Implementing Agreement

1.0 Introduction

The International Energy Agency (IEA) Implementing Agreement on wind energy began in 1977 and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). The 24 participating countries and international organizations (contracting parties) work to develop and deploy wind energy technology through vigorous national programs and through cooperative international efforts. The participants exchange information on their continuing and planned activities and participate in selected IEA Wind Research Tasks. In 2008, 24 contracting parties from 20 countries, the European Commission, and the European Wind Energy Association (EWEA) participated in IEA Wind (Table 1).

2.0 National Programs

The national wind energy programs of the participating countries are the basis for the IEA Wind collaboration. These national programs are directed toward the evaluation, development, and promotion of wind energy technology. An overview and analysis of national program activities is presented in the Executive Summary of this Annual Report. Individual county activities are presented in Chapters 11 through 31.

3.0 Collaborative Research

In 2008, participants in the IEA Wind Agreement worked on nine cooperative Research Tasks, which have been approved by the ExCo as Annexes to the original Implementing Agreement text. Each member country must participate in at least one cooperative research Task. Countries choose to participate in Tasks that are most relevant to their current national research and development programs. Additional Tasks are planned when new areas for cooperative research are identified by Members. Progress in cooperative research is described in chapters 2 through 10. Tasks are referred to by their annex number. The numbers of active Tasks may not be sequential because some Tasks have been completed and so do not appear as active projects in this report (Table 2).

The combined effort devoted to a task is typically the equivalent of several people working full-time for a period of three years. Some tasks have been extended to continue the work. The projects are either cost-shared and carried out in a lead country, or task-shared, when the participants contribute in-kind effort, usually in their home organizations, to a joint research program coordinated by an Operating Agent. In most projects each participating organization agrees to carry out a discrete portion of the work plan. This means that each participant has access to research results many times greater than could be accomplished in any one country. For example, as reported in the End-of-Term Report submitted to IEA, the following statistics for recently completed tasks show the benefit of cooperative research.

- Task 20 HAWT aerodynamics and models from wind tunnel measurements.
  - Contribution per participant: $9,375 USD plus in-kind effort
  - Total value of shared labor received by each participant: $2,036,300 USD
- Task 21 Dynamic models of wind farms for power system studies
  - Contribution per participant: 15,500 Euro plus in-kind effort
  - Total value of shared labor received: 4,760,000 Euro
- Task 24 Integration of wind and hydropower systems
  - Contribution per participant: $16,430 USD plus in-kind effort
  - Total value of shared labor received: $6,237,000 USD

By the close of 2008, 18 tasks had been successfully completed and two tasks had been deferred indefinitely (Table 3).

Table 1 Contracting Parties in 2008 to the International Energy Agency Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind)	
Country/Organization	Contracting Party to Agreement
Australia	Clean Energy Council
Austria	Republic of Austria
Canada	Natural Resources Canada
Denmark	Danish Energy Authority
European Commission	Commission of the European Communities
Finland	National Technology Agency of Finland (TEKES)
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Greece	Center of Renewable Energy Resources (CRES)
Ireland	Sustainable Energy Ireland
Italy	CESI RICERCA S.p.A. and ENEA Cassaccia
Japan	National Institute of Advanced Industrial Science and Technology (AIST)
Korea	Government of Korea
Mexico	Instituto de Investigaciones Electricas (IIE)
Netherlands	Netherlands Agency for Energy and the Environment (SenterNovem)
Norway	Norwegian Water Resources and Energy Directorate (NVE) and Enova SF
Portugal	National Institute for Engineering and Industrial Technology (INETI)
Spain	Instituto de Energias Renovables (IER) of the Centro de Investigación; Energetica Medioambiental y Tecnologica (CIEMAT)
Sweden	Swedish Energy Agency
Switzerland	Swiss Federal Office of Energy
United Kingdom	Department for Business, Enterprise & Regulatory Reform
United States	U.S. Department of Energy
Sponsor Participants	
EWEA	European Wind Energy Association

Table 2 Active Cooperative Research Tasks Defined in Annexes to the IEA Wind Implementing Agreement (OA indicates operating agent that manages the task)	
Task 11	Base technology information exchange OA: Vattenfall, Sweden (1987 to 2008) changing to CENER, Spain (2009-2010)
Task 19	Wind energy in cold climates OA: Technical Research Centre of Finland - VTT (2001 to 2008)
Task 23	Offshore wind energy technology deployment OA: Risø National Laboratory, Denmark and NREL, United States (2004 to 2008)
Task 24	Integration of wind and hydropower systems OA: NREL, United States (2004 to 2008)
Task 25	Power systems with large amounts of wind power OA: Technical Research Centre of Finland – VTT, Finland (2005 to 2008)
Task 26	Cost of wind energy OA: NREL, United States (2008 to 2011)
Task 27	Consumer labeling of small wind turbines OA: CIEMAT, Spain (2008 to 2011)
Task 28	Social acceptance of wind energy projects OA: ENCO Energie-Consulting AG, Switzerland (2008 to 2011)
Task 29	MexNex(T): Analysis of wind tunnel measurements and improvement of aerodynamic models OA: ECN, the Netherlands (2008 to 2011)

Final reports of tasks are available through the IEA Wind Web site: www.ieawind.org. Table 4 shows participation by members in active research tasks in 2008.

To obtain more information about the cooperative research activities, contact the Operating Agent Representative for each task listed in Appendix B or visit our Web site at www.ieawind.org under the tab for cooperative research or follow the links to individual Task Web Sites.

4.0 Executive Committee

Overall control of information exchange and of the R&D tasks is vested in the Executive Committee (ExCo). The ExCo consists of a Member and one or more Alternate Members designated by each contracting party that has signed the IEA Wind Implementing Agreement. Most countries are represented by one contracting party that is a government department or agency. Some countries have more than one contracting party within the country. International organizations may join IEA Wind as sponsor members. The contracting party may designate members or alternate members from other organizations within the country.

The ExCo meets twice each year to exchange information on the R&D programs of the members, to discuss work progress on the various Tasks, and to plan future activities. Decisions are reached by majority vote or, when financial matters are decided, by unanimity. Members share the cost of administration for the ExCo through annual contributions to the Common Fund. The Common Fund supports the efforts of the Secretariat and other expenditures, such as preparation of this Annual Report, approved by the ExCo in the annual budget.

Officers

In 2008, Ana Estanqueiro (Portugal) served as Chair. Morel Oprisan (Canada) and Brian Smith (United States) served as Vice Chairs. Brian Smith was elected to serve as Chair in 2009. Hannele Holttinen (Finland) and Joachim Kutscher (Germany) were elected to serve as Vice Chairs in 2009.

Table 3 Completed or Inactive Cooperative Research Tasks Defined in Annexes to the IEA Wind Implementing Agreement (OA indicates operating agent that manages the task)	
Task 1	Environmental and meteorological aspects of wind energy conversion systems OA: The National Swedish Board for Energy Source Development (1978 to 1981)
Task 2	Evaluation of wind models for wind energy siting OA: U.S. Department of Energy - Battelle Pacific Northwest Laboratories (1978 to 1983)
Task 3	Integration of wind power into national electricity supply systems OA: Kernforschungsanlage Jülich GmbH, Germany (1978 to 1983)
Task 4	Investigation of rotor stressing and smoothness of operation of large-scale wind energy conversion systems OA: Kernforschungsanlage Jülich GmbH, Germany (1978 to 1980)
Task 5	Study of wake effects behind single turbines and in wind turbine parks OA: Netherlands Energy Research Foundation (1980 to 1984)
Task 6	Study of local flow at potential WECS hill sites OA: National Research Council of Canada (1982 to 1985)
Task 7	Study of offshore WECS OA: UK Central Electricity Generating Board (1982 to 1988)
Task 8	Study of decentralized applications for wind energy OA: UK National Engineering Laboratory. (1984 to 1994)
Task 9	Intensified study of wind turbine wake effects OA: UK National Power plc (1984 to 1992)
Task 10	Systems interaction. Deferred indefinitely
Task 12	Universal wind turbine for experiments (UNIWEX) OA: Institute for Computer Applications, University of Stuttgart, Germany. (1988 to 1995)
Task 13	Cooperation in the development of large-scale wind systems OA: National Renewable Energy Laboratory (NREL), USA. (1990 to 1995)
Task 14	Field rotor aerodynamics OA: ECN, the Netherlands (1992 to 1997)
Task 15	Annual review of progress in the implementation of wind energy by the member countries of the IEA OA: ETSU, the United Kingdom (1994 to 2001)
Task 16	Wind turbine round robin test program OA: NREL, the United States. (1995 to 2003)
Task 17	Database on wind characteristics OA: RISØ National Laboratory, Denmark (1999 to 2003)
Task 18	Enhanced field rotor aerodynamics database OA: Netherlands Energy Research Foundation - ECN, the Netherlands. (1998 to 2001)
Task 20	HAWT aerodynamics and models from wind tunnel tests OA: NREL, the United States (2003 to 2007)
Task 21	Dynamic models of wind farms for power system studies OA: SINTEF Energy Research, Norway (2003 to 2007)
Task 22	Market development for wind turbines. Deferred indefinitely.

Table 4 Participation of Member Countries in Tasks During 2008. (OA indicates operating agent that manages the task)

	11	19	23	24	25	26	27	28	29
Australia				x			x		
Austria									
Canada	x	x		x			x	x	x
Denmark	x		OA		x	x			x
European Commission	x								
European Wind Energy Association					x				
Finland	x	OA		x	OA			x	
Germany	x	x	x		x	x		x	x
Greece									
Ireland	x				x				
Italy	x								
Japan	x						x	x	x
Republic of Korea	x		x						x
Mexico	x								
Netherlands	x		x		x	x			OA
Norway	x	x	x	x	x			x	x
Portugal			x		x				
Spain	x		x		x	x	OA		x
Sweden	OA	x	x	x	x	x	x		x
Switzerland	x	x		x		x		OA	
United Kingdom	x		x		x		x		x
United States	x	x	OA	OA	x	OA	x	x	x
Totals	17	7	10	7	12	7	7	7	11

Participants

In 2008, there were no changes in IEA Wind country participation however there were personnel changes among the Members and Alternate Members. (See Appendix B for Members, Alternate Members, and Operating Agent representatives who served in 2008.)

Meetings

The ExCo meets twice a year to review ongoing Tasks; plan for new Tasks; and report on national wind energy research, development, and deployment activities (RD&D). The first meeting of the year is devoted to reports on R&D activities in the member countries and in the Tasks, and the second meeting is devoted to reports about deployment activities.

The 61st ExCo meeting was hosted by Denmark in the city of Aalborg on 22, 23, and 24 April 2008. There were 32 participants from 15 of the contracting parties. Attendees included eight operating agent representatives of the Tasks and a representative of IEA Paris. The ExCo approved the final report of Task 20 HAWT Aerodynamics and Models from Wind Tunnel

Measurements and closed the project. The ExCo approved the final report of Task 21 Dynamic Models of Wind Farms for Power System Studies and closed the project. Technical progress reports of ongoing tasks were also approved: Task 11 Base Technology Information Exchange, Task 19 Wind Energy in Cold Climates, Task 23 Offshore Wind Technology Deployment, Task 24 Integration of Wind and Hydropower Systems, Task 25 Power Systems With Large Amounts of Wind Power, and Task 26 Cost of Wind Energy. Proposals for three new Tasks (27 Consumer Labeling of Small Wind Turbines, 28 Social Acceptance of Wind Energy Projects, and 29 MexNex(T) Aerodynamics) were approved to move forward. The audit report of 2007 Common Fund accounts was approved. On 24 April 2008, the ExCo visited Aalborg University's Institute for Water, Earth, and Environment and the test sites in Fredrikshavn Harbour. Siemens welcomed the ExCo to tour the new Blade Factory in Aalborg.

The 62nd ExCo meeting was hosted by the United States and the Commonwealth of Massachusetts in Boston, Massachusetts on 23, 24, and 25 September 2007. There were 29 participants from 15 contracting parties, including nine operating agent representatives of tasks, and six observers. The ExCo approved the budgets for the ongoing tasks and for the Common Fund for 2009. On 25 September, the ExCo visited the town of Hull and met with the utility and town officials about the town's two wind turbines which have tremendous support in the community. They also viewed the site of the future blade test facility on Boston Harbor.

5.0 Outreach activities

The 30th issue of the IEA Wind Energy Annual Report was published in July 2008 and the Web site, www.ieawind.org continued to expand coverage of IEA Wind activities.

The IEA Wind ExCo unanimously approved the End-of-Term Report and Strategic Plan documents to extend the Implementing Agreement for another 5 years by email ballot on 15 August 2008.

The key RD&D areas for the wind energy sector were identified by the IEA Wind ExCo as follows:

1. Wind Technology Research to Improve Performance and Reliability at Competitive Costs

2. Power System Operation and Grid Integration of High Amounts of Wind Generation Including Development of Fully-controllable, Grid-friendly "Wind Power Plants"

3. Planning and Performance Assessment Methods for Large Wind Integration

4. Offshore Wind in Shallow and Deep Watters

5. Social, Educational, and Environmental Issues

In the next five years the IEA Wind Agreement will focus on the completion of the R&D work already initiated and develop new research Tasks related to these five key research areas.

A planning committee consisting of the Chair, Vice Chairs, the Secretary, the former Chair, and the Operating Agent Representative for Task 11 Base Technology Information Exchange perform communication and cooperation activities between ExCo meetings. Support for IEA Paris initiatives has been provided by the Planning Committee. This support included attending NEET meetings in Russia, attending IEA meetings to present the End-of-Term Report and Strategic Plan for extension of the IEA Wind agreement, supplying materials for ministerial meetings, reviewing draft IEA documents that address wind technology, and supplying text for drafts of IEA annual reporting documents.

Chapter 2 **Task 11**

Base Technology Information Exchange

1.0 Introduction

The objective of this research Task is to promote wind turbine technology by co-operative activities and information exchange on R, D&D topics of common interest. These particular activities have been part of the IEA Wind Implementing Agreement since 1978. Most of the IEA Wind member countries participate in this Task so that researchers in their countries can benefit from this information exchange (Table 1). Proceedings of the meetings are immediately available to countries that participate in the Task. After one year, proceedings are made public on the IEAWind.org Web site. Only experts from participating countries may attend meetings.

2.0 Objectives and Strategy

The Task includes activities in two subtasks. The first is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices.

Table 1 IEA Wind Task 11 Participants in 2008

Country	Contracting Party
Canada	Natural Resources Canada
Denmark	Danish Energy Agency
European Commission	European Commission
Finland	Technical Research Center of Finland (TEKES)
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Ireland	Sustainable Energy Ireland
Italy	CESI RICERCA S.p.A.
Japan	National Institute of Advanced Industrial Science and Technology (AIST)
Korea	New & Renewable Energy Division of the Ministry of Knowledge Economy
Mexico	Instituto de Investigaciones Eléctricas (IIE)
The Netherlands	Senter/Novem
Norway	Enova SF
Spain	CIEMAT
Sweden	Swedish Energy Agency; Vattenfall (OA)
Switzerland	Swiss Federal Office of Energy
United Kingdom	Department for Business, Enterprise & Regulatory Reform
United States	U.S. Department of Energy

In the series of Recommended Practices, 11 documents have been published. Five of these have appeared in revised editions (Table 2). Many of the documents have served as the basis for both international and national standards.

The second sub-task is to conduct two types of meetings of experts on topics designated by the IEA Wind ExCo. The first kind of meeting is a Joint Action Symposium at which experts meet regularly to share progress. So far, Joint Action Symposia have been held on aerodynamics of wind turbines, wind turbine fatigue, wind characteristics, offshore wind systems, and wind forecasting techniques. The second type of meeting, Topical Expert Meetings, are arranged on topics decided by the IEA Wind ExCo. Proceedings are distributed to attendees and to the countries that pay fees to participate in IEA Wind Task 11. Sometimes Topical Expert Meetings result in a recommendation for a Joint Action, so participants can continue to share information on a regular basis.

Topical Expert Meetings can also begin the process of organizing new research tasks as additional annexes to the IEA Wind Implementing Agreement. For example, in 2007, the meeting on social acceptance issues of wind energy projects brought together interested experts who wrote a proposal for a new research task, Social Acceptance of Wind Energy Projects. This task began its work in 2008.

During these 28 years of activity to promote wind turbine technology through information exchange, 57 volumes of proceedings from Topical Expert Meetings (Table 3) and 27 volumes of proceedings from Joint Action Symposia (Table 4) have been published. The Task 11 Joint Action Symposium on Aerodynamics was previously arranged co-operatively by Task 20 HAWT Aerodynamics and Models from Wind Tunnel Measurements and Task 11. Task 20 is now finished. Aerodynamic challenges will be further studied by Task 29 MexNex(T) Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models.

3.0 Progress in 2008

To complete the work plan approved by the ExCo, three meetings were planned and completed during 2008:

- 57th Topical Expert Meeting on Wind Turbine Drivetrain Dynamics and Reliability
- 3rd Joint Action Symposium on Wind Forecasting Techniques.

The fourth meeting of the year will be arranged during 2009.

3.1 Smart structures for large blades

The objective of the 56th Topical Expert Meeting on the Application of Smart Structures for Large Wind Turbine Rotor Blades, held in 2008, was to report and discuss progress of R&D in this relatively new field of wind turbine technology. Much knowledge had been accumulated since the previous meeting on this topic in December 2006. In 2006, participants discussed basic performance of materials and flap principles. In 2008, they were able to report results of actual tests that incorporated blade profiles equipped with movable flaps. Micro-tabs equipped with control algorithms and actuators were also tested. The field now applies a more integrated approach by testing materials, measuring loads, and evaluating control strategies.

During final discussions, participants agreed that this is a new and challenging area of wind turbine research that may result in more effective ways of controlling power production. Highlights of the discussion include the following:

- Shape memory alloys (SMAs) have a slow reaction as actuators, which could be a problem.
- Surface suction and rubber trailing edges were mentioned as promising technologies.
- New types of sensors with increased performance are needed.
- Blade failure today is less of an issue than gearboxes.
- Reliability should be increased and incorporated in new system solutions.

The participants agreed that it was too

Table 2 List of Recommended Practices Developed by IEA Wind

No	Area	Edition	Year	First Ed.	Valid	Status
1	Power Performance Testing	2	1990	1982	no	Superceeded by IEC 61400-12, Wind power performance testing
2	Estimation of Cost of Energy from WECS	2	1994	1983	yes	
3	Fatigue Loads	2	1990	1984	yes	Part of IEC 61400-13 TS, Measurement of mechanical loads
4	Acoustics Measurement of Noise Emission From Wind Turbines	3	1994		no	Superceded by IEC 61400-11, Acoustic noise measurement techniques
5	Electromagnetic Interference	1	1986		yes	
6	Structural Safety	1	1988		no	See also IEC 61400-1
7	Quality of Power Single Grid-Connected WECS	1	1984			See also IEC 61400-21
8	Glossary of Terms	2	1993	1987		See also IEC 60030-413 International Electrotechnical vocabulary: Wind turbine generator systems
9	Lightning Protection	1	1997		yes	See also IEC 61400 PT24, Lightning protection for turbines
10	Measurement of Noise Immission from Wind Turbines at Receptor Locations	1	1997		yes	
11	Wind Speed Measurement and Use of Cup Anemometry	1	1999		yes	Document will be used by IEC 61400 MT 13, updating power performance measurement standard

early for a co-operative research task on this topic. However, another meeting to discuss progress should be held in one or two years.

3.2 Wind turbine drivetrain dynamics and reliability

The intention of this meeting was to facilitate an in-depth discussion of both research and application engineering of the current state of the art of drivetrain systems for wind turbine applications. The great interest in gearbox and drivetrain dynamics resulted in a large number of participants in this meeting, with 47 people registered for the event. All types of stakeholders were represented: sub-suppliers, manufacturers, utilities, and R&D.

Many talks focused on the analysis and validation of the complete drivetrain. It was concluded that the analytical capabilities are strong, and the challenge is to apply these capabilities appropriately. Validation using field data was considered as most important. Despite these efforts, there are still extensive problems with failures in gearboxes and gearbox subcomponents.

One cause of these problems may be incomplete load cases and transients used in the design process. The aeroelastic models of the turbine are sufficiently accurate; however, the elastic properties of the components in the nacelle and geometric nonlinearities are not fully understood.

To understand load flow and resulting forces in nacelles and bedplates, a number of dynamometers are available for tests. In addition to this, new dynamometers are planned, e.g., by the United Kingdom. The United States Gearbox Reliability Collaborative (GRC) was mentioned as a step forward and a possible source of future co-operation. A task force was set up to prepare for formulating a new task on this subject. An alternative would be to arrange a new meeting on the subject within one to two years to exchange information.

3.3 Wind forecasting techniques

The aim of this meeting was to gather a group of experts in the field of forecasting who were interested in sharing their expertise regarding optimal use of information in wind power forecasting. Wind energy forecasting has evolved rapidly during the past several years, both technically and from the point of view of its implementation. Wind forecasting models are now used operationally in some countries. The tendency is to increase the use of wind power forecasting to manage grids, trade in the market, perform maintenance, and so on.

Presentations by participants showed results coming from the meteorological community that can be applied to improve the prediction of wind power, and also improvements in the models specifically dedicated to forecast the power production of wind farms. There are many different approaches to the problems that use the fields of meteorology and mathematics.

End users of the forecasts explained what they need and how they would use wind forecasts in their environment. The circumstances and needs of the users can be very different depending on the country, area of interest, and so on. Another workshop with end users should be considered to better understand the various scenarios and their priorities regarding the use of wind predictions. The users present at the meeting were interested in extreme events, specifically on ramp forecasting.

The value of wind forecasts depends on factors including the characteristics of the system, the way the system is operated, regulations, climatic conditions, and so on. Some studies conclude that improvements in forecasting accuracy do not have an impact on the management of the system. These studies should be extended to consider extreme events (where the value of forecasting a single event can be enormous) and to other systems with different operational conditions. There was a consensus about the need to reduce errors and uncertainties, especially under extreme conditions.

Workshops with wind energy forecasters, meteorologists, and end users are needed to improve the quality of the forecasts and to improve decision-making processes involving wind energy management and integration with the electricity system. It was also mentioned that it is difficult to attract end users to these events, especially transmission system operators (TSOs) and large utilities.

There was interest in establishing a new task on wind power prediction. This new task should promote a “dynamic benchmarking” of wind power prediction models; organize a meeting with utilities, meteorologists and end users of wind power forecasting to share experiences; use meeting attendees to identify areas of interest to the end users.

Table 3 Topical Expert Meetings Held Since 2001*

57	Wind Turbine Drivetrain Dynamics and Reliability	Jyväskylä, Finland	2008
56	The Application of Smart Structures for Large Wind Turbine Rotor Blades	Albuquerque, USA	2008
55	Long-Term Research Needs – In the Frame of the IEA Wind Co-operative Agreement	Berlin, Germany	2007
54	Social Acceptance of Wind Energy Projects	Luzerne, Switzerland	2007
53	Radar, Radio, and Wind Turbines	Oxford, United Kingdom	2007
52	Wind and Wave Measurements at Offshore Locations	Berlin, Germany	2007
51	State of the Art of Remote Wind Speed Sensing Techniques Using Sodar, Lidar and Satellites	Risoe, Denmark	2007
50	The Application of Smart Structures for Large Wind Turbine Rotor Blades	Roskilde, Denmark	2006
49	Challenges of Introducing Reliable Small Wind Turbines	Stockholm, Sweden	2006
48	Operation and Maintenance of Wind Power Stations	Madrid, Spain	2006
47	Methodologies for Estimation of Cost of Wind Energy and the Methodologies to Estimate the Impact of Research on the Cost	Paris, France	2005
46	Obstacle Marking of Wind Turbines	Stockholm, Sweden	2005
45	Radar, Radio, Radio Links, and Wind Turbines	London, UK	2005
44	System Integration of Wind Turbines	Dublin, Ireland	2004
43	Critcal Issues Regarding Offshore Technology and Deploy-ment	Skærbæk, Denmark	2004
42	Acceptability of Wind Turbines in Social Landscapes	Stockholm, Sweden	2004
41	Integration of wind and hydropower systems	Portland, OR, USA	2003
40	Environmental issues of offshore wind farms	Husum, Germany	2002
39	Power performance of small wind turbines not connected to the grid	CEDER, Soria, Spain	2002
38	Material recycling and life cycle analysis (LCA)	Risø, Denmark	2002
37	Structural reliability of wind turbines	Risø, Denmark	2001
36	Large scale integration into the grid	Hexham, UK	2001
35	Long term research needs - for the time frame 2000 – 2020	Petten, The Netherlands	2001

*For meetings prior to 2001, see www.ieawind.org

4.0 Plans for 2009 and Beyond

The current Operating Agent (OA), Vattenfall, has resigned from managing this task. Several potential candidates were invited to apply, and CENER of Spain was selected to become the new Operating Agent beginning in January 2009.

Task 11 will continue coordinating Topical Expert Meetings and Joint Action Symposia. Four meetings of this type will be held in 2009. Examples of meetings

Table 4 Joint Action Symposia Held Since 2001*			
	Aerodynamics of wind turbines	Boulder, USA Athens, Greece	2003 2001
	Wind assessment	Roskilde, Denmark	2003
	Wind forecasting techniques	Madrid, Spain Lyngby, Denmark Norrköping, Sweden	2008 2004 2002
*For symposia held prior to 2001, see www.ieawind.org			

include but will not be limited to the following:

• Wind park performance assessment in complex terrain
• Wind turbine performance in complex terrain and cold climate
• Sound propagation models and validation
• Follow-up on wind measurements using sodar and lidar
• Micro-meteorology inside wind farms and wakes between wind farms
• Radar, radio links, and wind turbines, follow-up meeting.

Work related to the development of a Recommended Practice on the use of sodar for measuring wind speeds will continue.

All documents produced under Task 11 are available to organizations in countries that participate in the task. Organizations in these countries can receive the newest documents from the Operating Agent. All documents more than a year old can be accessed on the public web pages for Task 11 at www.ieawind.org.

Author: Sven-Erik Thor, Vattenfall, Sweden.

Task 19

Wind Energy In Cold Climates

1.0 Introduction

Wind energy is increasingly being used in cold climates, and technology has been adapted to meet these challenges. As the turbines that incorporate new technology are being demonstrated, the need grows for gathering experiences in a form that can be used by developers, manufacturers, consultants, and financiers. To supply needed information on the operation of wind turbines in cold climates, Annex 19 to the IEA Wind Implementing Agreement was officially approved in 2001. The resulting research Task 19 began in May 2001 and continued for three years. At the end of the first three-year period, the participants decided to extend the collaboration. The main drivers were the need to better understand wind turbine operation in cold climates and to gain benefit from the results of the national projects launched during the first three years. Continuation of Task 19 through 2008 was approved by the ExCo. Table 1 lists the participating countries in 2008.

The expression "cold climate" was defined to apply to sites where turbines are exposed to low temperatures outside the standard operational limit and to sites where turbines face icing. These cold conditions retard energy production during the winter. Such sites are often elevated from the surrounding landscape or located in high northern latitudes (1).

2.0 Objectives and Strategy

The objectives of Task 19 are as follows:

- Determine the current state of cold climate solutions for wind turbines, especially anti-icing and de-icing solutions that are available or are entering the market.
- Review current standards and recommendations from the cold climate point of view and identify possible needs for updates. Possibly recommend updates to standards that include comments from planners and operators.
- Find and recommend a method to estimate the effects of ice on production. A better method would reduce incorrect estimates and therefore the economic risks currently involved in cold climate wind energy projects. As possible, verify the method on the basis of data from national projects.
- Clarify the significance of extra loading that ice and cold climate induce on wind turbine components and disseminate the results.

Table 1 IEA Wind Task 19 Participants in 2008

Country	Contracting Party; Organizations
Canada	Natural Resources Canada
Finland	TEKES; VTT Technical Research Centre of Finland (OA)
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; ISET
Norway	Enova SF; Kjeller Vindteknikk
Sweden	Swedish Energy Agency; WindREN AB
Switzerland	Swiss Federal Office of Energy; ENCO
USA	U.S. Department of Energy; NREL

- Perform a market survey for cold climate wind technology, including wind farms, remote grid systems, and standalone systems.
- Define recommended limits for the use of standard technology (site classification).
- Create and update the Task 19 state-of-the-art report and expert group study on guidelines for applying wind energy in cold climates.

The national activities of task participants are designed to provide new information on issues that are preventing cold climate development today. The results of these activities will enable improvements of the overall economy of wind energy projects and lower the risks involved in areas where low temperatures and atmospheric icing are frequent. The reduced risk would thereby reduce the cost of wind electricity produced in cold climates.

Participants in Task 19 are active in several international projects and co-operative efforts. Some take part in the European Union–funded COST727 action, which aims to improve the Europe-wide ice measurement network and to forecast atmospheric icing. This information directly benefits Task 19's work.

The collaboration will continue to actively disseminate results through the Internet page of Task 19 (http://arcticwind.vtt.fi) and in conferences and seminars (2–6). At the end of the current task period, a final report will be published that describes updated state-of-the-art technology and issues updated recommendations regarding the use of wind turbines at sites where winter conditions prevail a significant amount of time during the year.

One important dimension of this work will be the initiation of conversation about whether cold climate issues should be recognized in future standards that set the limits for turbine design.

3.0 Progress in 2008

Three meetings were organized in 2008: the first in April in Anchorage, Alaska (United States), hosted by NREL; the second in September in Espoo, Finland, hosted by VTT; and the third in Norrköping, Sweden, hosted by WindREN Ab.

The need to continue the work of Task 19 in one way or another was expressed during 2008. The issue of low temperatures is mentioned in standards and recommendations; however, icing is rarely taken into account. Many projects are in the planning stage, but there is a lack of commercially available solutions especially for ice detection and blade anti-icing and de-icing. The development of such solutions may not be a suitable topic for an IEA Wind Task, but pointing out the needs and recommending tools to compare the solutions are goals of Task 19. It was decided to propose a third term to the ExCo at the first meeting of 2009.

The project web site at http://arcticwind.vtt.fi has been updated and serves as an extranet among Task 19 participants.

4.0 Plans for 2009 and Beyond

Final results of the task to be achieved by the end of the term include these:

- Publish updated state-of-the-art-report
- Publish updated recommendations report
- Complete database of wind turbines in cold climates
- Complete database of relevant reports
- Prepare a proposal for the extension of Task 19

The activities will help solve the most common issues causing uncertainty for cold climate wind energy development. These task activities are intended to match well with the national activities of participants.

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Authors: Esa Peltola, VTT Processes, Finland, and Timo Laakso, Pöyry Energy, Finland.

Chapter 4 Task 23

Offshore Wind Energy Technology and Deployment

1.0 Introduction

Installing wind turbines offshore has several advantages over onshore development. Onshore, difficulties in transporting large components and opposition due to various siting issues, such as visual and noise impacts, can limit the number of acceptable locations for wind parks. Offshore locations can take advantage of the high capacity of marine shipping and handling equipment, which far exceeds the lifting requirements for multi-megawatt wind turbines. In addition, the winds blow faster and more smoothly at sea than on land, yielding more electricity generation per square meter of swept rotor area. On land, larger wind farms tend to be in somewhat remote areas, so electricity must be transmitted over long power lines to cities. Offshore wind farms can be closer to coastal cities and require relatively shorter transmission lines, yet they are far enough away to reduce visual and noise impacts.

Recognizing the interest and challenges of offshore development of wind energy, IEA Wind Task 11 Base Technology Information Exchange sponsored a Topical Expert Meeting (TEM 43) in early 2004 in Denmark on Critical Issues Regarding Offshore Technology and Deployment. The meeting gathered 18 participants representing Denmark, Finland, the Netherlands, Sweden, the United Kingdom, and the United States. Presentations covered both detailed research topics and more general descriptions of current situations in the countries. After the meeting, the IEA Wind ExCo approved Annex 23 (Task 23) to the Implementing Agreement as a framework for holding additional focused workshops and developing research projects. The work would increase understanding of issues and develop technologies to advance the development of wind energy systems offshore. In 2008, 10 countries have chosen to participate in this task, and many research organizations in these countries are sharing their experiences and conducting the work (Table 1).

Table 1 IEA Wind Task 23 Participants in 2008

Country	Contracting Party
Denmark	Danish Energy Agency; Risø DTU (OA)
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Republic of Korea	Government of Korea
The Netherlands	Senter/Novem
Norway	Norwegian Water Resources and Energy Directorate
Portugal	INETI
Spain	CIEMAT
Sweden	Swedish Energy Agency
United Kingdom	Department for Business, Enterprise & Regulatory Reform
United States	U.S. Department of Energy; NREL (OA)

2.0 Objectives and Strategy

The overall objectives of Task 23 include the following:

- Organize workshops on critical research areas for offshore wind deployment. The goal of the workshops is to identify R&D needs of interest to participating countries, publish proceedings, and conduct joint research activities for task participants.
- Identify joint research tasks among interested countries based on the issues identified at TEM 43.
- Conduct R&D activities of common interest to participants to reduce costs and uncertainties.

This task has been organized as two sub-tasks. Sub-task 1, Experience with Critical Deployment Issues, is led by Risø National Laboratory (Risø) in Denmark, and Sub-task 2, Technical Research for Deeper Water, is led by the National Renewable Energy Laboratory (NREL) in the United States.

3.0 Progress in 2008

3.1 Sub-task 1: Experience with critical deployment issues

Statistics show a global wind energy capacity in 2008 approaching 1% of the global electricity capacity. Estimates predict a huge increase in wind energy development over the next 20 years. Much of this development will be offshore wind energy. This implies that billions will be invested in offshore wind farms over the next decades. The aim of Sub-task 1, therefore, has been to support this development by arranging workshops in which participants will inspire each other and test and improve research results. The work in Sub-task 1 has been divided into three research areas.

Research Area 1, Ecological Issues and Regulations, held a workshop in Petten, the Netherlands, in February 2008, and was attended by more than 20 experts. The workshop objectives were to

- provide a state-of-the-art overview of knowledge about impacts of offshore wind turbine systems on the marine environment.
- get a picture of the consequences for regulatory frameworks, such as requirements for environmental impact assessments (EIAs) and protection measures for nature reserve areas.
- generate ideas for frameworks on how results of nature research can be used to (re)formulate regulations and legislation.

Discussion and final recommendations fell into three categories. First, the knowledge base for planning and designing offshore wind farms needs strengthening. As ecological research progresses and experience from the planning and operation of existing wind farms emerges, documents covering the following issues need to be produced and distributed about offshore (wind energy) legislation, guidelines for EIAs and strategic environmental assessments (SEAs), and best practices.

Second, transfer is required between R&D establishments and the users who include wind farm planners and designers, as well as authorities responsible for approving wind farms and specifying EIAs and SEAs. A lack of knowledge for integrated spatial marine planning, was identified compared to other offshore activities such as sand mining, shipping, military activities, oil and gas production, and nature conservation.

Third, specific areas of and methods for co-operation between countries were identified during the workshop.

- Regular meetings of multidisciplinary research and industry groups, representing disciplines in the fields of ecology and wind energy technology. It appeared that the Task 23 workshop was one of the rare opportunities for representatives from both fields to meet and exchange views.
- Cumulative effects of an increasing number of wind farms on the marine ecosystem. There is an urgent need to

address this issue for spatial planning purposes.

- Integral risk analysis as part of the planning process and SEA.
- Geographic information system (GIS) mapping as a basis for representing R&D results.
- Integration of the three major issues for offshore wind energy planning: impacts on ecology, electrical infrastructure, and wind farm layout. This requires integration with other activities of IEA Task 23.
- Co-operation on the government level. Governments, which usually finance ecological research, should facilitate the exchange of information by disclosing results as they become available.
- Database formation.
- How to use ecological and environmental networks within the European Union (EU) (such as the Environmental Impact Information Tool [EIIT], which the European Wind Energy Association is designing, and possibly the Global Wind Energy Council [GWEC]) and other countries for the benefit of making knowledge available to potential users.
- Reviewing of siting decisions by international experts with the aim of learning and criticizing possible poor-quality decisions.
- How to deal with shipping safety and siting of wind farms with respect to shipping lanes.

Research Area 2: Grid Connection held a workshop in September 2005, at Manchester University in the United Kingdom. There it was decided to focus the work program on five issues: (1) offshore wind meteorology and impact on power fluctuations and wind forecasting, (2) behavior and modeling of high-voltage cable systems, (3) grid code and security standards for offshore versus onshore, (4) control and communication systems of large offshore wind farms, and (5) technical architecture of offshore grid systems and enabling technologies. A planning meeting at Risø in 2006 set up workshops where the five issues would be addressed. Also, participants agreed to supply information about projects in the member countries including results, to help coordinate activities under this IEA Wind task.

A workshop called Grid Integration of Offshore Wind conducted in June 2007 in London, included a brief overview of the situation in the UK. In that country, a number of early (Round 1) offshore wind farms are already connected to the onshore grid via low-voltage connections (33 kV). Larger Round 2 projects will be connected via offshore transmission systems (132+ kV). Significant work has been undertaken by the Department for Trade and Industry and the industry regulator, Ofgem, to develop an appropriate regulatory framework for offshore transmission. The UK government announced the appropriate model to follow for offshore, tenders will be held for regulated licenses to connect specific offshore projects, and minimum security standards which should apply to offshore have been consulted on. A final workshop, Power Fluctuation, is planned to take place in Denmark February 2009.

Research Area 3: External Conditions, Layouts, and Design of Offshore Wind Farms held a workshop in December 2005 at Risø, Denmark where wake modeling and benchmarking of models, marine boundary layer characteristics, and met-ocean data and loads were identified for inclusion in the future work program. As a result, another workshop on wake modeling and benchmarking of models was held at the Danish test station for large wind turbines, Høvsøre and Billund, in Jutland, Denmark. A great need was identified for further collaboration and exchange of data to develop and verify computational models and to understand the physics of wakes and meteorological backgrounds.

In addition to the work of IEA Wind Task 23, the EU R&D project UpWind includes similar activities. To multiply the benefits from both activities, during 2008, the benchmarking experience and results obtained from collaboration with UpWind were analyzed and discussed.

For marine boundary layer characteristics and met-ocean data and loads, a collaboration between two IEA Wind tasks (11 Base Technology Information Exchange and 23) resulted in a Topical Expert Meeting under Task 11 in January 2007. The meeting was titled The State of the Art of Remote Wind Speed Sensing Techniques Using Sodar, Lidar, and Satellites. These are very important techniques to explore boundary layer characteristics and offshore loads to wind turbines. Additional collaboration took place when an IEA Wind Task 23 meeting was held in February 2007 in conjunction with a German offshore conference and the EU policy seminar on offshore wind.

A follow-up workshop with focus on continued benchmarking was scheduled to take place in Denmark during the second half of 2008. However, it was postponed to February 2009 and held in conjunction with the workshop on power fluctuation as a back-to-back workshop, Wake Effects and Power Fluctuations.

A summary of the workshops described in this section will be published in 2009.

3.2 Sub-task 2: Technical research for deeper water

Sub-task 2 is intended to focus on technical issues associated with deeper-water implementation of offshore wind energy. In practice, however, the project has focused on the activities of the working group known as the Offshore Code Comparison Collaborative (OC3), which includes the analysis of shallow, transitional, and deep-water offshore wind turbine concepts.

The OC3 project is benchmarking system-dynamics models (i.e., design codes) used to estimate offshore wind turbine dynamic loads. Currently, conservative offshore design practices adopted from marine industries are enabling offshore wind development to proceed. But if offshore wind energy is to be economical, reserve margins must be quantified, and uncertainties in the design process must be reduced so that appropriate margins can be applied. Uncertainties associated with load prediction are usually the largest source and hence the largest risk. Model comparisons are the first step in quantifying and reducing load prediction uncertainties. Comparisons with test data would be the next step.

This project is designed to address near-term needs of the industry as well as future needs. Currently, the industry is focused on bottom-fixed, shallow-water applications, especially in Europe where shallow-water sites are plentiful. Deeper-water sites are more common in Greece, Republic of Korea, Japan, Norway, Spain, the United States, and many other countries. This project includes support structures that are likely to become solutions for these markets also. The scope of this collaboration includes technologies ranging from the current shallow-bottom monopiles to transition-depth tripods to deep-water floating platforms.

To test the offshore wind turbine system-dynamics models, the main activities of the OC3 project are (1) discussing modeling strategies, (2) developing a suite of benchmark models and simulations, (3) running the simulations and processing the simulation results, and (4) comparing the results. But these activities fall under the following much broader objectives:

- Assessing the accuracy and reliability of results obtained by simulations to establish confidence in the predictive capabilities of the models
- Training new analysts to run and apply the models correctly
- Identifying and verifying the capabilities and limitations of implemented theories
- Investigating and refining applied analysis methodologies
- Identifying further R&D needs.

In the past, such verification work has led to dramatic improvements in model accuracy as the code-to-code comparisons and lessons learned have helped identify deficiencies in existing models and needed improvements. These results are important because the advancement of the offshore wind industry is closely tied to the development and accuracy of system-dynamics models.

The simulation of offshore wind turbines under combined stochastic aerodynamic and hydrodynamic loading is very complex. The benchmarking task, therefore, requires a sophisticated approach that facilitates the identification of sources of modeling discrepancies introduced by differing theories and/or model implementations in the various codes. This is possible only by meticulously controlling all of the inputs to the codes and carefully applying a stepwise verification procedure in which model complexity is increased in each step.

The fundamental set of inputs to the codes controlled in OC3 relates to the specifications of the wind turbine. The OC3 project uses the publicly available specifications of the 5-MW baseline wind turbine developed by NREL (1), which is a representative utility-scale multimegawatt turbine that has also been adopted as the reference model for the integrated EU UpWind research program. This wind turbine is a conventional three-bladed upwind variable-speed blade-pitch-to-feather-controlled turbine. The hydrodynamic and elastic properties of the varying offshore support structures used in the project are also controlled. Furthermore, the turbulent full-field wind inflow and regular and irregular wave kinematics are model inputs controlled in the OC3 project. This approach reduces possible differences brought about by dissimilar turbulence models, wave theories, or stochastic realizations.

The key component of the stepwise procedure is the enabling and disabling of features of the model among different load-case simulations. Simulations are defined with and without aerodynamics and hydrodynamics, with and without the control system enabled, and with individual subsystems both flexible and rigid.

The OC3 project emphasizes verification of the offshore support structure dynamics as part of the dynamics of the complete system. This emphasis is a feature that distinguishes the OC3 projects from past wind turbine code-to-code verification exercises. Nevertheless, it was important to test the aerodynamic models separately so that modeling differences resulting from the aerodynamics could be identified. This identification is important because the aerodynamic models are routinely a source of differences in wind turbine code-to-code comparisons.

To encompass the variety of support structures required for cost-effectiveness at varying offshore sites, different types of support structures (for the same wind turbine) are investigated in separate phases of the OC3 project:

- In Phase I, the NREL offshore 5-MW wind turbine is installed on a monopile with a rigid foundation in 20 m of water.
- In Phase II, the foundation of the monopile from Phase I is made flexible by applying different models to represent the soil-pile interactions.
- In Phase III, the water depth is changed to 45 m and the monopile is swapped with a tripod substructure, which is one of the common space frame concepts proposed for offshore installations in water of intermediate depth.
- In Phase IV, the wind turbine is installed on a floating spar-buoy in deep water (320 m).

The OC3 project is performed through technical exchange among a group of international participants who come from universities, research institutions, and industry. Although several participants have come and gone, the main participants in 2008 were Acciona Energia (Spain), CENER (Spain), Fraunhofer Institute IWES (Germany), Garrad Hassan (United Kingdom), Institute for Energy Technology IFE (Norway), Marintek (Norway), NREL (United States), NTNU (Norway), Ramboll

(Denmark), Risø-DTU (Denmark), Siemens Wind Power (Denmark), StatoilHydro (Norway), University of Stuttgart (Germany), and University of Hannover (Germany).

Most of the codes that have been developed for modeling the dynamic response of offshore wind turbines are tested in OC3. Although more codes have been tested to some extent over the course of the project, the main codes currently being tested are ADAMS, ADCoS, ANSYS, BHawC, FAST, FLEX5, GH Bladed, HAWC2, NASTRAN, Poseidon, WAMIT, WaveLoads, and SESAM.

The OC3 project started in October 2004 and is scheduled to be completed in the fall of 2009. Over this time, Internet meetings have been held approximately every two months, which continue to be productive and significantly reduce the need for physical meetings and travel. In addition, nine physical meetings have been held at key points in the project: United States, October 2004; Denmark, January 2005; Norway, June 2005’ Denmark, October 2005; United States, June 2006; Germany, January, September, and December 2007; and Denmark, September 2008.

Since the start of the project, the reference 5-MW wind turbine, including the control system, has been developed; the wind and wave data sets have been generated; the simulations and code-to-code comparisons of Phases I, II, and III have been completed; and Phase IV has been initiated. Three conference papers have been published and presented—one for summarizing the results of each of the completed phases—see references (2), (3), and (4) for Phases I, II, and III, respectively. Figure 1 illustrates the model used in Phase III (4). A paper summarizing the results of Phase IV is tentatively planned to be published and presented at a conference in 2009. A final report will be compiled from all the conference papers, with new results added (from new participants, etc.) that have been contributed after the papers were first published. This report will be written after the Phase IV paper has been completed, and its publication is tentatively planned for fall 2009.

The natural next step for the OC3 project is to compare the analytical models to real test data—a significant increase in complexity. Usually it is difficult for a public project to gain access to the needed data. Obtaining the model properties is difficult, and they are usually proprietary. The

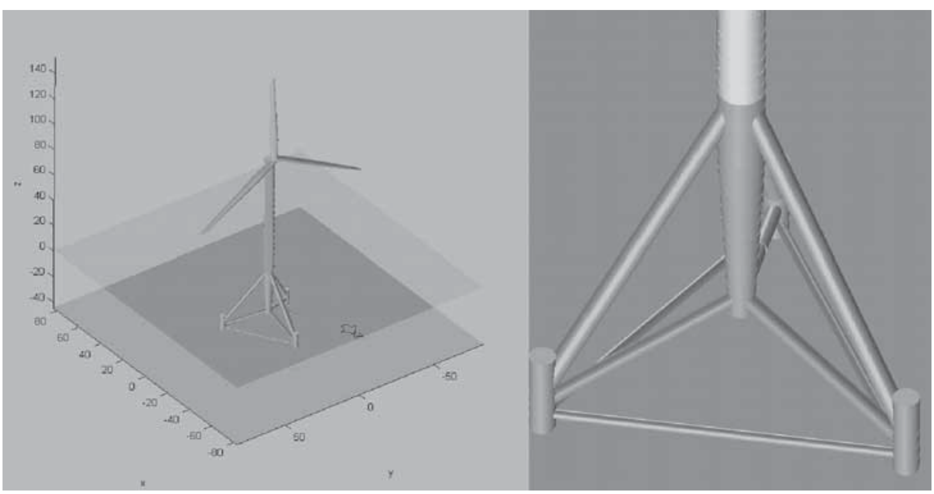

Figure 1 NREL 5-MW wind turbine with tripod support structure used in OC3 Phase III.

data sets are rarely complete enough for a good comparison with analytical models. Wind inflow data are usually from a single anemometer. Wave data are usually from a single point source. Currents might not be available. So comparisons are usually made on a statistical basis. However, even comparisons relying on statistical data are better than no comparisons at all. The value of such comparisons is that they give analysts and designers a measure of confidence that the loads they are predicting are representative of the conditions the turbines are actually operating in. Therefore, even though such a project is bound to be imperfect, it is essential.

4.0 Plans for 2009 and Beyond

In 2009, the 10 participating countries will continue work in both sub-tasks to complete final reports which will be posted to the Task Web site at www.ieawind.org. The task will end in December 2009 with approval of these reports.

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Chapter 5 **Task 24**

Integration of Wind and Hydropower Systems

1.0 Introduction

About 450 GW of hydropower capacity is operating in the IEA Wind Member Countries along with approximately 92 GW of wind power capacity. Because of the natural variability of wind power production and the inherent uncertainty in its prediction, integrating wind power into utility operations typically increases the amount of generation reserves required as well as the need for flexible, rapidly responding generation resources. Since hydropower is a generation resource that is generally quite flexible and able to provide reserves, many utilities are making use of these characteristics to help meet the balancing needs due to wind power. This approach raises many questions concerning economics, overall benefit to the electrical system, impacts on hydropower operations, and more. To address some of these questions, seven IEA Wind countries participated in Task 24 in 2008 (Table 1).

The proposal for Task 24 Integration of Wind and Hydropower Systems arose from an IEA Wind Topical Expert Meeting in 2003. It was approved by the ExCo in May 2004. This co-operative research effort was completed in 2008 and will publish its final report in 2009. It has allowed participating organizations to multiply the experience and knowledge gained from their individual efforts. This is particularly important since there are many different hydro system configurations in many different electricity markets. In addition, the IEA Wind Task 24 worked in co-operation with the IEA Hydropower Implementing Agreement, which is investigating integration of hydropower and wind through a complementary set of investigations. Task 24 is also working with IEA Wind Task 25 on the Design and Operation of Power Systems with Large Amounts of Wind Power.

2.0 Objectives and Strategy

Task 24 has two primary purposes: (1) to conduct co-operative research concerning the generation, transmission, and economics of integrating wind and hydropower systems, and (2) to provide a forum for information exchange.

The specific objectives of the task are as follows:

- To establish an international forum

Table 1 IEA Wind Task 24 Participants in 2008

Country	Contracting Party; Organizations
Australia	Clean Energy Council; Hydro Tasmania
Canada	Natural Resources Canada; Manitoba Hydro, Hydro Quebec
Finland	TEKES; VTT
Norway	Norwegian Water Resources and Energy Directorate; Sintef Energy Research, Statkraft Energy
Sweden	Swedish Energy Agency; KTH Swedish Institute of Technology
Switzerland	Swiss Federal Office of Energy; EW Ursern
United States	U.S. Department of Energy; NREL, (OA) Arizona Power Authority, Bonneville Power Administration,

for exchange of knowledge, ideas, and experiences related to the integration of wind and hydropower technologies within electricity supply systems
• To share information among participating members concerning grid integration, transmission issues, hydrological and hydropower impacts, markets and economics, and simplified modeling techniques
• To identify technically and economically feasible system configurations for integrating wind and hydropower, including the effects of market structure on wind-hydro system economics with the intention of identifying the most effective market structures.

The expected outcomes of the work conducted under Task 24 include the following:
• The identification of practical wind-hydro system configurations
• A consistent method of studying the technical and economic feasibility of integrating wind and hydropower systems
• The technical and economic feasibility of integrating wind and hydropower systems in specific case studies
• The ancillary services required by wind energy and the electric system reliability impacts of incorporating various levels of wind energy into utility grids that include hydro generation
• An understanding of the costs and benefits, and the barriers and opportunities, related to integration of wind and hydropower systems
• A database of reports describing case studies and wind-hydro system analyses conducted through co-operative research of the task.

Four types of case studies will be conducted by the participants: grid integration, hydrologic impact, market and economics, and simplified modeling of wind-hydro integration potential. While many case studies may involve all four of these topics, some studies may only address and share information related to one or two. Each case study will address problem formulation and assumptions, analysis techniques, and results.

2.1 Grid integration case studies

The wide variety of hydropower installations, reservoirs, operating constraints, and hydrologic conditions combined with the diverse characteristics of the numerous electrical grids (balancing areas) provide many possible combinations of wind, hydropower, balancing areas, and markets, and thus many possible solutions to issues that arise. Hydro generators typically have very quick start-up and response times and may have flexibility in water-release timing. Therefore, hydro generators could be ideal for balancing wind energy fluctuations or for energy storage and redelivery. Studying grid integration of wind energy, particularly on grids with hydropower resources, will help system operators understand the potential for integrating wind and hydropower resources. Each of the seven countries participating in the task is planning to contribute at least one case study covering a wide variety of system configurations and sizes ranging from <1,000 MW peak load such as Grant County Public Utility in Washington State, United States to >35,000 MW peak load such as Hydro Quebec, Canada. There is also a wide variety of hydropower facilities, ranging from essentially run-of-the-river with little storage capacity (a day or two) to very large hydro plants associated with reservoirs that have multiyear storage capability. This diversity should allow for a comprehensive look at grid integration scenarios.

2.2 Hydropower system impact case studies

Depending on the relative capacities of the wind and hydropower facilities, integration may necessitate changes in the way hydropower facilities operate to provide balancing or energy storage. These changes may affect operation, maintenance, revenue, water storage, and the capability of the hydro facility to meet its primary purposes. Beyond these potential changes, integration with wind may provide benefits to the hydro system related to water storage or compliance with environmental regulations (e.g., fish passage) and create new economic opportunities. Without a proper understanding of the impacts and benefits, it is unlikely that many hydro facility operators will be interested in using their resources to enable integration of wind power into their respective balancing areas. Thus, study of the impacts of wind integration on hydropower operations to determine the benefits and costs could help pave the way for implementation of wind-hydro projects. Four of the seven participating countries expect to contribute to these studies (Australia, Canada, Norway, and the United States). Examples of hydropower system impacts include the effects on meeting fish flow requirements, reservoir levels for recreation, irrigation deliveries of water, or other priorities in running a hydro facility that may supersede power production. It is worth noting that some of the hydropower facilities being considered have these constraints while others do not.

2.3 Market and economic case studies

While grid integration and hydrologic impact studies may demonstrate the technical feasibility of integrating wind and hydropower systems, implementation will often depend on the economic feasibility of a given project. Such economic feasibility will depend on the type of electricity market in which the wind and hydro projects are considered. Addressing economic feasibility in the electricity market will provide insight into which market types are practical for wind-hydro integration, as well as identify the key factors driving the economics. This understanding may provide opportunities to devise new methods of scheduling and pricing that are advantageous to wind-hydro integration and permit better use of system resources. These market and economic case studies will address the effects of today's market structures on wind-hydro system economics with the intention of identifying the most effective market structures. Economic studies that consider the value of wind energy generation and hydropower to the electricity customer are of greatest interest. Because economic feasibility is germane to integrating wind and hydropower, each participating country will contribute to these studies. Initial results of the case studies are consistent with other wind integration studies in that the efficiency and liquidity of the electricity market has a large influence on the economics, frequently dominating all other factors. Further, an important factor in interpreting the economic consequences of integrating wind with hydro is the perspective taken by the study—whether it is for the overall benefit of the electric customer or of a single actor in the market (e.g. a utility or wind developer).

2.4 Simplified modeling of wind-hydro integration potential case studies

Approximate methods for estimating the amount of wind power that can be physically or economically integrated into a balancing area with existing hydropower generation—based on the characteristics of the balancing area loads, hydropower facilities, and the wind power resource—are of keen interest. Such methods will be considered as the case studies of the participants come to a close, and a search for basic indicators for such methods will be conducted. The analysis methods should include only the most influential operational constraints for hydro and electric reliability concerns. The goal is to develop a technique to approximate the potential for integrating wind and hydropower without the need to conduct an in-depth study. However, any simplified method must still take a system-wide perspective, with the understanding that wind and hydropower interact within a larger grid that includes other generation resources. Because of this, it may be more fruitful for some investigators to consider simplified methods that study how much wind can be integrated into a large interconnected grid that includes significant hydropower resources but not to consider specific hydropower resources. Three of the participating countries expect to contribute to the simplified modeling (Australia, Norway, and the United States).

As the breadth of these case studies indicates, integrating wind and hydropower can be quite complex. Figure 1 provides a conceptual view of the relationships of wind, hydropower, and the transmission balancing area along with "surrounding" issues for a case study in the Southwestern United States.

3.0 Progress and Plans

By the end of 2008, six meetings of Task 24 participants had been held. The general work plan for participating countries was developed at the kickoff meeting in 2005 at Hoover Dam, Nevada, United States. The work of the task over these first two years was focused on initiating participant case studies and finding how best to collaborate. Differences in terminology and techniques inherent in an international collaboration made it necessary to create a consistent framework for formulating problems and presenting results (a matrix). Participants also decided to with a similar task of the IEA Hydropower Implementing Agreement. Thus a joint task or annex was approved by the IEA Wind and Hydropower ExCos in 2006.

In 2006, an R&D meeting was held online using a web meeting tool (Webex) through the U.S. Department of Energy. Meeting participants called into a central voice conference, while viewing and manipulating a common presentation accessed and displayed over the Internet. The matrix and details of the upcoming R&D meeting were discussed.

At the next R&D meeting in Launceston, Tasmania, it became clear that to achieve the expected results defined in the

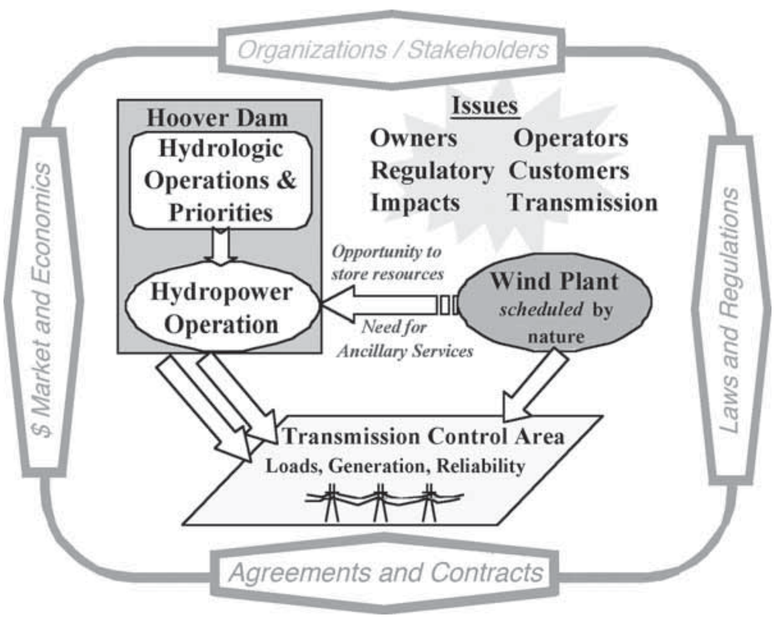

Figure 1 Conceptual view of the relationships of wind power, hydropower, and the transmission control area, and the issues surrounding their integration.

task work plan, distilling information from the case studies and describing the results in the final report will be necessary. Additional outcomes from the work plan were added as a result of collaborating with participants from the IEA Hydropower Implementing Agreement.

During 2007, two R&D meetings were held in collaboration with the participants of Task 25 on the Design and Operation of Power Systems with Large Amounts of Wind Power. Joint meetings with Task 25 were initiated because the tasks had some similar goals. The first was held in Milan, Italy in conjunction with the European Wind Energy Conference 2007. Twenty people from 11 countries attended the meeting. Participants discussed methods for determining the impacts of wind energy in power systems, what these impacts are, and how they are modeled and predicted.

The second joint R&D meeting, held in Oslo, Norway, was attended by 21 people from 12 countries. Task 24 participants presented updates on their case studies and addressed the primary hydropower impacts of integration of wind power. In all countries except the United States, the only impact on their hydropower utilities from wind power is in the optimal economic use of the hydro resource in the system. The United States is the only member country with specific flow constraints due to non-power requirements. The general consensus was that when considering energy storage, including that in hydro impoundment of water, wind integration requires no backup and/or storage. Wind generation is a system integration issue, and no local dedicated storage is needed. However, storage may make sense when considered in the context of the efficiency of the entire system.

Other important issues include how to properly define the wind penetration level, creating a "flexibility index," and the required success factors for wind integration studies. Participants agreed that wind integration studies should take a cost-benefit perspective of wind in the grid rather than a perspective of limited integration cost due to the variability and uncertainty of wind energy.

A final version of the matrix was adopted at the end of 2006, and each of the task participants has completed a matrix to describe its case study projects. This allows comparison and reporting of the results from the various case studies.

In June 2008, the final R&D meeting was held in Quebec City, Canada and was attended by 13 people from five countries. Task participants presented their case studies and discussed the similarities and differences among the various systems and studies. The outline for the final report was approved, and the participants will complete the case studies and produce the final report in 2009.

Author: Thomas L. Acker, NREL, United States.

Chapter 6 **Task 25**

Power Systems with Large Amounts of Wind Power

1.0 Introduction

Wind power will introduce more uncertainty into operating a power system; it is variable and partly unpredictable. To meet this challenge, more flexibility will be needed in the power system. How much extra flexibility is needed depends on how much wind power there is and on how much flexibility exists in the power system. To explore issues of wind power's effects on the overall power system, Annex 25 to the IEA Wind Implementing Agreement was approved in 2005 for three years (2006–2008) and was granted a second term (2009–2011) in September 2008. Table 1 shows the participants in the task. During the first term, 11 countries plus the European Wind Energy Association (EWEA) participated in the Task; for the second term, Canada and Japan also have joined.

The existing targets for wind power capacity anticipate a quite high penetration in many countries. It is technically possible to integrate very large amounts of wind capacity in power systems; the limits arise from how much can be integrated at socially and economically acceptable costs. So far, the integration of wind power into regional power systems has mainly been studied on a theoretical basis, as wind power penetration

Table 1 IEA Wind Task 25 Participants, Second Term (2009–2011)

Country	Contracting Party; Organizations Coordinating Work; [TSO participants in brackets]*
Canada	National Resource Canada; [Hydro Quebec]
Denmark	Danish Energy Agency; Risø-DTU; [Energinet.dk]
EWEA	European Wind Energy Association
Finland	TEKES; VTT Technical Research Centre of Finland (OA)
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; ISET; [RWE and E.ON Netz]
Ireland	Sustainable Energy Ireland; ECAR; [Eirgrid]
Japan	AIST
Netherlands	SenterNovem; ECN
Norway	Enova SF; SINTEF Energy Research; [Statnett]
Portugal	INETI; [Rede Electrica Nacional (REN)]
Spain	CIEMAT; Universidad de Castilla–La Mancha
Sweden	Swedish Energy Agency; Kungliga Tekniska Högskolan (KTH)
UK	Department for Business, Enterprise & Regulatory Reform; Centre for Distributed Generation and Sustainable Electrical Energy; [National Grid]
United States	U.S. Department of Energy; NREL; Utility Wind Integration Group (UWIG)

*In some countries, such as Finland and Sweden, the TSO follows the national advisory group. CIGRE JWG C1,3,6/18 and European TSO consortium EWIS have sent observers to meetings.

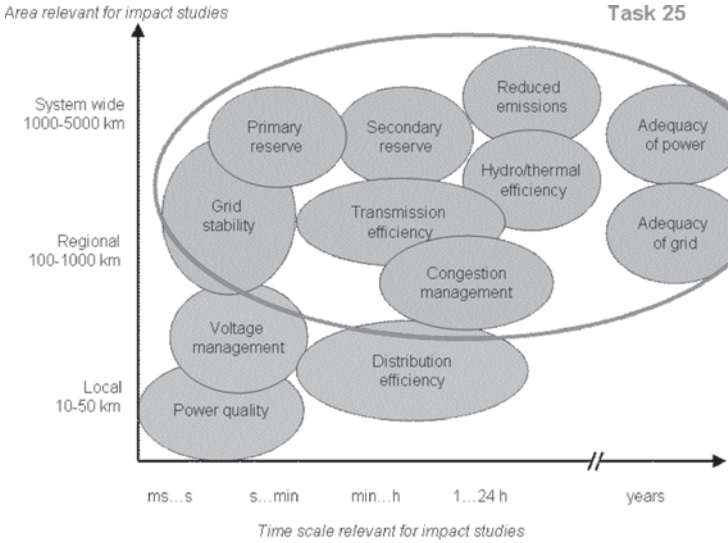

Figure 1 Impacts of wind power on power systems, divided into different timescales and sizes of area relevant for the studies. Primary reserve is denoted for reserves activated in seconds (frequency activated reserve; regulation) and secondary reserve for reserves activated in 5–15 minutes (minute reserve; load following reserve).

is still rather limited in most countries and power systems. However, some regions—e.g., western Denmark, northern Germany, and the Iberian Peninsula (Spain and Portugal)— have significant practical experience with wind integration and already show a high penetration of above 10% of electricity consumption coming from wind power.

In recent years, several reports have been published investigating the power system impacts of wind power. However, results on the costs of integration differ substantially, and comparisons are difficult to make. This is due to using different methodology, data, and tools during the investigations and different terminology and metrics in representing the results. An in-depth review of the studies has been started in Task 25 to draw any conclusions on the range of integration costs for wind power. Because system impact studies are often the first steps taken toward defining wind penetration targets in each country, it is important that commonly accepted standard methodologies are applied in system impact studies.

2.0 Objectives and Strategy

The ultimate objective of IEA Wind Task 25 is to provide information to facilitate the highest economically feasible wind energy penetration in electricity power systems worldwide. Task 25 work supports this objective by analyzing and further developing the methodology to assess the impact of wind power on power systems. Task 25 has established an international forum for exchange of knowledge and experiences related to power system operation with large amounts of wind power. The challenge is to create coherence between parallel activities with transmission system operators and other R&D task work and to remain as the internationally accepted forum for wind integration.

The participants will collect and share information on the experience gained in current and past studies. Their case studies will address different aspects of power system operation and design: reserve requirements, balancing and generation efficiency, capacity credit of wind power, efficient use of existing transmission capacity and requirements for new network investments, bottlenecks, cross-border trade, and system stability issues. The main emphasis is on technical operation. Costs will be assessed when necessary as a basis for comparison. Also, technology that supports enhanced penetration will be addressed: wind farm controls and operating procedures, dynamic line ratings, storage, demand side management (DSM), and so on.

The task work began with a state-of-the-art report collecting the knowledge and results to date. This report was updated as a final report of 2006–2008 work during spring 2009. The task will end with developed guidelines on the recommended methodologies when estimating the system impacts and the costs of wind power integration. Best-practices recommendations will be formulated on system operation practices and planning methodologies for high wind penetration.

3.0 Progress in 2008

3.1 Research progress

The meetings organized by Task 25 have established an international forum for exchange of knowledge and experiences. The spring task meeting in 2008 was organized in Denmark and hosted by the TSO Energinet.dk. In the autumn meeting, hosted by ECAR and SEI in Dublin, participating countries presented the national results in a one-day seminar followed by discussions about the final report.

Coordination with other relevant activities is an important part of the Task 25 effort. The meetings in 2007 were organized in conjunction with Task 24, Integration of Wind and Hydropower Systems. The system operators of Denmark, Germany, Ireland, Portugal, and the UK have joined the meetings organized thus far. Links between TSO organization working groups at CIGRE and ETSO European Wind Integration Study (EWIS project) have been formed, and observers have joined Task 25 meetings in 2008 and 2009.

Publication of the work is a key goal of Task 25 co-operative research. In 2007, national case studies presented in a session organized for the European Wind Energy Conference (EWEC) in Brussels in April 2008. Task 25 work and results were presented at several other key meetings in 2008: the CIGRE C6-08 meeting in Berlin, Germany; the Irish Wind Energy Association meeting; a wind integration workshop in Madrid, Spain; the Windpower 2008 conference in Houston, Texas, United States; and the IEEE Power Engineering Society meeting in Pittsburgh, Pennsylvania, United States.

Work has begun on a simplified assessment of wind integration effort and power system flexibility. The assessment draws on the work done by the Operating Agent for an IEA Secretariat study for the G8 on integrating renewable energy sources. In addition, a paper collecting results on statistical methods assessing short-term reserve requirements of wind power from Finland, Sweden, and the United States was published in *Wind Engineering*.

The Task 25 web site has been established at http://www.ieawind.org under Task Web Sites. The public portion of the site contains the Task 25 publications and a bibliography completed in 2008 in conjunction with Task 24 that lists publications related to system integration. The members-only section details the meeting presentations and information relevant to task participants.

3.2 Results of the final report 2006–2008

The results of the final report of the first phase of 2006–2008 can be used by participating countries to show the error of claims that wind power requires large amounts of reserve power and that integration costs erode the benefits of wind power. The report finds that a substantial tolerance to variations is already built in to our power network. This is why the influence of wind power fluctuations can be further balanced through a variety of relatively easy and inexpensive measures for reasonably large penetrations (10% to 20%). The impact of a large share of wind power can be controlled by appropriate grid connection requirements, extension and enforcement of transmission networks, and integration of wind power production and production forecasts into system and market operation.

The report emphasizes the benefits of operating the power systems in a coordinated manner and/or with larger balancing areas. The aggregation benefits of a power system that covers a large area help to reduce wind power fluctuations and improve predictability. A large power system also has more generation reserves available, and the increased regulation effort can be implemented cost-effectively. The transmission capacity between areas is crucial for the use of the benefits arising from large production areas. An electricity market in which production forecasts can be updated a few hours ahead also helps in limiting forecast errors and thereby the costs of balance power.

The main results of the state-of-the-art report can be divided into three categories:

(1) Additional costs arising from the balancing of wind power fluctuations. With wind power penetrations amounting to 10% to 20% of the gross electricity demand, the additional cost (per megawatt hour of wind power) arising from the balancing of wind power fluctuations is estimated to range between 1 and 4 €/MWh. This is less than 10% of the long-term market value of electricity.

(2) Grid reinforcement needs due to wind power. Current wind power technology makes it possible for wind power plants to support the grid in the event of faults such as significant voltage drops and to participate in voltage regulation. Wind power plants are also able to limit their production fluctuations. Grid reinforcement needs related to wind power vary among countries depending on the distance between consumption centers and wind power plants and the strength of the existing grid.

(3) Capacity value of wind power, i.e. the ability of wind power to replace other power plant capacity. Even though wind power is mainly an energy resource that replaces fossil power generation, it can also be used for replacing existing power plant capacity. In areas where the overall wind penetration level is low, wind power can replace other capacity by its average power, typically 20% to 40% of the installed wind power capacity. However, when penetration levels are high (e.g., 30%) and in areas where wind power production during peak demand is always low, wind power can only replace other capacity by 5% to 10% of the wind power capacity.

Figures 2 through 4 summarize the results from case studies reviewed in the final report for 2006–2008. They also illustrate the difficulties in comparing the results from existing studies. The range evident in the results is great due to the different power systems in question and different methodologies applied in the studies. Comparison of the studies showed that assumptions concerning the use of international transmission connections and the timescale of updating wind power forecasts had major impacts on the results.

4.0 Plans for 2009 and Beyond

The final report for 2006–2008 will be published in 2009. Journal articles will be written about some of the issues in the final report. A meeting is scheduled for early in the year hosted by Imperial College (DG&SEE) and National Grid. Another meeting is planned for mid-October in Germany in conjunction with the 8th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Farms, where Task 25 will organize a session. Task 25 work and results will be presented at several other meetings

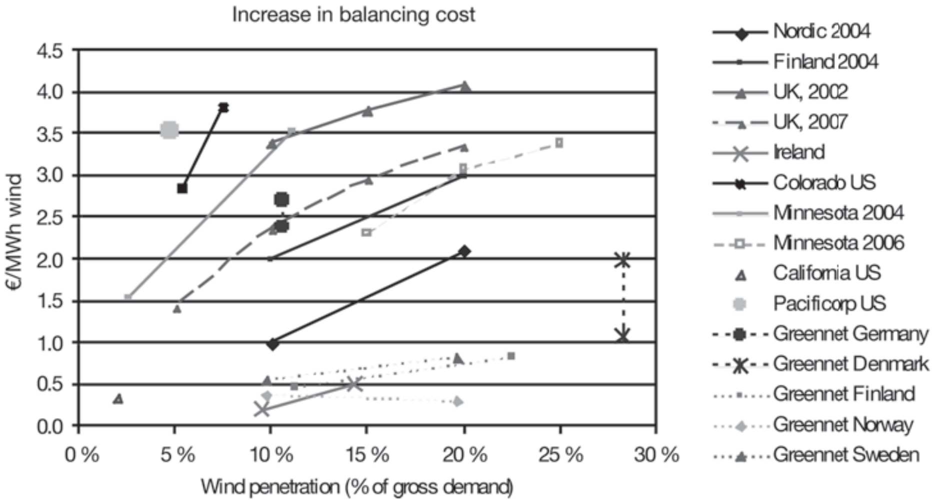

Figure 2 Results from estimates for the increase in balancing and operating costs due to wind power. The currency conversion used here is 1 € = 0.7 £ and 1 € = 1.3 USD.

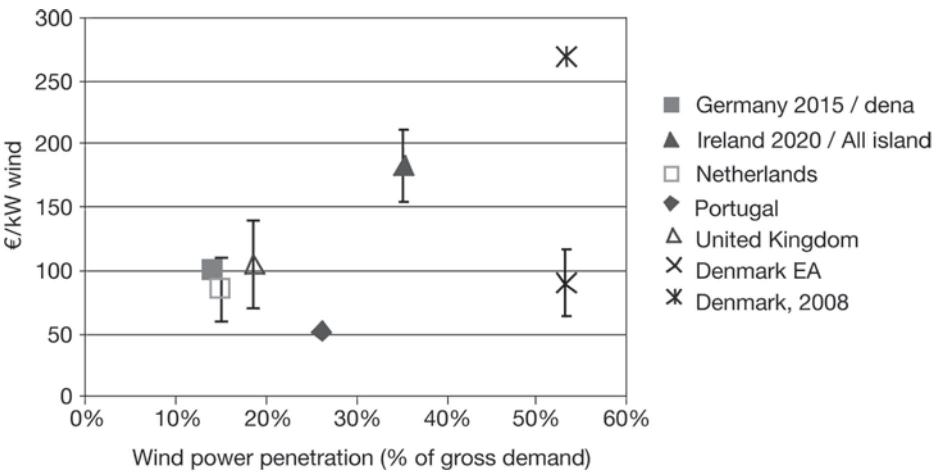

Figure 3 Results from studies on grid reinforcement costs due to wind power (for Denmark, the results are to reach from 20% to 50% penetration).

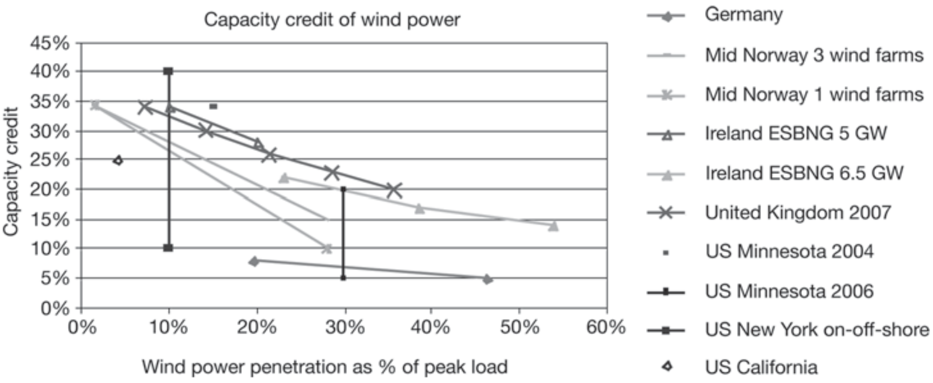

Figure 4 Results from studies on the capacity value (capacity credit) of wind power.

in 2009, including EWEC 2009 and the 14th Kasseler Symposium Energie-System-technik, Germany.

The topic being addressed by Task 25 is growing exponentially in importance in the member countries and more broadly. There is consensus that the work of the task has only just begun. During the second term, participants will expand into studies of higher-penetration that will address the important topic of cost/benefit analysis of wind power integration and will go more deeply into the subject of modeling power systems with wind power. Work on creating simple rules of thumb stating the probable impacts and cost ranges for different power systems with different levels of wind penetration will be continued in collaboration with the IEA Secretariat's IREG2 project. The library on the Task 25 web site will be complemented and updated.

Author: Hannele Holttinen, Operating Agent Representative, VTT Technical Research Centre of Finland, Finland.

Task 26
Cost of Wind Energy

1.0 Introduction
Wind power generation has come to a "historical" point at which, just as installed costs were becoming competitive with other conventional technologies, the investment cost per megawatt for new wind power projects has started increasing. This is believed to be the result of increasing commodity prices (mainly raw material such as copper and steel, plus a bottleneck in certain sub products) and the current tightness in the international market for wind turbines. Signals in the U.S. market indicate a 50% increase in the investment cost of wind systems, up to approximately 1,800 USD/kW. Other important markets for wind energy are also experiencing a rising costs, although noticeable differences still exist among countries.

This is precisely the background that justifies the initiation of a new task. Because wind is becoming an important source of electricity generation in many markets and is competing with other technologies—notably natural gas and nuclear—in terms of new installed capacity, it is crucial that governments and the wind research community are able to discuss the specific costs of wind systems on the basis of a sound methodology. Without a clear impartial voice regarding costs, organizations without a good understanding of wind systems are left to determine and publicize their costs, often in error. These issues are exacerbated by the diversity of the wind portfolio and variations in international project development costs assumptions. The work undertaken in this cost task is also expected to provide a methodology for projecting future wind technology costs. Finally, this task aims to form the basis for a more comprehensive analysis of the value of wind energy. Table 1 lists participants in the task for 2008.

2.0 Objectives and Strategy
The objectives of this task are
- To establish an international forum for exchange of knowledge and information related to the cost of wind energy.
- To identify the major drivers of wind energy costs—e.g., capital investment, installation, operation and

Table 1 IEA Wind Task 26 Participants in 2008	
Country	Contracting Party; Organizations
Denmark	Danish Energy Agency; Risø National Laboratory /DTU, EA Energy Analyses
EWEA	European Wind Energy Association
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; WindGuard
Netherlands	SenterNovem; ECN
Spain	CIEMAT; AEE
Sweden	Swedish Energy Agency; Vattenfall
Switzerland	Swiss Federal Office of Energy
United States	U.S. Department of Energy; NREL (OA)

maintenance, replacement, insurance, finance, and development costs—and to quantify the differences of these cost elements among participating countries.

- To develop an internationally accepted, transparent method for calculating the cost of wind energy that can be used by the International Energy Agency (IEA) and other organizations.
- To derive wind energy cost and performance projections, or learning curves, that allow governments and the research community to anticipate the future trends of wind generation costs.
- To compare the cost of wind energy with those of other electricity generation technologies, making sure that the underlying assumptions used are compatible and transparent.
- To survey various approaches to estimating the value of wind energy, e.g., carbon emission avoidance, fuel price stability.

Three activities are proposed to achieve these objectives: 1) development of a transparent method for estimating cost of wind energy and identification of major cost drivers; 2) estimation of future cost and performance of land-based and offshore wind projects; and 3) assessment of methodologies and results for estimating the value of wind energy.

Providing transparency in the cost elements of wind projects among all participating countries will result in better understanding of the cost drivers of wind technology and the reasons for differences among participating countries. Development of a simple spreadsheet model that represents the major elements of wind projects' costs will result in a tool that could be used by IEA or others in estimating wind project costs. The model inputs and methodology will be clearly defined and documented. A representative set of input parameters specific to each participating country will be collected. These data should represent typical costs and project performance for proposed or installed projects, for both land-based and offshore wind technology. Manufacturers, developers, and other wind industry participants should be engaged to obtain these representative costs. Methods such as surveys or interviews could be used. Based on this common set of data from each participating country, assumptions for a generic estimate of wind energy costs will be determined. Each participant will provide documentation of their representative cost data and will quantify the differences between their country's cost structure and that of the generic model. A report will summarize these results, providing insight into the different cost drivers for each participating country.

Estimates of future cost and performance for wind technology are important for analyses of the potential for wind energy to meet national targets for carbon emission reductions or renewable electricity generation. Learning curves are one method for assessing the effects of technology development, manufacturing efficiency improvements, and economies of scale. National laboratory component–level cost and scaling relationships can also be used to estimate future technology development pathways. Although costs have decreased since the early 1980s, recent trends indicate rising costs that have been attributed to tight supply, commodity price increases, and other influences. These effects may continue in the future, and it is important to identify the contribution of such market influences to wind technology costs. These effects, and their relation to technology advances, should be incorporated into methods to project future costs and performance for wind technology. A thorough assessment of the effect of wind technology changes such as increased generator size, larger rotors, and taller towers over the past decade will help inform the use of learning curves and engineering models to develop future cost and performance trajectories.

Wind energy technology ultimately operates in an electricity system that includes conventional and other alternative electricity generation technologies. Wind energy technology adds value to a system in several ways, including reducing carbon emissions, diversifying the fuel supply, and providing stable energy production prices. Various methods and approaches are used to quantify these impacts of wind energy deployment. This work package will provide a summary of these concepts and approaches.

3.0 Progress in 2008

Development of the work plan for this task was the primary activity in 2008. All participants agreed to the work plan in early 2009. Development of a cost of wind energy discounted cash flow model was also agreed on as the approach for the first work package.

4.0 Plans for 2009

During 2009, the primary activity will be directed toward the development of a cost of wind energy discounted cash flow model and a comparison of input data from each of the participating countries. Each country will provide specific guidance to ECN and NREL for development of a spreadsheet model and a glossary of terms. Next, input data representing the various wind energy costs in each participating country will be collected, and the model will be exercised to represent costs in each country. A generic representation of wind energy costs will be agreed on by all participants. Finally, an analysis in which each country identifies the primary differences between actual costs and the generic cost model will be conducted. A report summarizing the influences of different costs among the participating countries will be compiled in the following year. Most of this work will be conducted by web-based meetings. However, an in-person meeting will be held in Sweden in September. At this meeting, assumptions for a generic cost of wind energy model will be determined. An approach to begin the work of identifying future wind energy cost and performance projections will also be addressed. The work for this task formally began in January 2009 and is expected to continue for three years until the end of 2011.

Author: M. Maureen Hand, National Renewable Energy Laboratory, the United States.

Chapter 8 **Task 27**

Consumer Labeling of Small Wind Turbines

1.0 Introduction

This task, approved in April 2008, will develop and deploy a system of quality labeling for consumers of small wind turbines. The task will also contribute to and use an IEA Wind Recommended Practice for labeling small wind turbines. For anyone interested in buying a small wind turbine, this work will also provide information such as recommended methodologies and independent test reports on power performance curves, acoustic noise emissions, strength and safety, and duration tests. The actual testing of the wind turbines is beyond the scope of Task 27. Reliable third-party testers such as national laboratories, universities, and certification entities already exist. The Operating Agent of this task will direct small wind turbine manufacturers to these testers in order to get a label for their products.

The task's primary goals are to 1) build bridges between small wind turbine manufacturers and third-party testers and 2) to provide private companies with a commonly accepted testing methodology (IEA Wind Small Wind Turbine Recommended Practice). Table 1 lists the countries participating in Task 27 in 2008.

2.0 Objectives and Strategy

The entire wind energy sector should support the labeling initiative to reduce the risk of accidents with small wind turbines and to minimize deceptive investments in less than optimum equipment. The primary objective of this new task is to give incentives to this industrial sector to improve the technical reliability, and therefore the performance, of small wind turbines. The intention is to define a globally standardized product label for small wind turbines and minimum requirements for a testing process that would allow a label to be placed on products. This would give customers and governments minimum assurances regarding the safety and performance of small wind turbines. Common methodologies to test equipment and test results displayed in a form understood by consumers will increase the maturity of the small-scale wind power sector. In addition, consumer quality labels will benefit manufacturers of high-quality small wind turbines, that compete in a marketplace with outdated or untested technologies. But mostly, the outcome of this task will benefit potential buyers and installers of small wind turbines and the official energy entities that give permits to connect them to the electric grid.

Table 1 IEA Wind Task 27 Participants in 2008

Country	Contracting Party; Institutions Coordinating Work
Australia	Clean Energy Council; RISE, Murdoch University
Canada	Natural Resources Canada; WEICan
Japan	AIST; JEMA
Spain	CIEMAT (OA)
Sweden	Swedish Energy Agency; INTERTEK
United Kingdom	Department for Business, Enterprise & Regulatory Reform; BWEA, TUV-NEL
United States	U.S. Department of Energy; NREL, Small Wind Certification Corporation

To accomplish these outcomes, several goals must be met.

- To build up a critical mass of involvement the task will include government agencies, wind turbine manufacturers, and third-party testers (primarily universities, national laboratories and institutes, and companies having considerable experience in testing wind power devices) to develop methodologies for testing and presenting results and for labeling classification. This critical mass should provide the necessary basis for development and wide use of the IEA Wind Recommended Practices for the small-scale wind power sector.
- To test methodologies and labels on several small wind turbines and provide feedback to entities that are working to update methodologies in this area.
- Strongly increase consumer and official entities awareness.

The main deliverables of this new task are a system of quality labels for small wind turbines and an IEA Wind Small Wind Turbine Recommended Practice as a pre-normative international standard for testing and labeling small wind turbines.

During the preparation of the IEA Wind Task 27 work plan, several initiatives to develop domestic small wind turbine quality label procedures have been launched. Among them are the British Wind Energy Association (BWEA) Small Wind Turbine Performance and Safety Standard in February 2008 and the American Wind Energy Association Small Wind Certification Corporation (AWEA-SWCC) initiative in the United States proposed for January 2009. However, no systematic international approach for quality labeling of small wind turbines has yet been established.

3.0 Progress in 2008

In response to the same pressures that prompted development of the IEA Wind Task 27 proposal, IEC TC 88 proposed developing a third edition of the standard 61400-2 Ed 2 "Requirements for Small Wind Turbines." This initiative to improve the standard was presented and approved in the plenary meeting of the IEC in Beijing (China) in September 2008. In addition to the existing areas of 61400-2 Ed 2, the new edition would introduce changes desired by the small wind turbine industry relating to power performance testing; acoustic sound testing; strength, safety, and design requirements; duration testing; reporting and certification; change control of certified products; and, consumer labeling.

The IEC TC 88 revisions to 61400-2 and IEA Wind Task 27 initiatives regarding small wind turbine labeling have some important conceptual differences. IEC TC 88 prepares and publishes international standards for wind energy technology. IEA Wind will provide private companies with a commonly accepted methodology for labeling so they can enter or remain in the market. The IEC TC 88 proposal to revise 61400-2 is a very ambitious initiative that will take years to complete. The IEA Wind Task 27 initiative could be developed more quickly to deliver international recommendations for manufacturers and end users. By focusing on labeling, the Task 27 activities will complement the work of IEC TC 88 to produce 61400-2 Ed 3.

4.0 Plans for 2009 and Beyond

An IEA Wind Task 27 kickoff meeting was held in Madrid, Spain in February 2009 to analyze the status of the small wind sector in terms of quality certification in the various countries. This meeting was organized in liaison with the IEC TC 88. After this kickoff meeting, several other IEA-IEC liaison meetings were scheduled for 2009 in the United Kingdom, the United States, Canada, and Japan. The agenda for these meetings is to complete task planning and assign working groups for proposed activities.

The expected results of this task are as follows:

- An IEA Wind Small Wind Turbine Recommended Practice that is a base document in pre-normative form to guide and aid manufacturers, independent organizations acting as testers of small wind turbines, and public entities and investors involved in developing, selecting, and licensing wind turbines.
- An expanding worldwide list of manufacturers that have submitted their equipment to third-party tests according to the IEA Wind Small Wind Turbine Recommended Practice.
- An expanding list of third-party testers according to the IEA Wind Small Wind Turbine Recommended Practice.
- Within three years, to convey the work to IEC to develop an international standard, and/or to establish a more permanent hosting/funding of the management of the labeling effort.
- Higher consumer awareness of small wind turbines, resulting in the use of better equipment.
- Improved awareness of IEC standards in this area.

Author: Ignacio Cruz, CIEMAT, Madrid, Spain.

Chapter 9

Task 28

Social Acceptance of Wind Energy Projects

1.0 Introduction

The mission of the IEA Wind Implementing Agreement is to stimulate co-operation on wind energy research and development and to provide high quality information and analysis to member governments and commercial sector leaders by addressing technology development and deployment and its bene¬fits, markets, and policy instruments. Within IEA Wind, envi-ronmental and societal issues are sometimes referred to as 'soft issues' to differentiate them from technology aspects. However, environmental and societal issues have become pivotal to the deployment of wind energy in many countries. Even where the economics of wind energy are favorable, deployment can only occur when the public and the planning authorities accept the technology. This requires an appreciation of the benefits of wind energy that weigh against any local visual and environmental effects. To address these issues, seven countries participate in IEA Wind Task 27 (Table 1).

2.0 Objectives and Strategy

A first short report on social acceptance was presented to the IEA Wind ExCo at the end of 2007. Specific or partial objectives of this task are to establish an international forum for ex-change of knowledge and experiences related to social acceptance and other societal issues. The work will produce a state-of-the-art report on the knowledge and results so far on social acceptance of wind power installations, including a list of studies and online library of reports and articles. The participants will establish "Best Practices" and tools for policy makers and planners to reduce project risks due to lack of social acceptance, accelerate time of realization of projects, accelerate the exploitation of the full potential of wind energy in the concerned countries, and establish strategies and communication activities to improve or to maintain the image of wind power.

Three different groups of people participate in Task 28. The *Working Group* (1 or 2 people per participating country) represents the main working body of the task. Its members make the essential contributions to the task goals by working out the results of the work pack-ages (Table 2). Members of the *Support Group* (1 or 2 people per participating country) re-views and contributes to the results of the working group by commenting on the proposed reports and suggesting future activities to the working group. Members have yet to be defined. Members of the *Social Acceptance and Wind Energy Community* are the

Table 1 IEA Wind Task 28 Participants in 2008

Country	Contracting Party; Institution(s)
Canada	Natural Resources Canada; University of Québec at Montréal
Finland	TEKES; wpd Finland Oy
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; Martin-Luther-University, Otto-von-Guericke-University
Japan	AIST; the University of Tokyo
Norway	Enova SF; Centre for Energy and Society, NTNU
Switzerland	Swiss Federal Office of Energy; ENCO Energie-Consulting AG (OA)
United States	U.S. Department of Energy; NREL

Table 2 Members of Working Group for Task 28	
Canada	University of Québec at Montréal, Department of Political Science
Finland	wpd Finland Oy
Germany	Martin-Luther-University Halle-Wittenberg, Institute for Psychology; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; Otto-von-Guericke-University Magdeburg, Institute for Psychology
Japan	The University of Tokyo
Norway	Center for Energy and Society, Department of Interdisciplinary Studies and Culture
Switzerland	Swiss Federal Office of Energy, Wind Department; ENCO Energie-Consulting AG
United States	National Wind Technology Center, NREL

recipients of the task's results, persons to be invited to seminars, and scientists and researchers to be informed about the task activities.

2.1 Overview of anticipated results

The participants have formulated the possible results from the task's activities:

- State-of-the-art report
- Guidelines with a list of best practices (methodology, input data, especially how so-cial acceptance to be considered in project development)
- Translation of the existing knowledge of social scientists into the language of plan-ners and engineers to improve and speed up wind energy planning processes, e.g. how to elicit participation or how to turn affected people into positively involved parties
- Description of successful participation models
- Curricula on social acceptance issues for seminars, training courses, and teaching units for wind power people
- Conference on social acceptance with developers and politicians (in 2-3 years), and perhaps scheduled around an EWEA conference
- Published results of the task in reports and available on a server
- Proceedings from workshops (presentations given at research meetings plus notes of the summary discussions)
- An online library of case study reports generated by the research participants

Due to the expected relevance of the outcomes of this task to the policy makers of the different countries, results on guidelines, new methodologies, strategies, and best practices will be available to all participating countries, even when not directly represented in the task.

2.2 Structure of activities and projects

Based on the Task Proposal, the participants structured the possible activities and projects according to the list in Table 3. The website, the on-line library, and the questionnaire con-cerning various projects will be ordered in this way.

3.0 Progress in 2008

The Task proposal was approved to move forward by the ExCo at the meeting in April 2008. The proposed Operating Agent is ENCO Energie-Consulting AG Switzerland represented by Robert Horbaty. A first Pre-kick-off Meeting was held in August Bubendorf, Switzerland. Seven countries

Table 3 Structure of activities of Task 28	
0 Definition of Social Acceptance - What it is and why we need it.	4 Instruments - Visual impacts - Photomontage - Communication campaigns.
1 National Wind Energy Concepts - National / State incentive programs - Spatial planning, planning aid.	5 Stakeholders - e.g. Utilities - Financial institutions - NGO.
2 Distributional Justice - Burden sharing - Compensation of land use - Compensation of impacts.	6 Well-being - Standard of living - Quality of life - Health.
3 Procedural Design - Communication strategy - Step by step procedure - Participation of locals - Social design process - Siting.	

committed and another five expressed interest. A website has been developed that can be accessed through www.ieawind.org or www.socialacceptance.ch, internal pages are accessed by a password issued by the OA representative.

4.0 Plans for 2009 and Beyond

Task 28 work will officially start in 2009 and will conduct activities for three years– from 2009 through the end of 2011 (Figure 1). The participants discussed the work plan at the pre-kick-off meeting and agreed upon three work packages.

4.1 Work Package 1: State-of-the-art

• Produce a questionnaire for persons and projects
• Make a list for the Kick-off Meeting to state "Wishes" / "Needs" / "Requirements" and specify relevant projects (existing, planned, or open)
• Collect information on researchers and projects in different countries: Who is doing what
• Create a website and a online library
• Write a State-of-the-art Report
  – The report should have the same structure as in Table 1, except there will be an Introduction (What it is and why we need it), a detailed Description of Task 28, and Definitions.
  – Every chapter should distinguish between "What do we know?" and "What do we want to know?"
• Arrange a 1st workshop with the Support Group
  – Present state-of-the-art report
  – Define open questions
  – Define possible new case studies and research content
  – Evaluate key factors for success and non-success in the siting and micrositing proc-esses

4.2 Work Package 2: Best practice

• Analyse the various projects
• Analyse case studies to determine which strategy leads to the best results
• Compare and evaluate national and regional policy frameworks

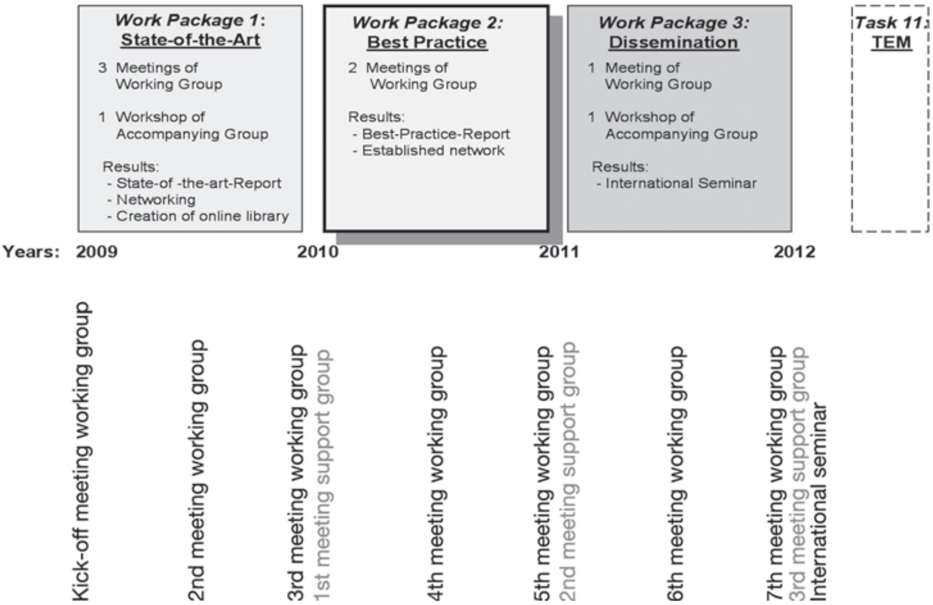

Figure 1 Work plan of Task 28 Social Acceptance of Wind Energy Projects.

• Verify the underlying concept of social acceptance (triangle model)
• Compare and evaluate different participation models ("How to turn affected people into involved parties")
• Understand and describe the concept of "procedural fairness"
• Describe proposed processes and strategies in the fields of:
 – Stakeholder analysis,
 – Participation processes, and
 – Planning procedures
• Write Best Practice Report
• Arrange a 2nd workshop with the Support Group.

4.3 Work Package 3: Dissemination

• Collect existing material on courses, etc.
• Produce manuals and instructions for planners
• Organize an international seminar or workshop in conjunction with the 3rd workshop of the Support Group.

4.4 Next Meetings

The following dates are proposed for the next meetings:

• Kick-off Meeting: 20-21 March 2009 (Magdeburg, Germany), only Working Group
• 2nd Meeting, Autumn 2009, Tentative dates: 26-27 October 2009 (Boulder, Colorado, United States), only Working Group
• 3rd Meeting, Spring 2010 with EWEA Conference, Tentative dates: 20-23 April 2010 (EWWC 2010 in Warsaw, Poland), Working Group and Support Group.

Reference:

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Author: Robert Horbaty, ENCO Energie-Consulting AG, Switzerland

Chapter 10 Task 29

Analysis of Wind Tunnel Measurements and Improvement of Aerodynamic Models

1.0 Introduction

The accuracy of wind turbine design models has been assessed in several validation projects (1, 2, 3). They all show that the modeling of a wind turbine response (e.g. the power or the loads) is subject to large uncertainties. These uncertainties mainly find their origin in the aerodynamic modeling where several phenomena such as 3-D geometric and rotational effects, instationary effects, yaw effects, tower effects, and stall, amongst others contribute to unknown responses, particularly at off-design conditions. These unknown responses make it very difficult to design cost-effective and reliable wind turbines. Turbines behave unexpectedly; they experience instabilities, power overshoots, or higher loads than expected. Alternatively, the loads may be lower than expected which implies an over dimensioned (and costly) design. To improve these models used to design wind turbines the countries and institutes listed in Table 1 have expressed their interest to participate, although some are not yet sure about the availability of funding (4).

The availability of high quality measurements is considered to be the most important pre-requisite to gain insight into these uncertainties and to validate and improve aerodynamic wind turbine models. However, conventional experimental

Table 1 IEA Wind Task 29 Potential Participants in 2009

Country	Contracting Party; Institution(s)
Canada	Natural Resources Canada; École de technologie supérieur, Montreal
Denmark	Danish Energy Agency; RISØ DTU/DTU-MEK, and LM-Glasfiber
Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; University of Stuttgart, University of Applied Sciences, Kiel and Forwind
Japan	AIST; Mie University, and National Institute of Advanced Industrial Science and Technology
Korea	New & Renewable Energy Division of the Ministry of Knowledge Economy; Korea Institute of Energy Research, and Korea Aerospace Research Institute
The Netherlands	Senter/Novem; ECN (OA), University of Delft, TUDelft, and AE-Rotortechniek
Norway	Enova SF; Institute for Energy Technology/Norwegian University of Science and Technology, IFE/NTNU
Spain	CENER
Sweden	Swedish Energy Agency; Royal Institute of Technology/University of Gotland
UK	Department for Business, Enterprise & Regulatory Reform; University of Liverpool
USA	U.S. Department of Energy; NREL

programs on wind turbines generally do not provide sufficient information for this purpose, since they only measure the integrated, total (blade or rotor) loads. These loads consist of an aerodynamic and a mass induced component and they are integrated over a certain spanwise length. In the late 1980's and the 1990's it was realized that more direct aerodynamic information was needed in order to improve the aerodynamic modeling. For this reason several institutes initiated experimental programs in which pressure distribution and the resulting normal and tangential forces at different radial positions were measured. Under previous research tasks of the IEA Wind, many of these measurements were stored in a database in Task 14 Field Rotor Aerodynamics and Task 18 Enhanced Field Rotor Aerodynamics Database (5). The results of these measurements turned out to be very useful and important new insights about 3-D stall effects, tip effects, and yaw were formed. However, the measurements were taken on turbines in the free atmosphere, where the uncertainty due to the instationary, inhomogeneous, and uncontrolled wind conditions formed an important problem (as it is in all field measurements).

This problem was overcome when the National Renewable Energy Laboratory (NREL) National Aeronautics and Space Administration (NASA)-Ames wind tunnel experiment that was carried out in 2000 in the United States (2). In this experiment, a heavily instrumented rotor with a 10 m diameter was placed in the 24.4-m by 36.6-m) wind tunnel and measured with few blockage effects. Although this rotor diameter is still much smaller than the diameter of modern commercial wind turbines, the blade Reynolds number (in the order of 1 million) was sufficiently high to make the aerodynamic phenomena, at least to some extent, representative of modern wind turbines. NREL made the measurements from this experiment available to other institutes and they were analyzed within IEA Wind Task 20 HAWT Aerodynamics and Models from Wind Tunnel Measurements, completed in 2007.

IEA Wind Task 29 MEXNEX(T) is the successor of Task 20. It will use the wind tunnel measurements from the EU project Model Experiments in Controlled Conditions (MExICo) that became available in December 2006 (1). In this project, detailed aerodynamic measurements were carried out on a wind turbine model with a diameter of 4.5 m, which was placed in the 9.5 m2 LLF facility of the German Dutch Wind Tunnel (DNW). Within the MEXICO project, pressure surface data were measured at five radial positions (25%, 35%, 60%, 82%, and 92% span) together with blade root bending moments and tower bottom moments from a tunnel balance from DNW (Figure 1). Perhaps the most important feature of the measurements is the extensive flow field mapping from the stereo Particle Image Velocimetry (PIV) technique.

Although the size of the wind turbine rotor used is smaller, the MEXICO experiments were designed to be complementary with the NREL measurements at NASA-Ames. The most important difference between the two experiments is that the MEXICO project includes extensive flow field measurements, simultaneous with the pressure and load measurements. Also, the MEXICO model was three bladed, whereas the NREL model used at NASA-Ames was two bladed. Furthermore, the majority of the NREL measurements concern (the very important) stalled flow, while the entire operational envelope was covered in the MEXICO measurements. Finally, the MEXICO measurements made use of fast Kulite pressure transducers, which measure absolute pressures, whereas differential pressures were measured in the NREL experiment (both techniques have pros and cons).

The MEXICO database is still in a rather rudimentary form and only limited analyses have been carried out (6, 9, 10). This is the case because the amount of data is vast and the time needed to analyse all

Figure 1 The MEXICO model turbine in the LLF tunnel of DNW. The blue box is the yawable balance and the (vertical) yaw axis passing through the rotor center. The tunnel collector is shown in the background and the nozzle in the foreground. The nozzle measures 9.5 m^2, the collector 9.7 m^2.

data is extremely long for a single country. A cooperative research task under IEA Wind is an efficient way to organize the analysis of the MEXICO data. Added value also lies in the fact that the task will serve as a forum for discussion and interpretation of the results. This will generate more value from the data than the summed value from the individual projects.

In the IEA Wind Task 29 MEXNEX(T), the data will be accessible and a thorough analysis will take place. This includes an assessment of the measurement uncertainties and a validation of different categories of aerodynamic models (rotor aerodynamics and near wake models, where the latter type of models form part of wind farm models as well). The insights will be compared with the knowledge that was gained from IEA Wind Task 20 on the NASA-Ames experiment and from other experiments such as wind tunnel measurements from the Technical University of Delft (7) and FFA (8).

2.0 Objectives and Strategy

The objective of the IEA Wind Task MEXNEX(T) is a thorough investigation of the measurements which have been carried out in the EU-sponsored MEXICO project. Special attention will be paid to yawed flow, instationary aerodynamics, 3-D effects, tip effects, non-uniformity of flow between the blades, near wake aerodynamics, turbulent wake, standstill, tunnel effects, etc. These effects will be analysed by means of different categories of models (computational fluid dynamics (CFD), free wake methods, engineering methods, etc.). A comparison of the MEXICO findings with the findings of the NASA-Ames and other experiments will also be carried out, providing insight on the accuracy of different types of models and descriptions for improved wind turbine models.

In order to reach the objective, the work plan is divided into five work packages (WP):

- WP1: Processing/presentation of data, uncertainties. The aim of this work package is to provide high quality measurement data to the calculational parties. In principle, the data is organized in a self explanatory way but it will be investigated whether some further processing, explanations, corrections, and descriptions are needed. Furthermore, an uncertainty analysis will be performed in the form of consistency checks and an investigation of the reproducibility of the data. The WP also includes an assessment of the blade manufacturing (note that the actual blade shape has been measured). This shape will be compared with the specified geometry.

• WP2: Analysis of tunnel effects. The 4.5 m diameter wind turbine model was placed in the open jet section of the 9.5 m^2 LLF facility. This ratio of turbine diameter to tunnel size may make the wind tunnel situation not fully representative of the free stream situation. Therefore tunnel effects will be studied with advanced CFD models. Supporting information on tunnel effects will also be obtained from eight pressures, which were measured with taps in the collector entrance. These pressures measure the speedup in the outer flow (outside the wake) needed for the mass conservation of the tunnel flow.

• WP3: Comparison of calculational results from different types of codes with MEXICO measurement data. In this WP the calculational results from the codes which are used by the participants are compared with the data from the MEXICO experiment. It is meant to be a thorough validation of different codes and it provides insights into the phenomena which need further investigation (see WP4). The following quantities will be compared:

- Pressure surface data
- Aerodynamic normal force coefficients
- Aerodynamic tangential force coefficients
- Blade root bending moments and tower bottom loads
- PIV flow field data.
- P4: Deeper investigation into phenomena.

In this WP a deeper investigation of different phenomena will take place. The phenomena will be investigated with isolated submodels, simple analytical tools, or by physical rules. Phenomena that will be investigated include 3-D effects, instationary effects, yawed flow, non-uniformity of the flow between the blades (i.e. tip corrections), and the wake flow at different conditions, among other things.

• WP5: Comparison with results from other (mainly NASA-Ames) measurements. The results from WP3 and WP4 are expected to provide many insights into the accuracy of different codes and their underlying sub-models. Within WP5 it will be investigated whether these findings are consistent with results from other aerodynamic experiments, particularly the data provided within IEA Wind Task 20from NREL's NASA-Ames experiment.

3.0 Progress in 2008

A kick-off meeting in September 2008 was attended by interested participants. Although formal work in the task begins in 2009, some interesting results were published in January 2009 (9, 10, 11).

4.0 Plans for 2009 and Beyond

As mentioned in section 3.0, Task 29 started only in September 2008 with a kick-off meeting which was attended by almost all interested participants. At this meeting a detailed time line was discussed. In 2009, the emphasis of the activities will lie on WP1 (Processing/presentation of data, uncertainties), WP2 (Analysis of tunnel effects), and WP3 (Comparison of calculational results from different types of codes with MEXICO measurement data). The time line of the project leads to production of the final report in 2011.

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