IEA Wind Implementing Agreement
Annex XXIV – Integration of Wind and Hydropower Systems

R&D Meeting #1
Meeting Synopsis and Summary

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Executive Summary

This report describes the objectives of R&D Meeting #1, the presentations made at the meeting, and specifically addresses the conclusions drawn relative to the objectives. The main objectives of the meeting were to devise a work plan for 2005-6, work on creating the "Matrix", and to hear project reports from Annex participants. Key outcomes of he meeting include:

- The "twin" Annexes of the Hydropower and Wind Power Implementing Agreements will continue to run in tandem. Meetings will be held jointly and the outcomes of both Annexes will be considered jointly. A joint work plan of the Wind/Hydro and Hydro/Wind Annexes will be created.
- There is significant overlap between Annex XXIV and newly formed Annex XXV on "System Operation with Large Amounts of Wind Power." As is practical, meetings of these Annexes will be held jointly with sharing of information that is relevant to both.
- Excellent progress was made on devising a "Matrix" for use by Annex participants. The purpose of the Matrix is to provide a framework for consistent formulation of case study projects and interpretation and comparison of their results. Over the next half year, the Matrix will be refined and formalized for use by the Annex participants.
- Prior to the next Annex meeting, the web site for the Annex should be completed.
- By the next meeting of the Annex, a "Long Version" of country contributions should be completed (essentially an extended abstract for the projects being undertaken and contributed to the work of the Annex). Once a final draft of the Matrix is arrived at, each participant should complete the matrix as part of their "long version" project descriptions.
- The Annex will meet again either in person or via web conference (to be determined) in approximately six months. It was agreed that an R&D meeting will also be held in September 2006 in Tasmania, Australia.

Introduction & Objectives

The purpose of R&D meeting #1 was to facilitate the collaboration among participants initiated at the Annex Kickoff meeting in February 2005. The IEA Wind Implementing

Agreement (Wind IA) and the Hydropower Implementing Agreement (Hydro IA) both have initiated annexes analyzing the potential for integrating wind and hydropower systems Participants from both annexes came together in this joint meeting for discussion of the collaboration between the annexes, research methods, case studies, and results. The primary purposes of these annexes are to conduct cooperative research concerning the generation, transmission, and economics of integrating wind and hydropower systems, to understand the related social and environmental issues, and to consider simulated water resource, reservoir and wind forecasting. The meeting was held in the spirit of cooperation between the two annexes, with the hope of maximizing the output of each annex by working together. Participants from each annex presented updates from on-going case studies related to wind and hydropower integration, including research methods, assumptions, and results.

R&D Meeting #1 was held in conjunction with the IEA Wind Implementing Agreement Executive Committee (ExCo) Meeting No.56, in Lucerne, Switzerland. The ExCo meeting was held September 27-28, an excursion to the Andermatt wind turbine and Grimsel hydropower station on September 29, and the Annex meeting was held September 30. The objectives of R&D Meeting #1 were as follows:

- Update on the status and progress of the Hydro IA Annex X
- Discussion and decisions on coordination of the Annexes
- Update on the status and progress of the Wind IA Annex XXIV
- Decisions on the Wind/Hydro Annex work plan for 2006
- Update on Wind IA Annex XXV "System Operation with Large Amounts of Wind Power"
- Presentation and discussion of the "Matrix"
- Participant presentations on case studies

Participants

Participants and ExCo members from seven countries attended the meeting, see Table 1.

Table 1– Registered attendees for R&D Meeting #1. The rows with gray shading indicate Wind IA ExCo members and the Hydropower IA Secretary.

	Name	Organization	Country	E-mail
1	* Piekutowski, Maria	Hydro Tasmania	Australia	marian.piekutowski@hydro.com.au
2	* Titchen, John	Hydro Tasmania	Australia	john.titchen@hydro.com.au
3	Molinski, Tom	Manitoba Hydro	Canada	tsmolinski@hydro.mb.ca
4	Oprisan, Morel	Natural Resources Canada	Canada	morel.oprisan@nrcan.gc.ca
5	Holttinen, Hannele	Technical Research Centre of Finland VTT	Finland	hannele.holttinen@vtt.fi
6	* Gjengedal, Terje	Statkraft Energy	Norway	Terje.gjengedal@statkraft.no
7	Tande, John Olav	SINTEF Energy Research	Norway	John.O.Tande@sintef.no
8	Söder, Lennart	KTH, Royal Institute of Technology	Sweden	Lennart.soder@ets.kth.se
9	Russi, Markus	Elektrizitätswerk Ursern	Switzerland	markus.russi@ew-ursern.ch
10	Acker, Tom	Northern Arizona University	USA	tom.acker@nau.edu
11	Sebastian Achilles	GE Global Research - Germany	USA	sebastian.achilles@research.ge.com
12	Estanqueiro, Ana	INETI, Dep. Energias Renováveis	Portugal	ana.estanqueiro@ineti.pt
13	Goldman, Peter	US Department of Energy	USA	Peter.Goldman@hq.doe.gov
14	Hallert, Sara	Swedish Energy Agency	Sweden	Sara.Hallert@stem.se
15	Horbaty, Robert	Enco Energie-Consulting AG	Switzerland	robert.horbaty@enco-ag.ch
16	Nielson, Niels	Secretary IEA Hydropower IA, Kator Research	Australia	nielsen_kator@iprimus.com.au
17	Smith, Brian	National Renewable Energy Laboratory	USA	brian_smith@nrel.gov

* Unable to attend meeting

Presentations

Each person attending the meeting was requested to make a presentation related to the work of the Annex, with the exception of the ExCo members (for whom presenting was optional). Table 2 shows a list of the presenters along with their topic, in the order presented during the meeting. M. Piekutowski from Hydro Tasmania and T. Gjengedal form Statkraft were scheduled to give presentations, but were unable to attend the meeting. All presentations are available to members of the Annex at the website: http://ieawind.org/Annex_XXIV.html.

Table 2 – List showing the presentations made during R&D Meeting #1, including presenter and topic, in order presented.

Presenter	Topic
T. Acker, NREL & NAU	Introductions and Discussion of Agenda
M. Oprisan, Natural Resources Canada	Update on Hydro IA Hydro/Wind Annex
T. Acker, NREL & NAU	Update on the Wind IA Wind/Hydro Annex
N. Nielsen, IEA Hydro IA	Coordination of the Annexes: Wind/Hydro and Hydro/Wind
T. Acker, NREL & NAU	Defining the Annex work plan for 2006
H. Holttinen, VTT Processes	Annex XXV proposal: Operation and design of power systems with large amounts of wind power production
L. Söder, KTH	Modelling approach impact on estimation of integration cost of wind power, plus discussion of Martrix
T. Molinsky, Manitoba Hydro	Qualitative Short-run Value of Wind Energy to Hydro Utilities
T. Acker, NREL/NAU	Update on U.S. projects
J. Tande, Sintef Energy	Planning and Operation of Large Wind Farms in Areas with Limited Power Transfer Capacity
H. Holttinen, VTT Processes	Finland country presentation
R. Horbaty, ENCO AG	Activities in Switzerland
S. Achilles, GE Global Research	Integration of Wind and Hydropower Systems
L. Söder, KTH	Four current Swedish wind power integration projects

Conclusions

The following conclusions were drawn related to the objectives of the meeting:

- Update on the status and progress of the Hydro IA Annex X

  After introductions and confirmation of the meeting agenda, Morel Oprisan made a presentation on the status of the Hydropower IA Hydro/Wind Annex. He summarized the background, objectives, potential participants, and the differences and synergies with the Wind IA Wind/Hydro Annex. The Hydro/Wind Annex X is still a proposed Annex with two prospective members committed, but in need

of four members (by rules of the Hydropower IA ExCo) to become an Annex. One objective of the Hydro/Wind Annex over the next few months is to firm up participation and become and official annex. It was pointed out during this discussion that hydropower owners and operators need to know how to respond to the many requests for wind integration, and that they need answers and specific information about how to consider and carryout wind integration. Answers are needed sooner than later because many requests are mandates to integrate wind energy and compliance is required in the near future.

- Discussion and decisions on coordination of the Annexes

  Because presentation of the Hydro/Wind Annex spurred discussion about the coordination between the two annexes, the order of the agenda was modified and Niels Nielsen presented next. Regardless of the official status of the Hydro/Wind Annex, it was unanimously agreed that the both annexes are studying identically the same problem, and though they have significant overlap between their desired outcomes (e.g., 80%), they do have some differences (e.g, 20%). After some discussion, it was agreed that a joint work plan for the two annexes should be created, stating all objectives and desired outcomes. To the extent possible, and as permitted within the resources and case studies being undertaken by each country, each participant will contribute towards the combined objectives and outcomes, share results, and work together in addressing and arriving at a uniform set of conclusions of the work of the Annex. Responsibility for leading the effort to accomplish each outcome will be assigned to the participants or the operating agent of the appropriate annex. It was also pointed out that the web site for the annex should contain a good public component to assist other interested parties in implementing wind and hydropower integration, especially hydro utilities with a pressing mandate or other desire to do so.

- Update on the status and progress of the Wind IA Annex XXIV

  Tom Acker made a presentation providing an overview of the Wind IA "Wind/Hydro Annex". The essence of this presentation was to provide progress report on the action items identified at the Kickoff meeting of the Annex held in February 2005. The progress report is summarized below:

  - Annex R&D Meeting #1 was planned for September 30, 2005 in Lucerne, Switzerland, in collaboration with meeting hosts Markus Russi and Robert Horbaty. The meeting was held in conjunction with ExCo 56.
  - Create an Annex web site – The web site was created and is currently being constructed. The web site can be accessed at ieawind.org, by clicking on the Annex XXIV "Wind/Hydro Integration" graphic on the IEA Wind splash page (http://ieawind.org/Annex_XXIV.html). The layout for the web site is depicted in Figure 1.
  - Create proceedings from Kickoff Meeting and post on Annex web site. Summary notes completed and to be posted on the Annex web site.

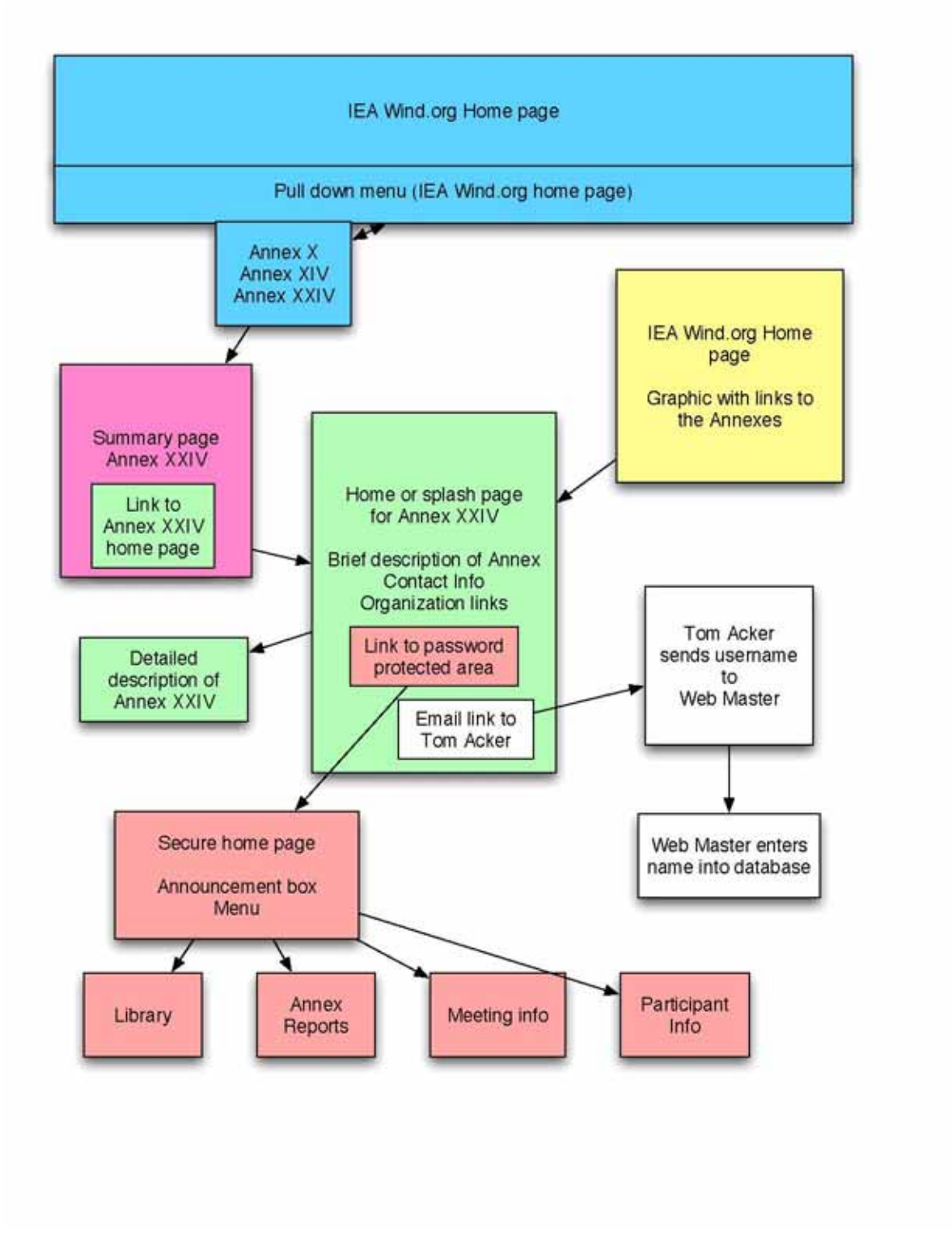

Figure 1 – Layout of the Annex XXIV web site, hosted at ieawind.org (source: Pat Weis-Taylor).

- Obtain commitment letters from remaining three participating countries – Completed.
- Invoice participants for Annex fees – Completed.
- Complete Article 6 of Annex work plan/ proposal ("short version" of country contributions) – Article 6 was completed, and is listed in Appendix A at the end of this report. A summary of Article 6, showing the expected effort and contribution to the case studies by each country is shown in Table 3.
- Kickoff meeting summary and proceedings – Summary notes of the kickoff meeting were created and distributed for comments and editing to the attendees of R&D Meeting #1. The summary notes will be posted on the web site by October 7, 2005. If any comments are received after this date, they will be added and an updated version posted.
- Initiate the "Matrix" – L. Söder published a paper entitled "Modelling approach impact on estimation of integration cost of wind power," at the 7th IAEE European Energy Conference European Energy Markets in Transition, in August 2005. It was proposed at the Kickoff meeting that a "Matrix" be created that will provide a framework for consistent formulation of case study projects and interpretation and comparison of their results. The items described in this paper will be the starting point for creation of the matrix.

- Decisions on the Wind/Hydro Annex work plan for 2006

  Several decisions were made concerning the work plan for the Annex for the remainder of 2005 through 2006. These decisions are all concerned with future activities, and are presented in the "Future Actions" section that follows.

Table 3 – Summary of expected contribution and case studies of each participant, as presented in Article 6 of the Annex XXIV work plan (formerly the Annex proposal).

Country	Effort (man-months/year)	Grid Integration Case Studies	Hydrologic Case Studies	Economic and Market Case Studies	Simplified Modeling	Comments
Australia	6	x	x	x	x	Three to five studies
Canada	4.5	x	x	x		Two studies plus RETScreen
Finland	4-6	x		x	x	Three studies
Norway	4	x	x	x	x	Two studies
Sweden	38-40	x		x		Four studies
Switzerland	3-4	x		x		Two to four studies
USA	6-18	x	x	x	x	Three or more studies

- Update on Wind IA Annex XXV "System Operation with Large Amounts of Wind Power"

  Hannele Holttinen from the Technical Research Center of Finland is the Operating Agent of the newly formed Annex XXV, and made a presentation covering the topics of the Annex and the overlap with Annex XXIV. The overall objectives of Annex XXV are to facilitate the highest economically feasible wind energy penetration within electricity power systems by analyzing and further developing the methodology to assess the impact of wind power on power systems. Because grid integration of wind energy is of key importance to both Annexes XXIV and XXV, there is a significant amount of overlap of topics. Figure **2**, Figure 3, and Table 4, each taken from H. Holttinen's presentation, illustrate the extent of the overlap between annex topics, and the topics to be covered as part of Annex XXV. It was agreed in principle to hold joint meetings of the Annexes when practical. The goal is to avoid duplicating efforts, to maximize sharing of information, to ease the burden of travel on those people/organizations that are members of both Annexes, and to draw consistent conclusions from the broadest base of information and case studies possible.

- Presentation and discussion of the "Matrix"

  It was decided at the Kickoff meeting of the Annex that there needs to be a way to fairly compare and interpret the results from different projects, based on their analysis techniques, assumptions, and completeness. To assist in this process, it was decided that a "Matrix" should be formed that essentially defines the elements of a complete wind/hydro integration study. To this end, Lennat Söder of KTH made a presentation on his paper "Modelling approach impact on estimation of integration cost of wind power," originally presented in Bergen Norway at the 7th IAEE European Energy Conference on European Energy Markets in Transition, August 2005. The content of this paper is being used as the basis of the "Matrix." There were numerous questions and comments during and after his presentation. The main theme of the presentation was to identify the topical categories of the Matrix, which are summarized below (refer to the paper for more detail):

  - Reliability (R)
  - Aim of the study (A)
  - Ways to perform an integration study (W)
  - Location of balancing resource (B)
  - Description of transmission limitations (L)
  - Treatment of uncertainties (U)
  - Modeling of power plant operation (M)
  - Simulation of the power system operation (S)
  - Time resolution (T)
  - Pricing method (P)
  - System design method (D)

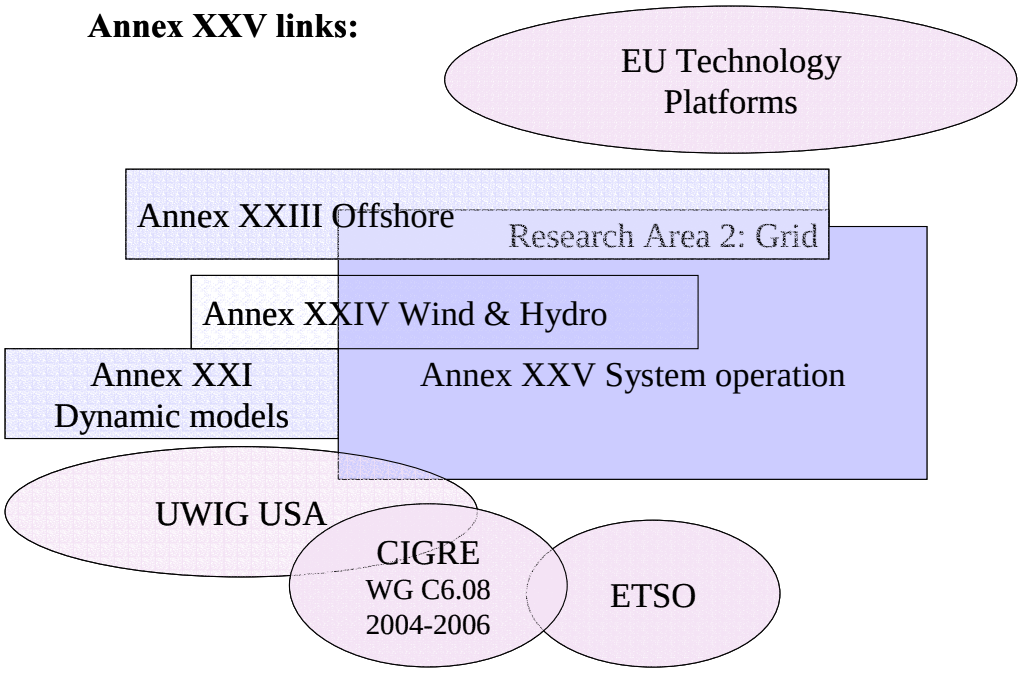

Figure 2 – Links between Annex XXV and other wind integration efforts (source: H. Holttinen).

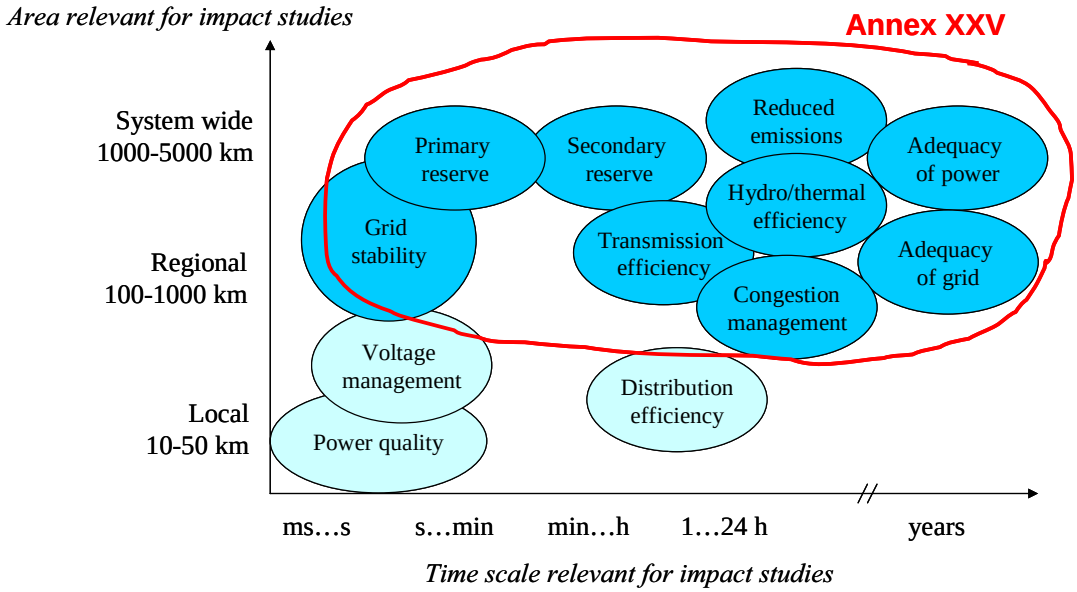

Figure 3 – Possible impacts of wind power on the power system related to studies addressed in Annex XXV(source: H. Holttinen).

Table 4 – List of topics to be addressed by Annex XXV, also showing links with other annexes (source: H. Holttinen).

ASPECT	SUBTASK	DATA AND TOOLS	RESULTS	LINKS
Security of supply	A Reserves and balancing (s-min): Frequency regulation and load following	- Wind and load variations and prediction errors.- Time series analyses for the unpredicted variations.- Grid dynamic model (freq-control).	- increase in primary/secondary reserves - frequency deviations, spinning reserve, effect of (reduced) power system inertia	- Annex XXIV Wind&Hydro
Efficient use	A Balancing (hours-days): Unit commitment. Energy system economics	- Wind and load variations and prediction errors.- Energy system dispatch/planning model.- Economic model for production (incl. grid losses).	- changed profile of use for the conventional power plants (full load hours, ramp rates, half-load operation)- impact on power plant losses/efficiency - emission savings - energy system optimisation	- Annex XXIV Wind&Hydro
Adequacy	B Adequacy of power and energy	- Reliability data of production units during peak load situations. - Supply / demand patterns. - Reliability model (LOLP).	- effect of large scale wind power on system adequacy in times of peak loads- capacity credit /value of wind power to the system	- Annex XXIV Wind&Hydro
Adequacy and efficient use of grid	C Grid: Steady state operation	- Wind farm aggregate model (power source). - Supply and demand patterns. - Grid load flow model.	-grid reinforcement measures - impact on bottlenecks and cross-border trade- impact on grid losses and efficient use of grid investments	- Annex XXIV Wind&Hydro- Annex XXIII Offshore
Security of supply	C Grid: Transient stability	- Wind farm models (detailed) - Requirements for wind power plants in grid codes. - Grid dynamic/transient model.	- impact on system stability, damping of power oscillations and system eigen values- means to increase system support ability	- Annex XXI Dynamic Models

A summary of the key points made during presentation and discussion of the matrix are provided below (note the letters identifying each topic are provided in the list of topical categories above):

- Topic W: add W4 – Estimate how the actual system being studied will respond to integrating wind energy, with all of its constraints and any economical inefficiencies that may exist (e.g., due to laws or regulations, etc.). This is an alternative to W3, which considers how an economically efficient system should be configured to accommodate new wind energy.
- Topic B: add point B4 – Need to identify the system and what is causing the imbalance, as well as "what" is being balanced. For example, is the entire system load plus the wind being balance, or some subset of the system load, etc.
- Topic U:
    - Add U7 – Load uncertainty
    - Add U8 – Uncertainty in hydro and other generators
    - Some consideration needs to be given to the assumptions relative to the time frame of the study. E.g., different assumptions may be applied during study of different time frames (e.g., regulation vs. capacity calculations).
    - Add to U5 or U6, or add another U – consider regional wind forecasts
    - Add U9 – Alternative method; allow an alternative method than those in the list (U1, U2, etc.) to be used; the alternate method must then be described with comments defining the technique
    - Modify U6 – "best available" should be change to "most economical"
- Topic M: This topic should deal only with thermal plants
- New Topic on hydropower modeling – A new topic should be added that deals only with hydro plants. This topic should cover all relevant aspects of hydropower operation including hydrological considerations, constraints due to environmental issues, seasonal supply issues, laws and regulations, etc.
- New Topic on wind plant modeling – A new topic should be added dealing specifically with wind plant modeling. For example, how is the proposed wind plant output being modeled, what is the nature of the data sources used in the model, etc.
- Topic S: general comments –
    - "deterministic" means you know your wind plant production
    - "stochastic optimization" takes too much time, though nice
    - Need "stochastic optimization" if studying capacity, but if looking for reserve limits then deterministic approach is okay; assumptions or technique depend on what you are trying to determine.
    - Studies are frequently small in scope and focused on certain aspects, and consequently don't require a full integration study

- General comments from discussion:
    - As part of one of the topics, perhaps hydropower or system simulation, etc., the method of integrating wind and hydropower should be described. For example, real-time integration of wind energy vs. a storage and shaping product.
    - The planning horizon considered in the study should be defined within one of the matrix topics.
    - H. Holttinen had several good ideas about how to add new topics and assign new letters to represent the topic; she will work with L. Söder on this.
    - Perhaps add a new chapter to deal with non-monetized "external impacts." For example, what are the impacts of wind development on environmental issues, carbon emissions, hydrological operations, etc.
    - Should put "losses" in the system somewhere in the matrix topics
    - L. Söder and H. Holttinen will come up with the next revised version of the Matrix.
    - The Matrix should be completed for all Annex studies; identify what is excluded in the study and why.
    - It would be of some value to suggest the scope of appropriate assumptions. E.g., "one does not need to look at voltage stability when the goal of the study is …"

Future Actions

The following tasks were identified as future actions for the Annex:

- ***Create a joint work plan of the Wind/Hydro and Hydro/Wind Annexes***, stating the objectives and desired outcomes. Responsibility for leading the effort for each outcome will be assigned to the participants or the operating agent of the appropriate Annex. (Responsible: Acker/Oprisan)
- ***The web site needs to be completed and kept updated***. User names and passwords for the password protected area of the web site need to be issued to Annex participants. The summary notes from the Kickoff meeting will be posted on the web site by October 17, 2005. (Responsible: Acker)
- ***Refine and formalize the matrix for use by Annex members***.
    - Any comments or suggestions on the matrix by meeting participants should be sent to L. Söder by mid-October. (Responsible: All)
    - L. Söder will revise the Matrix and send to H. Holttenin by Oct. 31, 2005. (Responsible: Söder)
    - H. Holttenin will futher refine the Matrix and submit to Annex members a final draft for consideration, by Nov. 31, 2005. (Responsible: Holttenin)
- ***"Long Version" of country contributions*** (due by next meeting of the Annex)
    - Each participant will submit "long versions" of their contributions to the Annex. In essence, a "long version" is a description of each separate

project being undertaken, similar to an extended abstract, which provides a high-level overview of the project. (Responsible: All)
    - Once the final draft of the Matrix is received by the Annex participants (December time frame), the Matrix will be completed by each participant for each project(s). (Responsible: All)
- ***Plan the next meetings of the Annex***, by October 31, 2005. The next meeting will be held in approximately six months, possibly less, and will be either a face-to-face gathering or a web conference.
    - Investigate the possibility of a web conference and report to participants. (Responsible: Acker)
    - Plan the next meeting. (Responsible: Acker/Oprisan)
- ***Plan a meeting of the Annex for September 2005 in Hobart Tasmania***, to be hosted by Hydro Tasmania. (Responsible: Acker, Piekutowski, Titchen)

APPENDIX A

Article 6 of Annex XXIV Proposal/Work Plan

6 Obligations and Responsibilities of Participants

In addition to any obligations listed in Article 7 of the Agreement:

(a) Each Participant shall bear its own cost for the scientific work, including travel expenses to Annual Research Meetings of the Annex;
(b) The host country shall bear the costs of workshops, meetings of experts, and Annual Research Meetings of the Annex including the Kickoff Meeting;
(c) The total costs of the Operating Agent, as specified in Article 8, shall be borne jointly and in equal shares by the Participants;
(d) Each Participant shall transfer to the Operating Agent its annual share of the costs in accordance with a time schedule to be determined by the Participants, acting in the Executive Committee;
(e) Each Participant shall collect and submit national statistics and other relevant information, especially as related to wind and hydropower resource potential and generation;
(f) Each Participant shall submit presentation materials and reports presented at the Annex Research Meetings to the Operating Agent for formation of proceedings, the format which shall be agreed upon by the Participants;
(g) Each Participant shall participate in the editing and review of the proceedings from the Annual Research Meeting, the Kickoff meeting, and the Annex Final Report.
(i) The individual Participants propose to carry out the tasks described below:

Australia *Hydro Tasmania, contribution 6 man-months/year*

Grid Integration Case Studies: Three study cases will be developed to demonstrate integration issues pertinent to a small system. The focus of work will be on identification requirements for minimum system inertia, minimum fault level, fault ride through, minimum system support services provided by hydro generators) and costs related to integrating wind and hydropower resources.
Hydrologic Impact Case Studies: A demonstration study will be provided to analyze impact of additional wind generation on spill and water flow changes due to different operating regimes.
Market and Economic Case Studies: A study case pertinent to Australian market design will be provided. Analysis of market rules and their adequacy for wind generation will be provided as well as identified market rule changes required to maximize wind penetration.
Simplified Modeling of Wind-Hydro Integration Potential: A modeling technique for estimating wind and hydropower integration potential for a given hydrological network and a simplified transmission grid will be developed. The work will be

based on the existing Temsim model used for analysis of energy capacity based on hydro inflows. The model will include some features of Australian market.

Canada *Natural Resources Canada, Manitoba Hydro, Total contribution 4.5 man-months/year*

Grid Integration Case Studies, Hydrologic Impact Case Studies, and Market and Economic Case Studies:

Canada has a large hydro electricity resource base and some 65% of the country's electricity is generated by hydro power plants. Some provinces, such as British Columbia, Manitoba and Quebec get almost all their power generation from hydro resources. Installation of large wind farms has recently increased significantly and we now have about 600 MW installed capacity, while over 5000 MW are expected to be installed by 2010. This creates an ideal situation for wind/hydro integration which will benefit the hydro and wind industries, as well as the power utilities involved. Of interest are the grid stability and grid management problems related to integrating wind energy.

Some work is now being done and the results of this work will be shared with the Annex members. RETScreen is one such activity, performed by federal government laboratories owned by Natural Resources Canada. By integrating wind energy and hydro energy modules, Version 4 of RETScreen® will include a "storage and shaping" option for wind projects. The option will account for the cost and revenues associated with projects where a hydro utility can offer the storage and shaping service to a wind developer. Wind developers will benefit because it provides a means to quickly evaluate the financial impact of storage and shaping services on their wind projects, taking into account increased costs (storage & shaping service) and increased revenues (stored and shaped energy sales).

Manitoba Hydro, the power utility in the Province of Manitoba, has been involved in a variety of studies on the issues, consequences, benefits and problems affecting their hydro-supplied power grid as more wind farms are being built and connected to the provincial power grid. Manitoba Hydro is involved in the Hydro-Wind Annex and making periodic presentations sharing their findings with other Annex members and with the members of the Wind-Hydro Annex.

Hydro-Quebec, a large hydro power utility, covering the Province of Quebec, is planning some 2500 MW of wind power by 2010. The utility has now been studying the implications and the effect the higher penetration of wind energy will have on their hydro-powered grid.

Finland VTT *Technical Research Center of Finland, Helsinki University of Technology, contribution 4-6 man-months/year, including input from companies running case studies*.

Grid Integration Case Studies and Market and Economic Case Studies: Finland has three case studies that will contribute mostly to grid integration and market subtasks. One case study is for a power company, scheduling hydro power in one river system and building wind farms along the coast of Finland. Two case studies are for the Nordic electricity market, but focusing on impacts of wind power on Finnish hydro power. These case studies are for two different models, with weekly and hourly time resolution.

Simplified Modeling of Wind-Hydro Integration Potential: In addition to case studies, there will be a M.Sc work performed at Helsinki University of Technology on the simplified modeling of wind-hydro integration potential starting late 2006.

Norway *Sintef Energy Research, contribution ~ 4 man-months/year*

Grid integration case studies: A minimum of two case studies will be developed, i.e., one study on a local / regional system and one study on the national system. Key issues to be considered are production management, wind power fluctuations and hydropower regulation capabilities.

Hydrologic impact case studies: The local case study will consider hydrologic impact in terms of reservoir management, river flows and the impact from hydro constraints on the interplay between wind and hydro.

Market and economic case studies: The case studies on grid integration will alsoconsider market and economic issues, i.e., markets for imbalance management, reserves and ancillary services,

Simplified modeling of wind-hydro integration potential: Existing software tools will be used, but supported with additional developments as required.

Sweden KTH *Royal Institute of Technology, Division of Electric Power Systems, contribution 38 to 40 man-months/year (L. Söder and three full-time Ph.D. students), plus input from companies running case studies*.

Grid Integration Case Studies / Market and economic case studies:

In Sweden there is currently a large project concerning integration studies of 4000 MW of wind power. The main objective with of the project is to describe possible impact from an increasing amount of intermittent wind power generation on the Swedish Power System regulation and reserve requirements. A final report will be available during autumn 2005 and a possible extension is under discussion.

Wind power in areas with limited export capabilities – In the actual area it is assumed that there is wind power, other power sources e.g. hydro power and also a load. Within the project the following items are planned to be covered concerning managing of congestion situations: Which methods can be used within a deregulated framework to make hydro power owners interested to balance wind power? How will uncertain wind speed forecasts affect the possibilities to balance wind power with hydro power? How can grid tariff construction affect the interest of hydro power owners? What are the possibilites to use pumped storage in the

hydro system to balance wind power? Can grid extensions also be motivated by the interest to use hydro power as reserve power?

Hydropower bidding model under significant uncertainty – When the amount of wind power increases in the power system, the uncertainties in the short time operation planning will increase. At KTH we develop models for how to bid power both on the day-ahead market and on the regulating market when the amount of uncertainties, caused by wind power, will increase.

Frequency control in a system with large amounts of wind power – When the amount of wind power increases the Transmission System Operator, the TSO, will face a larger challenge, since the imbalances (and thereby the frequency) will increase. One important question is then at which level of wind power it is necessary for the wind power to participate in the balancing. At KTH we develop a model that comparatively detailed simulates how the TSO will keep the balance in the system with a larger share of wind power. The aim of the model is to minimize the imbalance costs for the TSO.

Switzerland *Elektrizitätswerk Ursern (EWU), 2-3 man-months/year*

Grid integration case studies: (1) Test and evaluation of an existing integrated wind-hydro system, based on the EWU-owned hydro power plants and wind turbine. (2) Optimization of the automatic hydro power plant control system, based on the evaluation of the recorded operating data.

Market and economic case studies: (1) Economical optimization of the wind-hydro system taking into account the market data of the EEX (European Energy Exchange) and the local wind forecast. (2) Feasibility and economical study of the upgrade of the existing storage power plant to a pump/storage power plant. Modeling and optimization of the integrated operation of the pump/storage power plant and the wind turbines.

United States *National Renewable Energy Laboratory* (*NREL), contribution 6-18 man-months/year*

Grid Integration Case Studies: The US will develop a minimum of three case studies that analyze the grid integration issues and costs related to combining wind and hydropower resources.

Hydrologic Impact Case Studies: At least one of the case studies will consider hydrologic impacts in detail.

Market and Economic Case Studies: Each case study conducted will consider the market and economics in order to demonstrate economic viability and the effects of market structure.

Simplified Modeling of Wind-Hydro Integration Potential: A simplified modeling technique for estimating wind and hydropower integration potential on a given transmission grid will be developed. Riverware software will likely be the tool used in implementing the modeling technique.