (Reference 1) and recommendations by the REWP, to “Continue to involve industry and consider activities relating to developing countries” were incorporated.

This end-of-term report is an update on the work done under the Agreement since 1993 and summarizes a revision of the Wind Energy Strategic Plan that is currently being developed by a Planning Committee established by the ExCo.

A. Nature and Objectives:

The IEA cooperation on wind energy began in 1977. Initially two agreements were established. One agreement focused on wind energy research and development and the second on large scale wind turbine development under way in only a few of the member countries. On 31 December 1990, the two Agreements were merged into the Implementing Agreement for Cooperation in the Research and Development of Wind Turbine Systems.

The past twenty one years has seen the development and maturing of wind energy technology. Wind turbines are now being deployed commercially in some markets where subsidies are available. This process has only been possible through vigorous national programs of research, system deployment, demonstration and financial incentives for deployment. In this context the IEA Wind Energy Agreement has played an important role by providing a framework for joint research projects and information exchange.

The character of the cooperation has gradually adapted to the changing environment in which it functions. As wind technology has matured, the funding of national research and development programs has leveled off and even declined in some countries. Overall government funding for wind energy however, has continued to increase with a shift in emphasis toward financial incentives designed to encourage deployment of commercial systems. The ExCo and independent assessments (2) agree that continued government funding for advanced technology research, development and demonstrations is still needed to reduce costs and improve performance of wind systems. Incentive programs are also needed to allow new technologies to compete with other more established energy technologies and to account for the environment benefits of renewable energy.

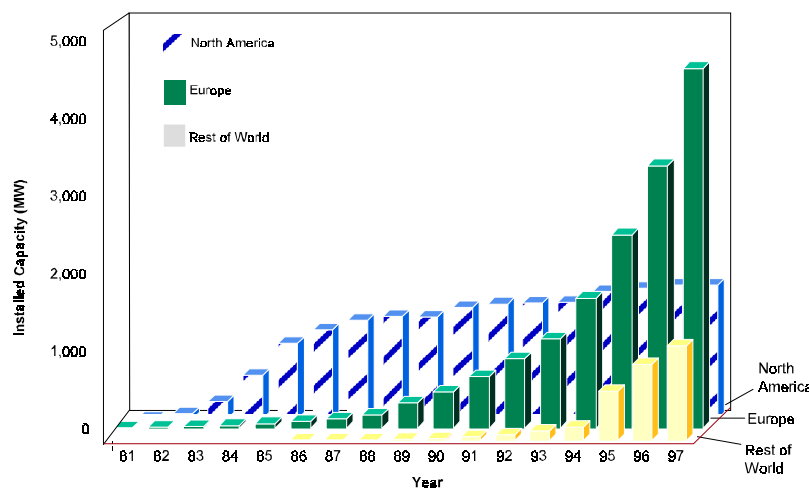


Figure 1. Global Trends in Wind Systems Installed Capacity.

In a wider context, the basic environment for IEA's work has also changed over the past five years. Energy markets have become increasingly deregulated and are driven more by market forces than by government intervention. Concerns about global climate change and other environmental impacts of energy are increasingly important. As a result, wind system sales are expanding around the world and now total \$1.5 billion annually. This includes deployment in non-OECD countries, where the demand for wind systems is expected to grow fastest in the future. See figure 1. As new regions are

opening up for the international markets, resulting interest in the IEA world wide, required a new orientation for the ExCo and its research and technology programme.

Tasks/Annexes: Twelve Annexes under the Agreement have been successfully completed. See Annual Report dated October 1997 (3).

Currently active Tasks/Annexes are:

[Questionnaire Number 1]

	<u>Task</u>	<u>Start</u>	<u>End</u>
Annex XI	Wind Technology Information Exchange	1988	Being reviewed by ExCo
Annex XV	Annual Review of Progress in the Implementation of Wind Energy by the Member Countries	1995	1998
Annex XVI	Wind Turbine Round Robin Test Program	1996	1998

Tasks/Annexes completed during reporting period (1993-1998):

[2]

	<u>Task</u>	<u>Start</u>	<u>End</u>
Annex VIII	Study of Decentralized Applications for Wind Energy (Wind/Diesel)	1987	1994
Annex XII	Universal Wind Turbine for Experiments (UNIWEX)	1988	1994
Annex XIII	Cooperation in the Development of Large-Scale Wind Systems	1991	1995
Annex XIV	Field Rotor Aerodynamics	1992	1997

Tasks/Annexes being prepared and planned:

[3]

There are new Annexes in preparation and up to three areas of cooperation under discussion. These new Tasks are: 1) Proposed Annex XVII, "Database on Wind Characteristics" to compile detailed wind measurement data cases for various terrain and conditions for use in turbine design. Nine countries are expected to join and start work in late 1998; 2) planned new Task "Wind Turbine Aerodynamics Database" to continue the sharing of wind turbine blade aerodynamic data that was begun under Annex XIV that was completed in 1997. Four countries would like to share new data cases and pursue further research on measurement and analysis of issues relating to blade angle of attack, discovered by the participants in the earlier Annex XIV; and 3) planned new Task "Wind Turbine Aerodynamic Measurements in Large-Scale Wind Tunnels" to collect related turbine performance and structural load data in the very large and unique laminar flow wind tunnels used for air and space craft testing. Three countries are discussing this Task and there is interest approaching Israel and possibly China about participating using the large wind tunnels in their countries.

There has been preliminary consideration given to developing one or more Annexes on topics relating to data sharing on development and deployment of wind power plants in new, extreme and difficult environments. Topics of interest are: offshore applications that are becoming common in several European countries; high-wind sites in countries including Greece, Italy, Mexico, New Zealand and Spain; and arctic applications, of interest in Scandinavia, Canada and United States.

Nature of Work: See Wind Energy Agreement Brochure dated 1998 (4).

Information Exchange and Coordination:

Information exchange about independent activities:

[4]

The framework of the Agreement has facilitated the dissemination of wind technology information to a variety of IEA and other sources. Members of the ExCo supported and served as technical reviewers for the "Mini-Review of Wind Energy," a technology assessment conducted by the IEA Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) in 1995. In response to a request for technology information from the IEA Centre for Greenhouse Gas Technology Information Exchange (GREENTIE), a technical paper titled "Present and Prospective Role of Wind Energy in the Electric Supply" was updated in 1996 from a paper presented at the IEA Conference - New Electricity 21, held in Paris, France, 22-24 May 1995. Responding to a request from the REWP to support the World Bank Solar Initiative, an ad hoc Task Force was created to address participation and information needs of Non-OECD Countries. The resulting Task Force report (5) was completed in April 1997. In addition, responding to the request from the REWP, the ExCo began discussions with the World Bank. A Bank representative attended the ExCo meeting in autumn 1996 and the ExCo supported the development of a "Wind Energy Theme Note" for the Bank.

Recently, a collaborative activity has been established with the World Energy Council (WEC), World Bank and Annex XV under the Agreement. Working with the WEC Committee on the Performance of Thermal Generating Plants, the purpose is to collect performance data on operating windfarms in at least six developed countries and six developing countries. The goal is to demonstrate the technical and commercial viability of wind power plants in a range of applications. World Bank has agreed to support report preparation.

Informal Coordination activities:

One area of informal coordination and controlled exchange of technology information is done through Annex XI. The objective is to promote wind turbine technology development and information exchange on topics of common interest to the members. The three subtasks in this Annex are:

- a. Development of recommended practices for wind turbine testing and evaluation. Many of these documents have served as the basis for subsequent international standards. See "Question 38, Success Stories."
- b. Joint Actions for periodic information exchange on ongoing research topics. These are areas of research that are of current interest to member countries, but where there is not a sufficient focus to allow a specific Task/Annex to be developed. Joint Action topics are selected by the ExCo.

Experts meet periodically at symposia or workshops on the topic and results are available to the member countries. So far, three Joint Actions have been initiated:

- Aerodynamics of Wind Turbines
- Fatigue of wind turbine blades
- Offshore wind systems

c. Experts Meetings are another form of informal coordination. Technical topics are selected by the ExCo with input and participation of industry. To date 30 Experts Meetings have been held on a wide range of scientific and wind energy engineering topics. Typically two meetings are held each year with 20 to 30 scientists from National Laboratories, utilities and industry attending by invitation only. A complete list of Expert Meetings, topics and results is included in each Annual Report.

Formal coordination of activities through mutually agreed projects:

Formal projects, which are developed by two or more member countries, is the most frequently done through a combination of cost and task shared projects administered as Tasks formed as Annexes under the Agreement. It was found that countries were unwilling to assume the role of Task Operating Agent unless the other participants were willing to contribute to the administrative expenses. Also, participants who were paying to join, have added commitment to the Task and are encouraged to meet schedules and deadlines. This approach has worked effectively to on schedule completion of Annexes.

All of the above coordination methods are currently working effectively for the Wind Agreement ExCo.

Technology areas currently being investigated under the Agreement:

[5]

Research programs in the member countries are focused on both the development of new and better turbines, as well as on the basic sciences and engineering methods. Some of the specific topics currently being addressed are:

- Wind flow description and characterization for wind turbine design
(Particularly turbulence effects from wind flow in complex terrain and rotor inflow models)
- Turbine rotor aerodynamics
(stall control and recovery, computational fluid dynamics and scaling effects)
- Full-scale blade fatigue testing
(Testing methods, protocols and standards)
- Wind turbine structural dynamics
(Effects of turbulence and model accuracy)
- Environmental effects of wind turbines

(Testing methods and standards for noise and safety)

Technology areas that are potentially within the scope of the Agreement:

[6]

- Power system effects and wind plant controls
(power quality, electric system stability and control with increasing wind energy penetration)
- Wind resource data collection and mapping
(This area being discussed for possible cooperation in development of worldwide wind resource maps. It is a key area in wind energy project planning and development and there are many wind resource and mapping studies being done differently in countries using a variety of methods. An Experts Meeting is being planned to explore the idea of integrating these efforts. IEA could be a leader for this effort, but clearly outside funding would be needed for such a large and complex task.)

Plans to add new areas of work:

[7]

Establishment and operation of scientific databases are a new area of work for the Agreement. Two databases are planned, one under proposed Annex XVII, "Database on Wind Characteristics" and a second on wind turbine rotor aerodynamics. Restricted, password protected, access is planned through the web. Details are being discussed.

Objectives:

[8]

The objectives of the IEA Wind Agreement are to undertake collaborative research, development and demonstration projects regarding wind turbine systems, and to exchange information on the planning and execution of national wind energy development and deployment programs.

[9]

The objectives of the Agreement are considered to be consistent with the scope of ongoing and planned programs.

[10]

The objectives of the Agreement are appropriate, considering the continuing needs and plans for research, development and deployment programs in the member countries, which are likely to continue for at least five more years.

[11]

The scope of the Wind Agreement is considered appropriate, but there is a growing need for ways to encourage the development and deployment of wind systems in combination with other renewable energy technologies. Overlaps in renewable energy resources occur in most applications and in some cases there are technical advantages of hybrid applications of wind with other renewable energy technologies, particularly in off-grid applications. This is especially true in developing countries where there are inadequate or nonexistent electricity grids. The IEA does not have a good vehicle for addressing cross technology issues. Possibly a new Agreement is needed, but it should not negate the need to continue the current technology specific work.

B. PARTICIPATION

Countries and organizations:

[12]

Table 2. Participants and their Role in IEA Wind Agreement

Country	Participating Organization	Participation					Type			
		Ex Co	Annex XI Technology Information	Annex XV Deployment	Annex XVI Round Robin Test	Annex XVII Wind Database	Gov.	Industry	Utility	Academia
Australia	Hydro Electric Co.	x	x	x					x	
Austria	Tech.Univ Wien Inst. Fur Stromungslehre und Warmeubertragung	x								x
Canada	Dept. of Natural Resources Canada	x	x			P	x	x		
	Atlantic Wind Test Site				x		x			
Denmark	Riso National Laboratory	x	x	x	x	OA	x	x		
	Tech. Univ. of Denmark	x	OA							x
European Union	European Commission	x	x				x			
Finland	Technical Research Centre of Finland (VTT)	x	x				x		x	
Germany	Forschungszentrum Jülich GmbH	x	x	x			x	x		
Greece	Ministry of Industry/Energy and Technolog;	x	x	x	x	P	x	x	x	
Italy	ENEL S.p.A.	x	x	x					x	
	Ente Nuove Tecnologie Energia Ambiente (ENEA)	x	x	x	x	P	x	x		
Japan	Government of Japan	x		x			x	x	x	
Mexico	Instituto_____	x	x	x					x	
Netherlands	Netherlands Agency for Energy and the Environment (NOVEM)	x		x			x	x	x	
	ECN Research Centre	x	x			P	x			
New Zealand	Electricity Corporation of New Zealand	x	x					x	x	

Norway	Norwegian Water Resources & Energy Administration	x	x	x			x			
Spain	Institut deEnergias Renovables.Centro de Investigación Energetica Medioambiental y TecnologicaCIEMAT	x	x	x		P	x	x	x	
Sweden	National Board for Industrial and Technical Dev. (NUTEK)	x	x	x		P	x	x	x	
United Kingdom	AEA Technology plc	x					x			
	Energy Technology Support Unit Harwell	x	x	OA		P	x	x	x	
United States	Department of Energy	x		x			x			
	National Renewable Energy Laboratory	x	x		OA	P	x	x	x	
	TOTAL	24	18	14	5	9				

Notes:

1. AO is Operating Agent
2. P indicates Planning to join Proposed Annex

Member Countries:

[13, 14]

Nearly all of the Member Countries participate in at least one of the Annexes. Austria is not currently participating in active Annexes, but there have been indications of interest. Several countries that were not currently participating in Annexes dropped out of the Agreement. In some cases this is because an Annex they joined has been completed and no other Annexes are currently of interest. In other cases changing priorities and cut backs in funding, prevent travel and other participation. The ExCo specifically designed Annex XV, to be low cost so funding would not be an obstacle to participation.

Non-Member Countries:

[15]

There are two categories of Non-Member Countries (NMC's) that have participated in the Agreement, those that are members of the Organisation for Economic Co-operation and Development (OECD) and non-OECD countries. Several NMC's that are OECD member countries have participated and subsequently joined the Agreement. During the review period Australia, Finland, Greece, Mexico and the European Commission (participates in OECD) joined the Agreement. Brazil, a non-OECD country, is in the process of joining. Belgium and Switzerland dropped out.

[16]

Several non-OECD, NMC's expressed interest or participated in one or two meetings, but so far could not obtain funding to travel to meetings and to join. Examples of past participation include: Estonia, Poland,

Israel and India attended the most recent ExCo meeting as an observer and expressed interest in joining. There is the general feeling that the countries, which have a serious commitment to develop a new technology, will come to meetings and join the Agreement.

[17]

NMC interest in the agreement can be stimulated by high-level IEA outreach and holding meetings in NMC's. A case in point is China, where following an IEA Conference in Beijing, there was a significantly increased interest in the Agreement. Making the case for IEA at all levels in non-Member national governments is helpful.

Other Participants:

[18-20]

Industry involvement and interest in IEA are increasing. More utilities, one of the key users of wind power, are participating and joining the Agreement. The Electric Power Research Institute, a research organization from the U.S., came and participated in the Wind Energy Symposium held in conjunction with the ExCo meeting in New Zealand. Industry Associations use data from the IEA in their promotional activities.

[21]

A goal resulting from the 1993 Strategic Plan was to increase industry and utilities' involvement in the Agreement. This has been quite successful and electric utilities from Brazil, Finland, Italy, Mexico, New Zealand, Norway and Sweden are participating in the ExCo. Industry frequently uses information produced under the Agreement and participates principally through Experts Meetings.

C. ACTIVITIES:

Meeting Attendance:

[22]

<u>Meeting</u>	<u>Number of Attendees</u>
ExCo	23
Experts Technical Workshop	30
Symposium	60

Cost of the Agreement Program:

[23]

The operating cost for the Wind Agreement ExCo Common Fund today is approximately \$75,000 (US Dollars) per year plus the costs of each active Annex. Currently there are three active Annexes that currently cost about \$75,000 annually to operate. One Annex, the Round Robin Test had a one time fee of \$10,000 each to join several years ago. Therefore, the total direct operating cost is about \$150,000 annually. In addition there are in-kind expenses and travel costs for the participants.

The size of the Common Fund for secretariat, annual report printing and distribution, newsletter, brochures, other publications and reserves in 1997, was \$95,000 including carryover funds from prior years and should be about the same in 1998.

The in-kind costs of participation vary and depend on the Tasks that are joined. The in-kind cost of participating in Annex XIV, Field Rotor Aerodynamics, just completed, was one full time equivalent person-year to conduct turbine field tests, or about \$150,000 to \$200,000 per year for several years. These are costs that would have been spent anyway and the savings by not having to duplicate the tests done by other participants far out weighs the cost of attending meetings and doing presentations. Participation in other

Annexes can be as low as several person-weeks preparation and meeting time.

The ExCo meets twice annually and some of the Annex working groups meet several times a year. Travel costs are minimized by doing business by postal and E-mail whenever possible. Often meetings are scheduled to coincide with other events to minimize travel costs.

The overall government funding for wind energy research, development, demonstration and deployment incentives was estimated to be about \$180 million in 1996 in the member countries. The amount allocated to research and development in member countries was about \$70 million per year.

Dissemination of Results [24-26]

Results of the work are disseminated through Task Reports, Annual Reports, biannual Newsletter that is placed on the world wide web, a brochure that is updated every 2-3 years, technical and overview papers presented at non-IEA meetings, and through direct involvement and participation of industry and academia. A list of publications is included as attachment A.

The most significant change in disseminating during the current term of the agreement is the advent of the world wide web. The Newsletter, example attached (E), which was printed with 5,000 copies distributed by the ExCo Members, is now also distributed through the web. The site address is <http://www.eren.doe.gov/IEAWind/>. During 1997, there were about 10,000 hits on the site originating from 44 countries. What is more important, the site is seeing an average of 100 per month connections to unique individual computers. These are considered to be serious users. The site is not yet linked to the IEA headquarters or other energy related sites. A Task Force has been appointed to review the Newsletter and other aspects of communications including possible additional links to other energy sites that could substantially increase its activity and usefulness..

Coordination with Other Bodies: [27-29]

There have been coordination and cooperation between the ExCo and IEA CADDET and IEA GREENTIE. See Question 4 for details.

There is continuing informal dialogue with ExCo Members of other Agreements, but more interchange and exchange of ideas with other IEA bodies in an organized way would be useful.

Internal Assessment and Planning: [30]

Internal Review Mechanisms:

The ExCo manages and reviews the nature, quality and schedule of work done on the Annexes. The overall program of the Agreement is reviewed every five years and a Strategic Plan is prepared. This is coordinated with the industry by the members in their respective countries. In addition, papers on the overall IEA Program are periodically presented by the Chairman at major industry sponsored conferences, in an effort to collect outside and independent views on the results and work plans.

Strategic Plan: is currently being updated. The previous Plan (6) covered the period 1993-1998. [31]

[32]

The new Strategic Plan is being developed by a Planning Committee established by the ExCo. The five Committee members included a cross section of the ExCo, with different backgrounds from National Laboratories, National governments and utilities. The group took into account input from industry, guidance from the REWP, IEA headquarters, and diverse view points and experience in developing and deploying wind systems in Europe, North America and numerous developing countries. A Plan was drafted by the group, presented to the ExCo for review and comment. Changes are currently being made and the final Plan will be considered at the next ExCo meeting in May 1998.

[33]

Previous Strategic Plans have had significant impact in shaping work under the Agreement. The first Plan completed in 1987, resulted in the merging of the two Wind Energy Agreements. The second Plan opened the door to more involvement of electric utilities in the Committees and for increased out reach to OECD and to Non-OECD countries. One result is that membership in the Agreement has grown from 13 countries in 1992 to 17 plus the European Commission today.

D. Achievements AND BENEFITS OF COOPERATION

Technology Development:

[34]

The Agreement has contributed to wind energy technology development through information sharing and task-shared cooperative research. Cooperative test programs and jointly developed databases on airfoil aerodynamics and on wind turbine blade material properties, have reduced the cost of research in the individual member countries. The collaboration and peer review between scientists and researchers that were facilitated under the Agreement has helped move the technology forward more quickly. Following are specific results of the successful results of the collaboration:

[35]

1. *IEA Recommended Practices Led to International Standards* - Nine Volumes of Recommended Practices for Wind Turbine Testing and Evaluation have been developed under Annex XI, Base Technology Information Exchange. Topics include wind turbine power/performance testing, structural safety, cost estimation, fatigue characteristics, terminology, power quality, and noise, wind and electromagnetic interference measurement. See reference (4) for a complete list of Recommended Practices and current Editions. Many of these Recommended Practices have served as the basis for national and more important, international standards being developed by the International Electrotechnical Commission and others. Harmonization of these international standards is a key result from the IEA work.
2. *Universal Wind Turbine for Experiments (UNIWEX)* - Experiments on the UNIWEX, under Annex XII, were supported by seven organizations in the three participating countries, Germany, Netherlands and Sweden. The goal of the project was to study aerodynamics, operational behavior, loads and control strategies for different turbine hub configurations, as well as the validation of computer codes. As a spin off, several commercial projects were conducted and further research on: inflow turbulence, induced velocities for instationary inflow and on yaw operation, hub configurations, mass distribution in the blades and blade root stiffness. Some of the concepts tested on UNIWEX are being used on commercial turbines today.
3. *Aerodynamics Test Data is Used in Blade Airfoil Design* - Under Annex XIV, Field Rotor

Aerodynamics, airfoil surface pressure data and resulting aerodynamic forces on blade sections were collected in atmospheric tests on full-scale turbines in four countries. The resulting 125 time-series data sets are now available on CD-ROM for use in continuing airfoil stall and performance research by industry, universities and laboratories. These test results are also the basis for large scale wind tunnel tests being planned in Netherlands and the United States, under a new Annex intended to resolve unexpected results on recovery from airfoil stall and uncertainties on the airfoil angle of attack measurements.

4. *Wind Turbine Blade Material Properties* - were shared between the ECN in Netherlands and the Sandia and NREL Laboratories in the U. S. Fatigue properties for a variety of glass-reinforced-plastic (GRP) materials were studied in both countries. Cost and time were saved by sharing the ultrahigh cycle (4×10^8) data being accumulated for different GRP materials tested under a variety of conditions. The testing methods and data collection protocols were developed under the Joint Action on Fatigue under Annex XI.

[36]

Important publications have been produced under the Agreement. The final report from Annex VIII, Study of Decentralized Applications for Wind Systems, was written as book on wind diesel systems that was published by Cambridge University Press in 1994. This book is sold today and produces \$4 to 5 thousand in royalties that are paid to the ExCo annually. A list of publications is included as Attachment A.

Technology Deployment

[37-39]

As a result of the increasing interest in the rapid expansion in wind power plant deployment, Annex XV, Annual Review of Progress in the Implementation of Wind Energy, was started in 1995. Reports from the Task are considered to be one of the most accurate, unbiased and best sources of data on wind system deployment world wide.

Perhaps the most significant new mechanism and future role for IEA Wind, is to support technology transfer and deployment increased collaboration with other international organizations. In 1994, the European Commission joined IEA Wind, with considerable support for, and involvement in, wind energy research, development and deployment projects in Europe. World Bank approached IEA Wind (through the REWP) and representatives of the Bank have attended IEA Wind ExCo. In response to World Bank's request, IEA Wind has prepared a Theme Paper on the basic techno-economics of wind energy systems, currently under review at the Bank, and ExCo has agreed to prepare two Issues Papers for the Bank on grid-connected applications.

To consider plans for supporting the World Bank and other multilateral organizations, the ExCo established an ad-hoc task force to explore ways to encourage the development of wind energy in non-OECD countries. This Task Force has completed its work and recommended the following:

1. That the Agreement should encourage participation of non-OECD countries that have wind energy programs. This should be facilitated by streamlined procedures adopted by the IEA Governing Board in January 1997, for approval of new Country participation.
2. Conditions for joining the Implementing Agreement are to:
 - support a national wind energy R & D program
 - participate in at least one IEA Wind Annex

- contribute to the ExCo common fund
 - contribute an agreed share to all Annexes joined
3. Consider establishing a new Annex to encourage the deployment of wind systems in both grid connected and off-grid applications in non-OECD countries. This recommendation is still under consideration by the ExCo.
 4. Encourage the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) to provide project financial data for the World Bank and other financial institutions.

Networking:**[40-42]**

The Agreement has proven to be effective for encouraging networking. Networking through the ExCo has been particularly strong and effective, mainly because there has been quite consistent participation and continuity in the ExCo membership. The networks resulting from Experts Meetings and Joint Actions have also proven to be very useful information channels.

Networking may continue after the IEA work is complete. For example in the area of wind/diesel research, the people involved in the Annex VIII, Decentralized Applications, were completed in 1994, but the participants have continued to meet annually at a workshop. These meetings are organized by the Canadian and American Wind Energy Associations. The best features of the network established by the IEA are now continued by industry and trade associations.

Policy Relevance:**[43]**

The work done under the Annex XV, Annual Review of Wind Energy Implementation, and data exchanged through the ExCo, have provided information that is useful by both Member and Non-Member countries in policy planning. An example where this data proved helpful was in formulating incentives for encouraging wind energy deployment. Experience in the United States during the early 1980's showed that incentives in the form of investment tax credits worked well to start the turbine building that resulted in the installation of 1,000 MW in California in less than five years. But many of the turbines built were early models that did not have sufficient testing time, resulting in premature failures in some cases. Many European countries learned from this experience, at least in part through the IEA, and used incentives that were based on energy production rather than encouraging only the initial investment in the turbines.

The IEA Wind Agreement has not undertaken any significant tasks that would directly affect policy making.

[44]

The IEA Wind Agreement has had little effect and no programs to directly transfer technology or to influence policy in Non-OECD-Member countries. Other than information transfer, the ExCo does not have the financial resources for conducting policy formulation work.

Environment:**[45]**

The Agreement has supported the study and development of Recommended Practices on environmental issues relating to deployment and operation of wind systems. Specific areas addressed were: acoustic noise, and possible electromagnetic interference from wind turbines.

Efficient Use of Resources:**[46]**

Efficient use of limited resources is an important benefit of the IEA Agreement. By combining funding from member countries, more comprehensive and higher quality research is a result. For example in the UNIWEX Task, a unique experimental turbine was developed, at a cost of about \$3 million [check] and this machine was used over a five-year period by the three member countries for a comprehensive cost-shared research program. Results from more than 280 separate experiments are now available on CD-ROM for wider dissemination and evaluation.

In another example, under Task XIV, aerodynamic tests were conducted at five laboratories in four countries. Each country shared results from three to six person-years of work during the three-year program. The total program was valued at \$2 to \$4 million just in direct labor. It would have cost each country up to \$3 million to do the same work. Another benefit was accelerating the work by allowing data collection in parallel and by collecting data under a variety of wind and atmospheric conditions not readily available in individual countries.

[47]

Information transfer on large scale (1-4 MW) turbine development and field test programs has been very useful especially in the pre-commercial phase of machine development. The data on government sponsored large turbine design concepts and the results of testing of prototype machines has been shared under the Agreement. Detailed designs and proprietary company information were not shared. The resulting data, available in member countries is now being used to develop commercial turbines.

[48]

Exchange of scientific personnel between member countries is facilitated under the Agreement. For example, recently the Electricity Corporation of New Zealand was interested in learning more about wind energy meteorology and wind technology in general. Through the Agreement two helpful actions were taken. First, under a cost-shared arrangement, an atmospheric scientist from the National Wind Technology Center in the United States was sent to New Zealand on a week long training/consulting program. Later, New Zealand agreed to host a symposium on wind energy, that was held in conjunction with an ExCo meeting, so experts from every country with a significant wind energy program were available to share their knowledge and experiences. The meeting, held in Rotorua, NZ in November 1997, was valuable for New Zealand and 60 people from the utility and government attended.

Overall Significance of the Agreement:**[49-50]**

Tracking the progress being made in the development and deployment of wind technology is one of the achievements of the Agreement. The IEA is viewed as an objective and unbiased source of information since all countries with significant wind energy programs are participants. There are several reasons that IEA is viewed as an important data source, and that its future roles and activities will continue to influence wind energy development and deployment. Three principal features are:

- Knowledge
Through its members, IEA Wind has access to all major public and private sector performers in wind energy
- Strength
Through the combined efforts of several nations, IEA Wind can plan, support, and undertake projects beyond

capability of any single country or group

- Neutrality
IEA Wind has no nationalistic orientation: its sole motivation is the improvement and appropriate deployment of energy technology worldwide.

[51]

The Strategic Plan for the Wind Energy Agreement is still in preparation and will be finalized late in 1998, but there are several actions that are anticipated:

1. Extend the Agreement for an additional five years, 1999-2003.
2. Implement two new Tasks, one on wind characterization and another on additional joint aerodynamics tests. Several additional Tasks are under consideration.
3. Encourage more cooperation with other elements of the IEA, to share ideas and experiences to help improve work done under the Agreements; and more importantly, to compile and present cross-technology information on renewable energy, especially to developing countries where the need for information is the greatest.

References:

1. IEA/CERT(92)10, letter, Subject: Maximum Term of Implementing Agreements and Annexes.
2. IEA/OECD Report, Energy Technologies for the 21st Century, Paris, 1997.
3. IEA Wind Energy Executive Committee, IEA Wind Energy 1996 Annual Report, October 1997. (Attachment B)
4. IEA Wind Energy Brochure, November 1997. (Attachment C)
5. IEA Wind Agreement Non-OECD Countries Task Force Report, April 1997. (Attachment D)
6. IEA R&D Wind Executive Committee, "IEA Wind Energy Strategic Plan 1994-1998," August 1993. (Attachment F)

Attachments:

- A. List of Publications.
- B. Annual Report.
- C. Brochure.
- D. Non-OECD Task Force Report.

E. Newsletter.

F. Strategic Plan 1994-1998.

Attachment A
LIST OF PUBLICATIONS
from the
International Energy Agency
WIND ENERGY R&D AGREEMENT

1. Rangi, R., Ancona, D.F., The International Energy Agency's Role in World-Wide Wind Energy Development, Proceedings of American Wind Energy Association, June 1997.
2. Rangi, R., Avia, F., The International Energy Agency's Role in World-Wide Wind Energy Development, Proceedings of European Wind Energy Association, October 1997.
3. Sesto, E., Ancona, D., Rangi, R., Present and Prospective Role of Wind Energy in Electricity Supply, IEA-International Conference on New Electricity 21, Paris, France, update published by IEA GREENTIE, December 1996.
4. Schepers, J.G., IEA Final Report on Annex XIV, Field Rotor Aerodynamics, Stichting Energieonderzoek Centrum Nederland (ECN), October 1996.
5. Sesto, E., Ancona, D., Present and Prospective Role of Wind Energy in Electricity Supply, Proceedings of IEA-International Conference on New Electricity 21, Paris, France, 22-24 May 1995.
6. IEA Experts Meeting, "State of the Art of Aeroelastic codes for Wind Turbines," Lyngby, Denmark, 11-12 April 1996.
7. Carlin, P., IEA Final Report on Annex XIII, Cooperation in the Development of Large-Scale Wind Systems, U.S. National Renewable Energy Laboratory, September 1995.
8. IEA Experts meeting, "Current R&D Needs in Wind Energy Technology," Utrecht, Netherlands, 11-12 September 1995.
9. IEA Experts Meeting, "Lightning Protection of Wind Turbine Generator Systems and EMC Problems in the Associated Control Systems," Milan, Italy, 8-9 March 1994.
10. Argyris, J., Braun, M., Müller, M., Final Report on Annex XII, UNIWEX - A Universal Wind Turbine f Short Summary Report on the German Contribution, ICA-Report No.43, University of Stuttgart, 1993.
11. Argyris, J., Braun, K.A., Müller, M., "UNIWEX - An international Research Project - History - Community Wind Energy Conference and Exhibition, Lübeck-Travemünde, 8-12 March 1993.
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14. Heim , "Numerische Simulation des aeroelastischen Verhaltens der Versuchs-turbine UNIWE Pendeldämpfer und Blattwinkelrücksteuerungsfaktoren", Studienarbeit, Universität Stuttgart, 1994.

15. Bühler M., "Einfluss der Massenverteilung im Rotorblatt der UNIWEX Windturbine auf deren Universitat Stuttgart, 1994.

16. Brand A.J., et. al., "The Dutch contribution to the IEA UNIWEX project", ECN-C-94-075, Sep 1994.

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19. IEA Experts Meeting, " Wind Conditions for Wind Turbine Design, Risø, Denmark, 29-30 April 1993.

20. IEA Experts Meeting, "Increased Loads in Wind Power Stations (Wind Farms)," Gothenburg,, Sweden, 3-4 May 1993.

21. Stevenson, W.G., Pershagen, B., "The Wind Energy Programme of the IEA," Proceedings of the American Wind Energy Association, San Francisco, CA, 12-16 July 1993.

22. Stevenson, W.G., Pershagen, B., "The Wind Energy Programme of the IEA," Proceedings of the European Commission Wind Energy Conference, Lubec-Travemunde, Germany, 8-14 May 1993.

23. "Offshore Wind Energy in Mediterranean and other European Seas," La Maddalena, (Sardinia), Italy, 10-11 April 1993.