POW WOW Virtual laboratories and best practice guides for the prediction of Waves Wakes and Offshore

Gregor Giebel, Rebecca Barthelmie, Torben Skov Nielsen, Georges Kariniotakis, I.M. Perez, I. Sanchez, Julio Usaola, Lueder V. Bremen, Abha Sood, Jens Tambke, et al.

POW'WOW – Virtual Laboratories and Best Practice Guides for the Prediction Of Waves, Wakes and Offshore Wind

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***Abstract*-- This paper describes a new project trying to harmonise approaches to wave and wind modelling offshore, helping the short-term forecasting and wake research communities by establishing virtual laboratories, offering specialised workshops, and setting up expert groups with large outreach in the mentioned fields.**

Currently, a good number of research projects is underway on the European and national level in the fields of short-term forecasting of wind power, offshore wind and wave resource prediction, and offshore wakes in large wind farms. The leaders of those research projects are assuming the function of a multiplier towards the larger research and user community. In the fields of short-term forecasting and offshore energy resource, Expert Groups will be formed to act as the central focus point for external stakeholders. The liaison with other groups will also include groups outside of Europe.

To facilitate the spread of knowledge, a number of workshops is planned. One of them took place just before this conference on the topic of best practice in the use of short-term forecasting systems, where utilities with a combined experience of over 50 years and a combined wind power installation of over 30 GW could share their experiences and views on the best use of those systems. A preliminary overview of the resulting best practice guide will be given.

One issue hampering the progress in our fields is the difficulty of getting access to good data. In most cases, data on offshore wind or power is strictly confidential, and also data on onshore wind power, especially in conjunction with numerical weather predictions, is not easy to come by. One example of a good testing procedure comes from the Anemos project, where in all 6 test cases were defined, to be run by all involved institutes. This idea is taken to the next level with the set-up of two Virtual Laboratories, one for offshore wake modelling, the other one for short-term forecasting. Both laboratories will be well-defined and maybe already open for business by the time of the workshop.

***Index Terms*—Meteorology, Wind Energy.**

I. Introduction

THE POW'WOW project (Prediction of Waves, Wakes and Offshore Wind, a EU Coordination Action) focuses on improving both wind and wave predictions from short-to-resource timescales by integrating modelling approaches currently used by the communities separately. It has been described on a previous conference [3], and more description is available from the website powwow.risoe.dk. There will be no model development but rather coordination of results from existing and previous projects and dissemination of information about state of the art in the different fields. The major issue is to try to bridge the gaps in spatial and temporal scales, which currently divide the wind and wave resource and the short-term forecasting modellers. This will happen mostly on a workshop, tentatively scheduled for winter or spring 2008 in Oldenburg.

While wind energy resource predictions are typically made at the site level with linearised models or statistical methods, wave energy predictions are more likely to be large scale based on numerical models (physical methods). Clearly though the physical links between wind and waves (heat and momentum transfer) exist and we will need to work with weather forecasters also to complete a thorough review of the methods used and how these can be better integrated. In addition to organising an offshore meteorology workshop we

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will establish and extend the expert group by organising a scientific session at a European conference (likely the European Geophysical Union annual conference). Uncertainty is a key factor in wind farm financing and the inventory made as part of the review will used to identify areas for future research. The major benefits will better integration of modelling approaches for resource prediction and a more harmonised approach.

The project will link between networks funded by the EU including Wavenet, WindEng and others which do not focus on the resource, such as CA Ocean Energy and COD (CA on Offshore Wind Development). It will utilize also elements from other EU funded projects like ENVIWAVE.

The core of the short-term prediction work package is to support research by helping with development of the models by furnishing a Virtual Laboratory, where other modellers can try their models on the same footing with everyone else, using identical data. Additionally, we will enhance the outreach of the short-term forecasting community through the set-up of an Expert Group for short-term forecasting, trying to work closely together with the Commission and other European and world-wide stakeholders. Resources are earmarked for visits to interested parties to disseminate the state of the art in short-term forecasting inside and outside of Europe. This group also is to co-ordinate and disseminate results obtained in national projects, to try to avoid overlap of effort, but also to make sure that all researchers in the field are aware of the latest developments and research results. This includes evaluation of the input data for models, not only trying to disseminate the latest efforts within the meteorological community to the modellers, but also by sensitising the meteorological community to the higher accuracy demand of this particular customer of their data. At the other end of the data flow, the use of short-term predictions on the clients' side can be improved upon by establishing some guidelines of best practice in their use. These practices will first be devised in close conjunction with current users of predictions, and then will be distributed to a larger audience through training courses and a separate workshop, and dissemination activities on conventional energy conferences and in power industry journals. This would have the side benefit that utilities with low exposure to wind power will be able to work constructively with wind, and not completely reject wind power on grid stability grounds.

A major issue here is not just the long-term forecasting of average wakes which is used for initial estimates of power output from wind farms (mainly for planning and financing) but also the online prediction of wakes that links with short-term forecasts of power output from wind farms. The current approach is mainly a sector (wind direction)/wind speed prediction of wake losses in the form of a lookup table. However, given the complexity of wake losses within wind farms including wake turning within the wind farm this approach is likely inadequate. Introducing online wake models adds a degree of complexity and many wake models (CFD type) are likely too computationally intensive to be considered. Scientists and engineers will work together to consider how short-term forecasting and wake modelling can be operationalised. The work will take the form of wake case studies via a Virtual Laboratory, an open workshop for scientists and engineers and finally a set of guidelines for best practise in including wake models in short-term forecasts.

II. Planned and Executed Work

In a practical context the work proposed is based on:

- setting up of expert groups
- reviews of existing projects and results
- integration of results across sub-sets of the same disciplines
- set-up of Virtual Laboratories to facilitate benchmarking of models
- workshops to discuss integration and to disseminate results beyond the project

The success of the project relies on the integration of a group of international experts furthering their cooperation and disseminating their results.

A quite important step for the project is the removal of barriers for the larger scale implementation of our techniques, and of renewable energies in general. Some of these barriers are more technical, like the relatively high uncertainty in the offshore wind resource estimation due to limited knowledge of the wind flows offshore, some are more a mindset, like the perceived lack of usefulness of short-term forecasts to utilities due to the limited accuracy obtainable. The technical barriers will benefit indirectly from the project, by connecting existing knowledge and co-ordinating the acquisition of new knowledge. The non-technical barriers can be tackled more directly, aiming for example directly at utilities with low penetration of wind power to convince them of the good experiences high-penetration utilities have made with short-term forecasting. One barrier for technical development is the lack of good quality comparison data, on which to hone the models. This will be taken care of by the establishment of two Virtual Laboratories, one for short-term forecasting, the other one for wakes.

A. *Virtual Laboratory for Short-Term Prediction*

The idea of the Virtual Laboratory (ViLab) is in part, to take some of the cumbersome work of data acquisition out of the research projects themselves and put it here, and in part to have common evaluation criteria and common evaluations of the work, being able to compare one's own research with the best (and worst) in the field. This idea is somewhat modelled after two very successful efforts, one being winddata.com and the other one the Anemos case studies and benchmarking process. In winddata.com, quality checked measurement campaigns (of usually short duration) were put into a central repository in a common data format, so that institutes that have signed up to it can download the data and use it. The data spans 165000 hours from 57 sites, and is used for many different purposes ranging from resource assessment (the data of the Horns Rev meteorological mast is there) to structural high-resolution measurements on actual wind turbines for load cases. The other case to model it on is the Anemos benchmarking exercise, where in all 11 different models were fed with the same NWP data for 6 wind farms in Europe. One institute (CENER) did the common evaluation, and presented the results in London on the EWEC conference in November 2004 [4]. One important part for this was the development of a common evaluation procedure and common evaluation criteria, which IMM led [1]. The details of access to data, the potential worries of the data owners (wind turbine data and NWP) against making their data public, and the exact demands to publication from ViLab participants will have to be decided during the set-up of the ViLab.

Nowadays, a number of research institutes or companies develop models for short-term wind power forecasting. However, evaluation of such models depends on the test-case and its characteristics such as complexity of the terrain, spatial and temporal resolution of Numerical Weather Predictions, Measurements etc. A high number of approaches are reported today also from the side of Weather Prediction Systems. As a consequence it is very difficult to make cross-comparisons by different prediction systems and take decisions on the optimal ones to implement operationally.

The latest news is that the ViLab has been designed, including the following aspects:

- Wind farm selection.
- Database characteristics (to be populated after the agreement with wind farm owners).
- Data format.
- Evaluation of NWP and power production forecasts with training and validation periods for the statistical models that guarantee a reliable comparison of results.
- Analysis of results with standard criteria.
- Confidentiality restrictions.

The contacts for the agreement with the wind farm owners to populate the databese are actually under development. After the completion of the database the ViLab will be published and launched.

B. Virtual Laboratory with Cases of Offshore Wakes

Initially, the aim of this Task is to evaluate the state-of-the-art on wake modelling. The Task will give emphasis on models and evaluation results reported in the bibliography and from ongoing national or EU research projects. A major issue at present is that offshore resource and wake data (SCADA) is mainly commercial which can make further model development and evaluation difficult. Data from smaller wind farms such as Vindeby and Middelgrunden are available and will be provided. In order to address the problem of wake studies in large offshore wind farms the partners will identify test cases and request data for Horns Rev, Nysted and any other wind farms which are erected during the project. The data will be converted to common formats. The form of the Virtual Laboratory will be based on input from modellers in order that the input data and the results are displayed and available for all partners. The partners of the Task will assess then the outcome from the ViLab activities related to wakes. This Task will provide also documentation that will be accessible through the ViLab.

Since the project was funded two other activities have also started under the UPWIND EC funded integrated project and through the International Energy Agency Offshore Wind Energy Annex 23 which is holding a workshop on wake modelling and measurements in Billund in Septmber 2006. A representative from POW’WOW was present at the meeting and initiated a joint wake model benchmarking activity between the three projects.

C. Best Practice for the Use of Short-Term Prediction

Thomas Ackermann has an interesting classification of utilities with regard to wind power penetration [2]: When the penetration of wind power is very small, utilities tend to ignore it. When the penetration grows to a point where it can be felt in some special situations in the power system, many utilities panic and declare a total stop of new installations, until the get more acquainted with the peculiarities of wind power. The third group is using tools for the administration of wind power in the power system, is adjusting their grid codes and procedures and is looking towards the best practice of handling the large penetration. In the last group, which for the time being is very small, the utilities actively use research and development in-house and with external contracts to be able to integrate wind power better, and to increase the penetration of wind power, to more than the occasional 100% wind power in the grid.

In the above classification, it is important to help utilities over the hurdle of stage 2, and for utilities in class 3 aiming at optimization of their procedures to an exchange with other utilities of the front-runner groups. To this aim, a workshop is organized on October 25, 2006, in Delft (The Netherlands), with the explicit aim of delivering a platform for those in the utility world having plenty of experience with short-term forecasting to share experiences and tricks among themselves. It also will be targeted towards utilities only now getting sizeable contributions from wind energy, bringing them into contacts with utilities who already have mastered that stage. In short, it is going to be by utilities for utilities. The experiences gathered here will be used as input for a Best Practice Guide, to be published by the POW'WOW project. The target group are TSOs, people involved in trading wind power or scheduling power plants, or scheduling maintenance on conventional or wind power plants.

D. Wind Resource Model Benchmarking

Although there is significant experience in offshore wind and wave resource modelling in the European arena, the increase in expertise has been more than matched by a demand from financing institutions for accuracy and quantified uncertainty in resource predictions for new wind and wave power plants. The work will focus on a study of methods for quantifying uncertainty and in identifying areas where increased resources for research would bring pay-back in terms of reduced uncertainties in resource/power prediction. Here, we will focus on the exchange and dissemination of good practice to reduce uncertainty in resource modelling. In wind energy there are two fundamental approaches to offshore resource modelling: one is physical modelling (e.g. linearised models such as WAsP, mesoscale models such as MC2, KAMM, MM5, WRF, SKIRON/Eta, RAMS), and the other one is stochastic/statistical, such as one of the several variants of a Measure-Correlate-Predict technique, or Kalman filtering. Although these are commonly used for prediction from onshore data to offshore resource, there are two major issues, which have not yet been addressed. One is that in the near-coastal zone (of the order <50 km to the coast where all current offshore wind farms are at present planned/installed) the underlying assumption of equilibrium conditions is violated leading to over-prediction of the resource. The second is the MCP methods tend to under-predict the offshore wind resource because they do not account for the shift in the wind speed distribution in offshore areas. For both issues, advanced downscaling techniques in operational numerical weather prediction modelling can be applied – thanks to cheap computer power available today (RAMS modelling can be operational with grid spacing of a few hundred or tens of meters). Benchmarking will utilise the most common approaches and attempt to identify what the uncertainties are associated with each method: how they are propagated through the methods, where they are largest and where they might be reduced. The benchmarking activities will be supported technically by the ViLabs developed in WP-2 and 3. Wave analysis and forecasting is a must for both systems (offshore wind farming or wave energy utilization), especially in the coastal zone (<50 km). Wave modelling together with the utilization of satellite data (ASAR and RA-2) is a new technique that developed at the framework of ENVIWAVE project with promising results. The utilization of the integrated system developed at the framework of this project (SKIRON/Eta and/or RAMS atmospheric models coupled with the WAM –wave analysis and forecasting - model and the assimilation of altimeter and wave spectra data) will be exploited for energy production.

In wave energy, the accuracy of wave forecasts using data assimilation (buoys and remote sensed data) is very good. This accuracy is now limited by the quality of the input wind fields at the ocean surface; therefore, the improvement of wind fields over the ocean basins will result in better quality of the predicted offshore wave conditions. In the coastal area within the 50m+ water depth, where offshore wave power plants are deployed, the most important source of spatial variability is shelter by the coastline and/or the presence of islands. Enhanced prediction of plant performance in general requires further development of mathematical models. Short-term (wave to wave) resource time variability needs to be taken into consideration to enable better prediction of produced power. A joint position paper is currently under development.

E. Workshop on Integration of Wind and Wave Resource Modelling

The physical processes in the marine atmospheric boundary layer and its interaction with the wave field in the coastal zone is the underlying common background for wind and wave resource modelling. The workshop will focus on this common scientific background and will give each of the two (wind and wave) communities insight in the models used by the other one for the same processes, namely the momentum and heat transfer between air and sea. Understanding of the different perceptions and approaches taken by the two groups is a prerequisite for a successful integration of wind and wave resource modelling. We will also need to include experts from the meteorological communities to integrate the state of the art in wind and wave predictions for weather forecasting. The workshop is currently planned to take place during the European wave and tidal energy conference in Portugal 2007. A further linking activity, organising a session at for example the European Geophysical society meeting in the Energy and Environment Section under Wind Energy (this is currently waiting for confirmation).

The approach taken here will try to draw the communities together by establishing a common understanding of the scientific background and harmonisation of the best practice in resource modelling. The workshop will be open to all participants. Funding is requested to provide travel grants to participants from less favoured regions from EU member states, especially NAS states, but also for others including Ph.D. students.

F. Workshop on Integrating Wake Models into Short-Term Forecasting Models

Wake modellers have tended to work mainly either within the CFD/aeroelastic design fields or in resource modelling leaving a gap at the short-term forecasting time scale. We will open the workshop to participants from all EU countries and offer travel grants with a preference to NAS researchers. The workshop will focus on the test cases from the virtual laboratory and drawing up guidelines for good practice for integrating wake and short-term forecasts. The workshop is intended to be the major dissemination forum for these results (beyond the virtual laboratory web site) and we will solicit a special issue of Wind Engineering for the papers presented.

This activity will also lead to a definition of the best practice guidelines for the integration of wake models into short-term prediction models. Since we intend a major result of this WP to be an improvement in the state of the art in wake modelling in short-term forecasts we will need to demonstrate that on-line wake models give better results than the ‘look-up table’ approach currently used. The guidelines will outline approaches that can be used with both physical and statistical methods of short-term forecasting and describe conditions under which the largest errors in wake prediction are to be expected. The guidelines will be made publicly available for comment before being finalised.

III. Conclusions

The POW'WOW project supports activities in the area of offshore energy meteorology and short-term prediction with various activities. Among them are Virtual Laboratories for model benchmarking and model development in the areas of offshore wind and wave, of wakes, and for short-term forecasting of wind power. Other activities include workshops and training for researchers in offshore meteorology, but also for engineers in the control rooms of utilities with high wind power penetration. These will be open to third countries, with supplemental funding for NAS and developing countries.

Last but not least, Expert Groups are founded with the intent to increase visibility of the field, not the least in respect to policy development and an influence on the research agenda.

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V. Biographies

Gregor Giebel was born in Wiesbaden in the Federal Republic of Germany, on October 24, 1968. He graduated from the Technical University of Munich, with a research stay for the thesis at Trento University, and received a PhD from Oldenburg University during his work at Risø.

He started work in wind energy at Risø National Laboratory as an external PhD student, and is now there as a senior scientist. He manages the Zephyr/Prediktor short-term forecasting tool, is involved in projects on Condition Monitoring for wind turbines, including the IEC Technical Committee 88, and is interested in the large-scale integration of wind energy in continental energy grids.

Rebecca Barthelmie is the Ewart Farvis Chair of Renewable Energy at IES and was formerly a senior scientist in the Wind Energy Department at Risø National Laboratory, Denmark. She is an international expert with more than 15 years experience in predicting wind resource in offshore areas.

She has managed many commercial projects for determining offshore wind resource/power output in the UK, Sweden, Poland and Denmark. She recently coordinated the EU project Efficient development of offshore windfarms (ENDOW), is a principal investigator on two Danish projects to model and analyse data pertaining to wind turbine wake development within and downwind of large offshore wind farms and leader of the Flow Workpackage within the EU Integrated Project UPWIND. She is author/coauthor of 78 papers in refereed journals.

Torben Skov Nielsen was born in Odense in Denmark on December 26, 1963. He studied Control Systems at the Technical University of Denmark followed by a Ph.D. on the topics statistical methods for prediction and control of non-linear stochastic systems.

He was employed at the Technical University of Denmark in 1993 where he currently holds a position as Associate Professor. He has more than 15 years experience with on-line application of mathematical models and has worked with forecasting of wind energy in more than 13 years, where he has been the main responsible for the development of WPPT - a on-line tool for prediction of wind energy.

In March 2006 he started his own business as part owner and managing director of ENFOR A/S – a spinoff company from the Technical University of Denmark providing solutions and services related to forecasting and optimization in energy systems.

George N. Kariniotakis was born in Athens, Greece. He received his Engineering and M.Sc. degrees from the Technical University of Crete, Greece and his Ph.D. degree from Ecole des Mines de Paris in 1996.

He is currently with the Center for Energy and Processes of Ecole des Mines de Paris as a senior scientist. He is the scientific and technical coordinator of the EU projects Anemos and Anemos.plus on wind power forecasting. His research interests include among others renewable energies, wind power forecasting, distributed generation and artificial intelligence. He is a member of IEEE and of the Technical Chamber of Greece.

Ignacio Marti was born in Madrid in 1971. He studied physics at the University Complutense of Madrid being specialised on atmospheric physics.

He started working at Ciemat in 1994 in the wind energy department. The main area of work was site resources assessment in complex terrain, participating in numerous projects for private and public companies as well as European R&D projects in this field. In 2001 he became head of the wind resources assement unit until 2003. After Ciemat he joined the Renewable Energies National Center (CENER) as head of Wind resources assessment and forecasting Service. The main expertise is in the development and operation of power prediction models for wind farms and site assessment studies.

Ismael Sánchez was born in Madrid in 1964. He has Ph.D in Industrial Engineering from Universidad Carlos III de Madrid. He is Associated Professor in the Department of Statistics of Universidad Carlos III de Madrid.

His main research interest is the modelling of dynamic systems, and has published scientific articles in leading statistical journals as JASA and Technometrics. He has been working in the development of the wind power prediction tool Sipreólico, which is running operational at the control room of the Spanish TSO since 2002.

Julio Usaola received his B.S. degree and his PhD degree in Electrical Engineering from E.T.S. de Ingenieros Industriales de Madrid in 1986 and 1990 respectively. In 1988 he joined the Department of Electrical Engineering in E.T.S. de Ingenieros Industriales de Madrid where he remained until 1994.

He is presently an Associated Professor in the Department of Electrical Engineering in the Universidad Carlos III de Madrid. His research interests are centered on grid integration of wind energy systems and electricity markets.

Lueder von Bremen was born in Bremen (Germany) on May 08, 1972. He studied Meteorology at the University of Kiel (Germany) and worked in Satellite Meteorology and Remote Sensing of clouds during his PhD.

He was working for 3½ years as a consultant in the Research Department of the European Centre for Medium-Range Weather Forecasts (ECMWF). In the beginning of 2005 he started his career in wind power forecasting at ForWind (Center of Wind Energy Research at the University of Oldenburg, Germany). In his position as project leader he developed wind power forecasts for several offshore wind farms and together with his team a new wind power forecasting tool for Germany.

Abha Sood was born in Delhi, India on March 27, 1963. She completed her school education at Bal Bharati Air Force School, Delhi in March 1980 with the All India Senior School Certificate Examination. She studied at the Trent University, Peterborough, Canada, Albert Ludwig University, Freiburg, Germany and Carl von Ossietzky University, Oldenburg, Germany, where she completed her PhD degree in physics.

She was employed at the GKSS Research Center, Geesthacht and the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven in the federal research projects SEAL and ACSYS, modeling the climate feedbacks of the Greenland icesheet. She is presently working at Forwind, Center for Wind Energy Research of the Carl von Ossietzky University Germany as a project manager for Offshore Wind Energy.

Jens Tambke graduated with a MSc in Physics from Oldenburg University in 2004, and works now towards his PhD there. He works on offshore wind power meteorology at Oldenburg University, especially in the fields of atmospheric boundary layer modelling, air-sea interaction and wind power forecasting.

Since 2003 he was responsible for Oldenburgs contribution to the EU-project ANEMOS, working with the wind power forecast system PREVIENTO. Jens Tambke is one of the developers of the new ICWP-model to simulate offshore wind profiles. Since 2004 he leads the ANEMOS workpackage for offshore predictions. He also contributes to several other regional and European projects on wind power prediction and grid integration like POW'WOW.

Ulrich Focken was born in Suderburg in the Federal Republic of Germany, on March 12, 1970. He studied Physics at the University of Oldenburg and received his PhD in 2003 on the topic of the influence of thermal stratification on wind power predictions.

He started working during his PhD as a freelance consultant for wind power assessment. In the beginning of 2004 he lead the group for grid integration and wind power forecast for half a year at ForWind, Oldenburg. In July 2004 he started his own business as general manager of energy & meteo systems GmbH. He now operates the wind power prediction system Previento for all grid operators in Germany. In November 2005 the book "Physical approach to wind power predictions" was published at Springer, Heidelberg, Germany.

Ulrich Focken received several prices for best company foundation in northern Germany in the year 2004.

Bernhard Lange was born in Bremen, Germany, in 1966. He studied physics at the Universities of Konstanz, Germany, University of Edinburgh, Great Britain and Oldenburg, Germany. He prepared his PhD at the Risø National Laboratory and the University of Oldenburg on offshore meteorology.

He is currently head of Information and Prediction systems at the division Information and Energy Economy of Institut für Solare Energieversorgungstechnik ISET in Kassel, Germany. His main research interests are in the field of wind power meteorology with main focus on offshore meteorology and wind power forecasting.

George Kallos was born in Lamia, Greece, on March 10, 1951. He graduated from the University of Athens, School of Mathematics. He has Graduate studies in Meteorology at University of Athens, School of Physics (MSc) and Atmospheric Sciences at Georgia Institute of Technology (MSc and PhD).

He started working at University of Ioannina (1977-1980) in Greece and continued at University of Athens where he is working until now as Associate Professor. He is also affiliate with State University of New York at Albany (SUNY/ASRC) and Institute of Accelarating Systems and Applications (IASA). He leads the Atmospheric Modelling and Weather Forecasting Group (AM&WFG) that is specializing in Atmospheric and Sea State model development and applications. The applications involved are related to weather, wave and air pollution forecasts (http://forecast.uoa.gr). Special applications are related to wind power siting and predictions as well as optimal ship routing.

In 2004 he received the Award from International Union on Air Pollution Prevention Association for his work related to air pollution and Saharan dust studies in the Mediterranean Region.

Teresa Pontes was born in Lisbon, Portugal, on December 13, 1946. She graduated from Lisbon Technical University on Chemical Engineering and received a Ph.D. on Mechanical Engineering with a thesis on Wave Energy Resource Assessment. She started work on Wave Energy at INETI, National Institute on Engineering Technology and Innovation in 1985, where she is Principal Researcher.

She was Director of INETI Renewable Energy Department (1993-96). She coordinated the development of the European Wave Energy Resource Atlas (WERATLAS) and national nearshore wave energy atlas. She is partner of the Portuguese team who developed technology and pre-designed the European 400 kW Pico Plant, Azores, the first connected to the grid (1999). She launched the IEA Implementing Agreement on Ocean Energy Systems in 2001, being past president of the ExCo Committee.

Katarzyna Michalowska-Knap was born in Tomaszow Mazowiecki, Poland on September 12, 1971. She studied environmental engineering and applied meteorology on Technical University of Warsaw being specialized on meteorological modeling.

She started to work for EC BREC/IBMER in 2001, as wind energy specialist. The main area of work was wind resource assessment for wind farms development purposes, as well as participation in the preparation of many strategic and political documents concerning RES development in Poland. She also participated in several EU funded R&D projects. In 2002 she becomes the head of wind energy department. From 2006 she started working for EC BREC Institute for Renewable Energy as senior wind energy specialist. The main area of interest is now the integration of wind energy with the energy system, and market issues related to large scale wind energy development.

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