CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

norcowe

Norwegian Centre for Offshore Wind Energy

NORCOWE
Annual Report 2009

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Summary

NORCOWE had its first year in 2009 and most of the work was focused on establishing the centre and getting it up and run.

NORCOWE's history in brief:

- April 2008: Announcement from RCN
- Sept 2008: Outline submitted to RCN
- Nov 2008: Workshop in Denmark
- Dec 2008: Application submitted
- Feb 2009: CEER status awarded
- Oct 2009: Official centre opening

There are 15 partners in the centre, 9 partners from the industry and 6 scientific partners. The partners in NORCOWE are located in Kristiansand, Grimstad, Stavanger, Bergen and Aalborg (Denmark). Christian Michelsen Research (CMR) is the host institution. There is a board with 12 members (7 from industry and 5 from science), with Hans-Roar Sørheim, CMR, as chair.

A permanent centre director was appointed in November 2009. She started in January 2010.

Much effort was put in defining the research fields and making all partners familiar with each other. There were several meetings during spring, summer and autumn 2009 in order to address scientific, administrative and legal aspects of the centre.

The partners address a wide range of topics, and that is reflected in the five work packages (WP) within the centre. Most of the industrial partners are interested in several work packages, and they have been active in defining the topics and subtopics to be addressed in NORCOWE.

The work packages are:

- WP1 Wind and ocean conditions
- WP2 Offshore wind technology and innovative concepts
- WP3 Offshore deployment and operation
- WP4 Wind farm optimisation
- WP5 Common themes

Each work package group had a meeting late 2009 to plan the work for 2010.

NORCOWE has established close cooperation with the other CEER addressing offshore wind energy (NOWITECH) and with ARENA NOW. We have also cooperation with CEDREN on environmental topics.

Public outreach has been stressed, and more than 20 presentations and posters have been hold by persons from NORCOWE at conferences and public meetings in addition to the presentations given at the centre opening.

Table of Contents

Summary **2**
1 Vision **4**
2 Members in the NORCOWE consortium **5**
3 Research plan and strategy **6**
4 Organisation **9**
5 Results 2009 .... **10**
5.1 Activities and results WP1 10
5.2 Activities and results WP2 10
5.3 Activities and results WP3 11
5.4 Activities and results WP4 12
5.5 Activities and results WP5 13
6 International cooperation **15**
6.1 International contacts 15
6.2 Participation in international committees 15
7 National cooperation **16**
8 Public outreach **17**
Appendix A Personnel, key scientists **18**
Appendix B Statement of Accounts **20**
Appendix C Publications **21**
Appendix D Presentations **23**
Appendix E Extract of work plans for 2010 .... **24**
E 1 WP1 - Wind and ocean conditions 24
E 2 WP2 - Offshore wind technology and innovative concepts 26
E 3 WP3 - Offshore deployment and operation 27
E 4 WP4 - Wind farm optimisation 28
E 5 WP5 - Common themes 30

1 Vision

NORCOWE is an interdisciplinary resource centre for exploitation of offshore wind energy as a natural sustainable energy source.

The vision of NORCOWE is to combine Norwegian offshore technology, and leading Danish and international communities on wind energy in order to provide innovative and cost efficient solutions and technology for large water depths and harsh offshore environments.

It is a goal that NORCOWE will help building strong clusters on offshore wind energy in Norway by developing new knowledge and by providing skilled persons for the industry.

2 Members in the NORCOWE consortium

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3 Research plan and strategy

NORCOWE has five work packages (partners involved in the work package in parentheses):

- WP1 - Wind and ocean conditions (UoB, Uni, CMR)
- WP2 - Offshore wind technology and innovative concepts (CMR, Uni, UoS, NorWind)
- WP3 - Offshore deployment and operation (CMR, UoA, UoS, AAU, NorWind, Uni, Origo)
- WP4 - Wind farm optimisation (CMR, AAU, NorWind, Uni)
- WP5 - Common themes (CMR, Uni, UoB)

Assessment of meteorological and oceanographic conditions
It is a key topic in NORCOWE to make good assessment of the offshore wind resources along the Norwegian Coast and in the North Sea.

Since the depreciation time for offshore wind installation is comparable with currently predicted rapid climate changes, a sound assessment of wind power potential should include state-of-the-art information about future perspectives for offshore wind power potential. Some of the efforts will put into investigation of variability of storm tracks and calm weather periods in the past, and address potential for such in the future.

Reliable prediction of power production for a time window from +12hrs to +48hrs is essential for optimizing the price of the produced energy. Knowledge about the uncertainties attached to the production estimates maybe used in a cost/loss-relation. Thus the former requires an accurate deterministic forecast and the latter a reliable ensemble forecast. For improvement of deterministic forecasts, identification of the source of errors is among the most important objectives. For ensemble forecasts, the initialization procedure has many challenges, and several methods should be investigated.

The environmental conditions due to wind, waves and currents need to be provided from observations and model simulations. The turbulence structure in the marine atmospheric boundary layer, especially in the presence of ocean waves, is not well documented by measurements. A main goal is therefore the development and test of a measurement system that will enable the direct measurement of the turbulence structure and the corresponding heat and momentum fluxes directly over the sea surface, by adapting a well established system of a sonic anemometer to a potentially moving platform, e.g. a buoy.

Parameterization of turbulence is a recurring challenge that must be adjusted to the problem at hand. In turbine wakes, the turbulent elements are controlled by environmental parameters such as stability and ambient wind speed, surface friction modified by ocean waves, and the properties of the free atmosphere. The mixing of momentum from the free atmosphere into the wake is not understood, and must be investigated before models will be able to deal with this in a satisfactory way. We also lack the understanding what atmospheric background parameters control the energy production in large offshore wind farms.

Dynamical response of wind turbines and their operation in offshore wind farms
Exploitation of wind energy at deep-water locations requires floating wind turbine installations. Deep-water offshore solutions will give access to large areas with high wind, and less sensitivity to noise, visual impacts and size. Several examples of floating wind turbine concepts are reported in the literature. A common challenge is to make low cost

installations with acceptable motion characteristics. Installations that minimize fatigue of key components while maximizing power production.

To describe the motion characteristics of a floating wind power installation the coupled action of wind, waves, wires as well as the turbine control system must be considered. The wind-induced loads may amplify or damp the wave-induced motions but this coupling may partly be compensated through active use of the control system, by the pitch of the rotor blades, the electromagnetic torque of the generator and the yaw drive of the nacelle. The coupling of aerodynamics, structural dynamics, hydrodynamics and control system calls for elements of concurrent analysis and design.

The objective is to improve the understanding of the dynamic response of a complete fixed or floating offshore wind turbine system subjected to wind, waves and current. A better understanding of the dynamical response will provide valuable information for design of single wind turbines; structures, mooring and anchoring; large wind parks; and instrumentation and control systems algorithms.

One key challenge expected to be given much attention is the improvement of the stability of floating wind turbines through lighter gearbox design, hydraulic transmission, new low speed generators, and possibly by positioning the gearbox and generator at, or below, sea level, but projects related to control systems and power transmission may also be included in this work package. The work will consider the interaction between the main components of the wind turbine, and the interaction between the main components and the surrounding environment (including the power grid, modes of operation, climatic conditions, and other factors).

Wind farm layout

Construction of wind farms requires large investments, and it is important to optimize farm layout with respect to energy production and cost. Remote measurements of the wind upstream of wind parks can provide information on the wind speed and its rapid fluctuations (turbulent conditions) in the coming minutes, so-called *nowcasting*. The control system may utilize these measurements to optimize blade pitching, yaw angles and rotor speeds, both to reduce loading on individual turbines and to optimize the overall energy production from the wind park.

Each wind turbine in a wind farm generates a wake, and wind turbines within this wake experience lower wind speeds and increased turbulence intensity compared to unobstructed turbines. Power losses from wakes in wind farms are difficult to predict, and this effect is often underestimated with current models. The impact on the overall power output from a wind farm is likely to be in the range 5-10 per cent or more (EWEA, 2009).[1] Hence, there is an obvious need for improved predictive capabilities on the optimisation and layout of both onshore and offshore wind farms.

Marine operation and maintenance

Costs related to operation and maintenance of offshore wind turbines are large, typically more than 25% of the cost of energy produced. Studies show that failures of wind power plants have many sources, ranging from sensor/control system faults, mechanical backlash, failure of gears/bearings and hydraulic leakage. Results from the recently completed 5-year EU funded project Condition Monitoring for Offshore Wind Farms (CONMOW 2002-2007), show that at present there is insufficient knowledge available to assess the condition of wind farms and to

[1] EWEA (2009). *Wind Energy – the facts: a guide to the technology, economics and future of wind power*. European Wind Energy Association (EWEA). Earthscan, London. ISBN 978-1-84407-710-6.

estimate how failures develop over time. This implies that a broad scope of new methods and techniques is required for management of offshore wind turbines.

At present the costs of installation, intervention and decommissioning of offshore wind concepts are unreasonably high when using state of the art conventional technology. There is thus a need for new thinking to develop safe but less costly technology and procedures for said operations

In view of this, it is proposed that new technology for installation, intervention and decommissioning of offshore wind concepts be developed. We will in particular investigate the use of ballast procedures combined with use of offshore service vessels to perform said operations safely. The technology development should include new concepts that can be handled by work procedures developed by the offshore service industry.

Environmental impact

Effects on the environment from large-scale offshore wind-power installations have been studied for some time. The data collected and the conclusions drawn are, however, restricted to a few sites in one type of marine habitat, *i.e.* shallow water sediments and sand banks in the relatively calms seas of the Southern Baltic Sea and the North Sea. Ecological and oceanographic differences between those sites and the Norwegian Sea are dramatic including salinity, temperature, and dominating species abundances. Long term, accumulative effects on organisms such as fish and cetaceans from *e.g.* underwater noise are also not known. We are working to develop an Environmental Monitoring Plan (EMP) for the wind farm. It is anticipated that this EMP will set a standard for future offshore wind farms and that data generated by the EMP will be of great importance for research projects on short and long term environmental impact from Norwegian offshore wind farms.

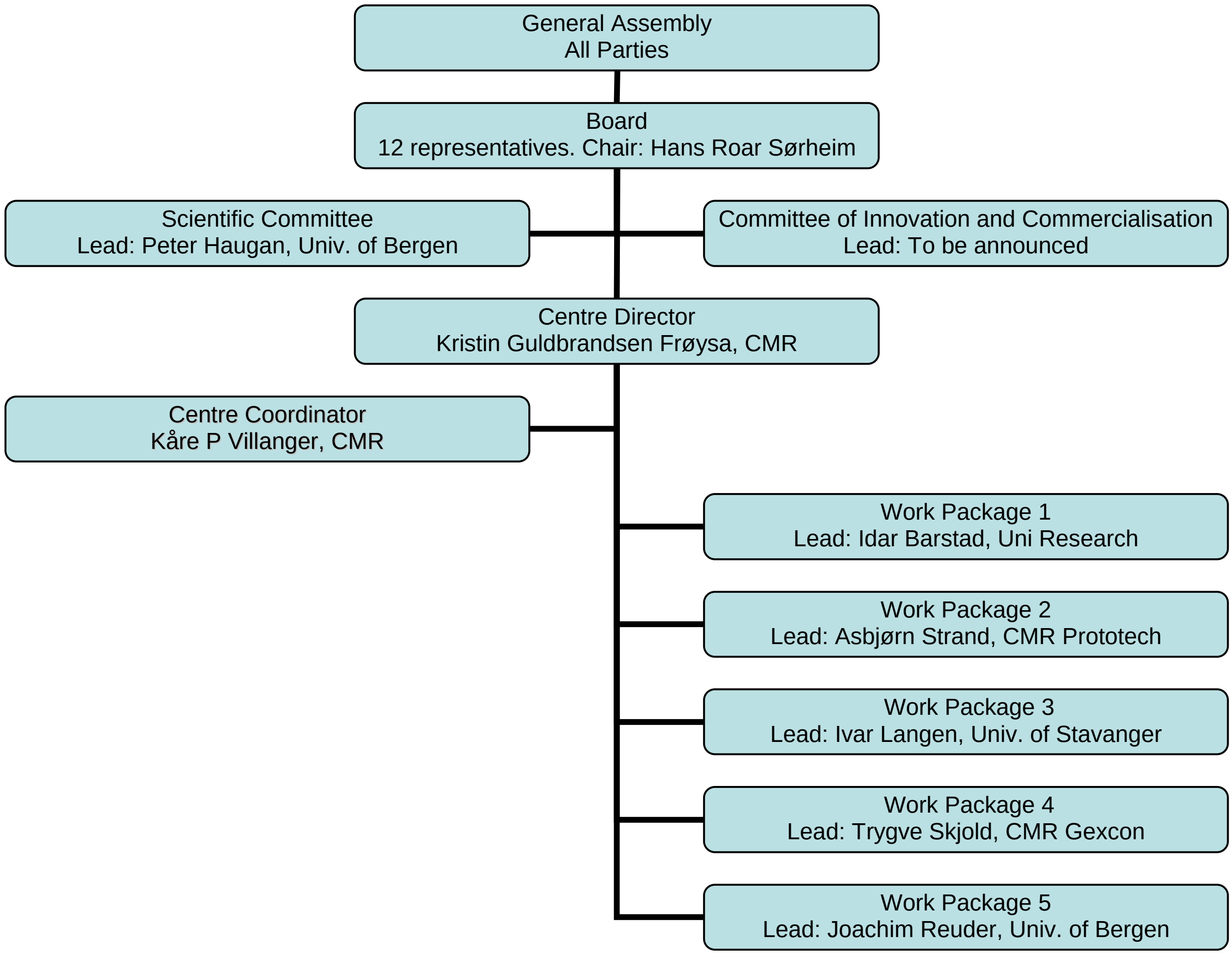
New concepts

A number of ideas is expected to pop up within the industry, academia, as well as from private inventors. The maturity level of such ideas will vary. They can have the form of visionary concepts for new ways to harvest wind energy over sea, to concrete ideas of how to improve or replace technological elements. The technology may be part of the offshore turbine installation, the power transmission system or related to the marine operations of commissioning and maintenance.

Promising new ideas should always be allowed to pass a first scientific evaluation, a so called *analytical proof of concept*, to actually classify how good the idea really is. NORCOWE gathers the expertise required for this sort of evaluation of all technological and operational elements.

4 Organisation

The NORCOWE organisation as of April 1st 2010 is shown in the figure below.



5 Results 2009

5.1 Activities and results WP1

In WP1, an extensive model tool simulating the geophysical processes relevant for offshore wind parks will be compiled and tested. A next-generation mesoscale models (WRF) will be coupled to ocean wave models and microscale models (LES and RANS-types). Before this comprehensive system may come in use, it will be necessary to test both individual components as well as the coupled version of the system.

In 2009 testing of the components commenced. Tests consisted of choices of schemes in the model, configurations and so forth. Furthermore, the effort in coupling one of the wave models to the atmosphere model started. This work is not yet completed, and extends into 2010. We expect to couple a second wave model to the system in 2010.

In WP1, existing data from various sources will be used in an analysis of historical and future wind climate (climatology). Information relevant for offshore wind farms in Nordic Seas, has been compiled.

Analysis of existing data set was started and results from this work were presented at a conference in Stockholm in September 2009. The work revealed some information of what can be expected for wind energy potential in the next 30 years; the potential of offshore wind energy stays at about the same level as of today.

The work on short-term forecasting has not yet started.

The work has been done by Uni Research and University of Bergen.

5.2 Activities and results WP2

A detailed overview of research tasks and involvement by the various research groups was established following the NORCOWE Workshop on 15-16 April 2009, and this was updated regularly throughout the year.

Several initiatives were taken to promote the cooperation between research partners and industrial user partners in NORCOWE, and between research partners in NORCOWE and NOWITECH. The following projects were proposed:

- Dynamic Response and Statistical Models for Floating Wind Turbines
- Dynamic Analysis of Offshore Wind Turbines,
- Wind Turbine Modelling
- Detailed Benchmark CFD Modelling of Flow Field Near Turbine Blade
- Innovative Concepts
- Optimisation of Offshore Wind Power Conversion Systems
- Design Optimization of Offshore Wind Turbines
- Reliability Analysis of Wind Turbines.

Before approval of the work plan for 2010 it was decided to put all CFD related activities in WP4. In addition to that the CFD activities have been moved from WP2, “Reliability Analysis” has been moved to WP3, and some activities have been put on hold due to budget restrictions per institution. The approved work plan for 2010 for WP2 therefore has the following activities:

- Dynamic Analysis of Offshore Wind Turbines
- Innovative Concepts
- Design Optimization of Offshore Wind Turbines

As a necessary preparation to the R&D activities the participants have used resources on literature survey and participation on important international offshore wind events. Some research on the above topics has also been performed. Specifically this relates to the topic Wind Energy Capture and the project Wind Turbine Modelling. The flow sheet and functional relationship for a sub grid model has been established. The model shall be used in comprehensive CFD models for complete wind farms for modelling of wind energy production and turbine pressure. A first implementation has been established, and verification with BEM theory for wind turbines in a simplified computer simulation program has started. Some work on the project Detailed benchmark CFD Modelling of Flow Field Near Turbine Blade has also been accomplished. This will include computationally intensive simulations which shall function as reference simulations for more simple parameterizations to be used in complete wind farm simulations. Different modelling strategies for CFD have been briefly tested and different methodology together with software and hardware for the modelling work.

5.3 Activities and results WP3

To plan and coordinate these activities, two work package meetings have been arranged. The first meeting 28 May discussed proposals from each partner, and based on this meeting and discussions afterwards Scope of Work and Budget for WP3 for the period 2009-2013 have been worked out. The Scope of Work was further discussed with the industry partners on 23 November. This activity also includes meetings for the work package manager in the interim board and a coordination and cooperation meeting with NOWITECH.

At CMR the activity “Measurement technology for asset management” has started with literature survey and technology gap analysis.

The activities at UoA, UoS, AAU and Origo in asset management have been related to planning of the activities, recruiting of PhD students and establishing international contacts. 1 PhD student will start 2 Quarter 2010. Some literature study has started. The work within reliability and operation and maintenance the work will be coordinated with research activities in the EU FP6 research project ‘UpWind: Integrated Wind turbine Design’ and the research project ‘REL-OWT: Reliability-based analysis applied for reduction of cost of energy for offshore wind turbines’ financed by DSF (Danish Strategic Research Council) and industry (DONG Energy and Vestas Wind Systems).

Two PhD projects started in 2009 at AAU on single turbine control systems. These are “Decentralized Wind Flow Estimation” and “Control of Floating wind turbine installation”. “Decentralized Wind Flow Estimation” is a PhD study focusing on wind flow modelling. There has been carried out survey on wind flow modelling, wind prediction problem and decentralized state estimation and fusion schemes. PhD problem has been formulated and initial analysis of data from ECN wind farm has been completed.

The PhD project “Combinatorial Control of Wind Farms” started in 2008 and is included in NORCOWE as in-kind contribution. This is a PhD study has initially focused on problem formulation and literature study.

A dynamical model of the wind flow in wind farms has been established. The model has been transformed into a discrete framework. Initial design of optimal control for wind farm based on flow model, considering structural loads (at this step only the tower is considered).

“Control of Floating wind turbine installation” is a PhD study that has just started. Focus has been on problem formulation and literature study. In addition definition of preliminary PhD study plan is done.

Within the other activities both at AAU and UoA the work done is planning and recruiting of PhD students and some paper writing. One more PhD students will start during 3 Quarter 2010, respectively.

The work on Remote operation has started at CMR within Visualization for remote operation with literature survey, technology gap analysis and identification of partners for cooperation. UoA has started content planning and hiring of PhD student. 1 PhD student will be in place 4 Quarter 2010.

In the subtask marine operation planning of activities and recruiting of a PhD student have taken place at UoS together with initial planning of the in kind contribution from NorWind. 1 PhD student will start 2 Quarter 2010.

5.4 Activities and results WP4

A detailed overview of research tasks and involvement by the various research groups was established following the NORCOWE Workshop on 15-16 April 2009, and this was updated regularly throughout the year.

Several initiatives were taken to promote the cooperation between research partners and industrial user partners in NORCOWE, and between research partners in NORCOWE and NOWITECH:

- Preparation of a joint proposal from CMR, UoB and AAU for a Knowledge-building Project with User Involvement (KMB) dedicated to Nowcasting (WP4.1).
- Coordination of the efforts on power system integration between Statkraft, Troll Windpower and AAU (WP4.2).
- Exchange of terrain data between Agder Energi and CMR GexCon to facilitate future modelling of wind farms (WP4.3).

The scientific work related to Nowcasting (WP4.1) and Optimization of wind farms with the computational fluid dynamics (CFD) code FLACS-Wind (WP4.3) include:

- A literature search dedicated to nowcasting.
- A literature search dedicated to models for simulating wind turbines and wind farms.

- Implementation and initial testing of the Blade Element Momentum (BEM) model (from WP2) in FLACS-Wind.
- Implementation and initial testing of a new graphical user interface for visualising wind turbines in the post-processor for the CFD diode FLACS-Wind.
- Implementation and initial testing of the Blade Element Momentum (BEM) model developed in WP2 in the CFD code FLACS-Wind.
- Implementation and initial testing of a simple wake model in the CFD code FLACS-Wind.

The modelling activities will continue in 2010, in addition to systematic validation work on effective handling of complex terrain and simulation of flow over sea and terrain with CFD.

5.5 Activities and results WP5

Due to its highly inhomogeneous character WP5 has been structured in 7 thematic sub-packages (SPs), which have been assigned to SP-leaders with corresponding background and experience.

SP1) Education
A survey on wind energy relevant courses at all NORCOWE participating research institutions was started in 2009. Planning of HAWC training and LES summer school was started.

SP2) Dissemination of results
The NORCOWE-webpage was designed and put up early 2009. It operates with one open area for the wide public and a closed area for internal project work and communication between all research and industry partners. Together with the webpage suitable illustrative pictures have been collected and graphical design for e.g. power point and posters has been delivered. Moreover various project templates have been designed and published.

SP3) Safety
The SP has started to develop the ship drift model by defining and implementing a system which will collect data from drifting ship. These data is collocated with data from meteorological and oceanographic forecast models and observation systems. A tool which can be used for running data collecting experiments and extracting data from these experiments is being tested. This tool is being finalized and will be developed further and used in a new project "Uncontrolled drift of vessels and larger floating objects" sponsored by RCN.

SP4) Environment
A literature review on environment impact from constructing and running offshore wind farms is completed. Major conclusions include that effects from the production stage and operations offshore are poorly investigated. It is also suggested that planning can mitigate much of the effects. During 2010 work will be done on the design of environment monitoring programs for the construction and production phases of off shore wind farms.

SP5) Infrastructure: Measurement atmosphere
1 PhD position in connection to NORCOWE (award from UoB to GFI for NORCOWE success) was announced and the selected candidate will start his work in January 2010. A survey on existing and potentially useful met-ocean data is in work, instrumentation required for one of the PhD positions related to flux measurements from a moving buoy is in the

purchase process. NORCOWE got positive response from the German FINO consortium with respect to the scientific use of all met-ocean measurements of the FINO platforms 1 to 3, the infrastructure for data access is under preparation. Both CMR and GFI/UoB have contributed substantially to two KMB and BIP applications related to advanced met-ocean measurements related to offshore wind energy.

SP6) Infrastructure: Measurement ocean

The oceanographic measurements will be mainly performed through the Fugro-Oceanor buoy systems to be purchased through the recent EFOWI funding. The details of the mooring system are laid out and the purchase order was issued on 4 December 2009. An announcement for a 4-year research fellow in physical oceanography was posted in December 2009. The PhD study will address the air-sea interaction processes and movement of surface platforms under the influence of ocean surface waves and harsh wind conditions. This project will utilize data to be collected from the EFOWI buoys.

SP7) Infrastructure: Full scale pilot installations

This SP is closely connected to the EFOFI infrastructure project (17 MNOK funding by NFR). The proposed (and partially ordered/purchased) instrumentation covers 3 wind lidar systems, 1 scintillometer and 2 advanced met-ocean buoy systems. The use and placement of this mobile instrumentation will take place in close cooperation with all NORCOWE (and partially NOWITECH) research and industry partners, corresponding contacts have been established. Locations actually under consideration are the Utsira/Karmøy/Kvitsøy area with the HyWind turbine, the Stad area north of Sognefjorden and Sletringen/Frøya/Titran further north.

6 International cooperation

6.1 International contacts

- National Center for Atmospheric Research (NCAR), Boulder, Colorado, USA.
- Risø National Lab. for Sustainable Energy/Technical University of Denmark – DTU, Roskilde, Denmark
- VTT – Technical Research Centre of Finland, Finland
- IMS Center of Intelligent Maintenance Systems , University of Cincinnati, USA
- CBM network Europe http:/www.cbm-europe.org
- Group of Modal Intervals and Control Engineering, University of Girona, Spain
- Dept. of Applied Mathematics, Universitat Politècnica de Catalunya, Spain.
- Institute for Energy Meteorology, University of Oldenburg, Germany
- Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Germany
- Prof. Jim Edson, University of Connecticut, USA
- FORWIND, Center for Wind Energy Research, Germany
- Dong Energy, Denmark
- Vestas Wind Systems, Denmark

6.2 Participation in international committees

- Finn Gunnar Nielsen: ISSC 2009: Chairman Specialist committee "Ocean energy" 2006 - 2009. Report issued in Seoul August 2009, http://www.issc.ac/
- Finn Gunnar Nielsen: Member of the Marine Board Vision Group on Renewable Ocean Energy, http://www.esf.org/research-areas/marine-sciences/marine-board-vision-groups.html
- Peter M Haugan: ESFRI Environment Thematic Working Group (ENV TWG).
- Peter M Haugan: Marine Board-ESF

7 National cooperation

Several initiatives were taken to promote the cooperation between research partners and industrial user partners in NORCOWE, and between research partners in NORCOWE and NOWITECH.

- Preparation of a joint proposal from CMR, UoB and AAU for a Knowledge-building Project with User Involvement (KMB) dedicated to nowcasting (WP4.1).
- Coordination of the efforts on power system integration between Statkraft, Troll WindPower and AAU (WP4.2).
- Exchange of terrain data between Agder Energi and CMR GexCon to facilitate future modelling of wind farms (WP4.3).
- Joint BIP project of Oceanor, CMR and UoB dedicated to turbulence (by sonic anemometer) and wind profile (by lidar) measurements: "Målinger av vindprofil og strømprofil for havvindmøller".
- Coordination meeting between CEDREN, NORCOWE and NOWITECH in Trondheim 18th January 2010.

NORCOWE, NOWITECH, ARENA NOW and ARENA Vindenergi started to work on a proposal for a Norwegian test and demonstration programme in 2009. The proposal for DEMO 2020 was submitted to the Norwegian government 1st March 2010.

8 Public outreach

The NORCOWE webpage was designed and put up early 2009. It operates with one open area for the wide public and a closed area for internal project work and communication between all research and industry partners.

The official opening of the centre in October 2009 by the Mayor of Bergen, Gunnar Bakke, was a success and the centre got much publicity.

There is a great interest in NORCOWE, and we have got many invitations to give presentations at conferences, meetings and at companies. Much of the outreach in 2009 was focused on getting partners and to inform possible stakeholders.

Appendix A Personnel, key scientists

Name	Institution	Topic
Thomas Bak	AAU	Control systems
Zhe Chen	AAU	Power system integration
Frede Blaabjerg	AAU	power electronics
John Dalsgaard Sørensen	AAU	Reliability & OM
Thomas Bak	AAU	Control systems
Jens A. Melheim	CMR GexCon	Computational fluid dynamics
Idar Storvik	CMR GexCon	Computational fluid dynamics
Trygve Skjold	CMR GexCon	Computational fluid dynamics
Ivar Øyvind Sand	CMR	Computational fluid dynamics
Ole Jacob Taraldset	CMR GexCon	Computational fluid dynamics
Asbjørn Strand	CMR Prototech	Wind Power Technology
Eivind Olav Dahl	CMR	Centre manager (2009)
Anders Hallanger	CMR	Wind energy capture
Marie Bueie Holstad	CMR	Asset management
Inge Klepsvik	CMR	Asset management
Gaute Øverås Lied	CMR	Asset management
Kjetil Daae Lohne	CMR	Asset management
Trygve Buanes	CMR	Asset management
Tor Langeland	CMR	Remote operations
Inge Morten Skaar	CMR	Remote operations
Yngve Heggelund	CMR	Remote operations; Safety
Kjell Røang	CMR	Safety
Tor Chr. Bekkvik	CMR	Safety
Morten Graff	Grieg Logistics	Marine operations/ Logistics
Jørgen Jorde	NorWind	Marine operations/ Installations
Adam Schwartz	OceanWind	Wind farm development
Trond Friisø	Origo Engineering	Condition based maintenance
Paweł Wójcik	Origo Engineering	Condition based maintenance
Christer Olerud	Troll Windpower	Electrical engineering
Idar Barstad	Uni Research	Coordination, Mesoscale meteorology
Michel Mesquita	Uni Research	Large-scale meteorology
Ulla Heikkila	Uni Research	Mesoscale meteorology
Alla Sapronova	Uni Research	Artificial intelligence (AI)
Klaus Johannsen	Uni Research	Coordination, AI
Jeremy Cook	Uni Research	Programming
Geir Hovland	Univ of Agder	Condition monitoring
Michael R. Hansen	Univ of Agder	Heave compensation and hydraulic systems
Andreas Prinz	Univ of Agder	Remote operations
Hamid Reza Karimi	Univ of Agder	Turbine control systems
Ilker Fer	Univ of Bergen, Geophysical Institute	Oceanic turbulence

Peter M. Haugan	Univ of Bergen, Geophysical Institute	Oceanography and offshore wind energy
Alastair Jenkins	Univ of Bergen, Geophysical Institute	Air sea interaction
Finn Gunnar Nilsen	Univ of Bergen, Geophysical Institute	Offshore wind turbines, dynamic response
Joachim Reuder	Univ of Bergen, Geophysical Institute	Atmospheric boundary layer research
Ivar Langen	Univ of Stavanger	Head of WP3
Jasna Bogunovic Jakobsen	Univ of Stavanger	Dynamic analysis
Jonas Thor Snæbjörnsson	Univ of Stavanger	Dynamic analysis
Arnfinn Nergaard	Univ of Stavanger	Design optimization, new concepts
Ove T Gudmestad	Univ of Stavanger	Marine operations, marine technology
Jayantha Liyanage	Univ of Stavanger	Asset management, operations and maintenance

PhD students with financial support from the Centre budget				
Name	**Nationality**	**Period**	**Sex M/F**	**Topic**
Anna Fitch	Eng	8 2009 ->	F	Mesoscale meteorology
Søren Christiansen	Danish	12 2009 - 11 2012	M	Control of Floating wind turbine installation

PhD students working on projects in the centre with financial support from other sources					
Name	**Funding**	**Nationality**	**Period**	**Sex M/F**	**Topic**
Maryam Soleimanzadeh	AAU	Iranian	11 2008 - 11 2011	F	Combinatorial Control of a Wind farm
Sayed Mojtaba Shakeri	AAU	Iranian	04 2009 - 04 2012	M	Decentralized Wind flow Estimation
Marius Jonassen	UoB fellowship	Norwegian		M	Norcowe/Nowitech think tank on renewable energy

Appendix B Statement of Accounts

Funding (all figures in 1000 NOK)

Institution	Amount Public	Amount Research	Amount Enterprise	Total
The Research Council	4 280			4 280
The Host Institution (CMR)		1 950		1 950
CMR Prototech AS			532	532
CMR GexCon AS			0	0
Uni Research AS		975		975
University of Bergen	800			800
University of Stavanger	340			340
University of Agder	209			209
Aalborg University	1 200			1 200
Statkraft Development AS			750	750
Vestavind Offshore AS			500	500
Agder Energi AS			500	500
Statoil Petroleum AS			425	425
Lyse Produksjon AS			250	250
Aker MH AS			250	250
National Oilwell Norway AS			250	250
Origo Engineering AS			448	448
NorWind AS			290	290
Total	**6 829**	**2 925**	**4 195**	**13 949**

Costs (all figures in 1000 NOK)

Institution	Amount Public	Amount Research	Amount Enterprise	Total
The Host Institution (CMR)		5 048		5 048
CMR Prototech AS			1 218	1 218
CMR GexCon AS			806	806
Uni Research AS		3 010		3 010
University of Bergen	1 183			1 183
University of Stavanger	450			450
University of Agder	309			309
Aalborg University	1 387			1 387
Origo Engineering AS			348	348
NorWind AS			190	190
Total	**3 329**	**8 058**	**2 562**	**13 949**

Cost per work package (all figures in 1000 NOK)

Work package	Amount
WP 1 - Wind and ocean conditions	2 121
WP 2 - Offshore wind technology	2 321
WP 3 - Offshore deployment and operations	2 687
WP 4 - Wind farm optimisation	486
WP 5 - Common themes	1 541
Education	97
Equipment	60
Administration	4 636
Total	**13 949**

Appendix C Publications

M d-s Mesquita (2009), High-resolution wind data from dynamical downscaling: An important asset in offshore wind research", Conference proceedings, Stockholm offshore conference, 14-16 Sept, 2009.

Melheim, J.A., Jenkins, A.D., Barstad, I., Skjold, T. & Dahl, E.O (2009), Norwegian Centre of Offshore Wind Energy – overview of research activities. Poster, European Offshore Wind, 13-16 September 2009, Stockholm, Sweden.

Karimi; H.R. (2009), Semiactive vibration control of offshore wind turbine towers with Tuned Liquid Column Dampers using *H_infinity* control techniques, submitted to the 2010 IEEE Multi-conference on Systems and Control.

Karimi, H.R (2010), Robust vibration control for structures equipped with wireless sensors, Accepted and to be presented at the 5th World Conference on Structural Control and Monitoring, July 12-14, Tokyo, Japan.

Karimi; H.R (2010), Robust vibration control for structures equipped with wireless sensors, Accepted and to be presented at the 5th World Conference on Structural Control and Monitoring, July 12-14, Tokyo, Japan.

Gholami, M, Schiøler, H, Bak, T & Tabatabaeipour, SM (2009), 'Active Fault Detection and Isolation for Hybrid Systems ', In ICSE 2009 Twentieth International Conference on Systems Engineering, Coventry.

Tabatabaeipour, SM, Ravn, AP, Izadi-Zamanabadi, R & Bak, T (2009), 'Active fault diagnosis of linear hybrid systems', In Safeprocess'09, pp. 211-216.

Tabatabaeipour, SM, Ravn, AP, Izadi-Zamanabadi, R & Bak, T (2009), 'Active fault diagnosis-A model predictive approach', In IEEE International Conference on Control and Automation.

Tranberg, S, Svenstrup, M, Andersen, HJ & Bak, T (2009), 'Adaptive Human aware Navigation based on Motion Pattern Analysis', In The 18th IEEE International Symposium on Robot and Human Interactive Communication, 2009. RO-MAN 2009, IEEE conference proceedings pp. 927-932.

Andersen, HJ, Bak, T & Svenstrup, M (2009), 'Adaptive Robot to Person Encounter by Motion Patterns', In Proceedings of the International Conference on Research and Education in Robotics - EUROBOT 2008: Mission to Mars, Springer Science+Business Media B.V., Heidelberg, pp. 1-11.

Grunnet, JD, Bendtsen, JD & Bak, T (2009), 'Automated Fault Tolerant Control Synthesis based on Discrete Games', In Proceedings of the 48th IEEE Conference on Decision and Control, IEEE conference proceedings.

Tabatabaeipour, SM, Izadi-Zamanabadi, R, Bak, T & Ravn, AP (2009), 'Automatic sensor assignment of a supermarket refrigeration system', In 2009 IEEE Control Applications, (CCA) & Intelligent Control, (ISIC), IEEE conference proceedings pp. 1319–1324.

Knudsen, T, Bak, T & Soltani, M (2009), Distributed Control of Large-Scale Offshore Wind Farms, Paper presented at European Wind Energy Conference and Exhibition (EWEC) 2009, Marseille, France. 16. - 19. March.

Soltani, M, Knudsen, T & Bak, T (2009), 'Modeling and Simulation of Offshore Wind Farms for Farm Level Control', In Proceedings of the European Offshore Wind 2009,

Grunnet, JD, Bak, T, Bendtsen, JD & Ankersen, F (2009), 'PAHSCTRL - A Control Synthesis Toolbox for Piecewise-Affine Hybrid Systems', In Proceedings of the 2009 European Control conference, IEEE conference proceedings.

Svenstrup, M, Tranberg, S, Andersen, HJ & Bak, T (2009), 'Pose Estimation and Adaptive Robot Behaviour for Human-Robot Interaction', In IEEE International Conference on Robotics and Automation 2009, IEEE conference proceedings pp. 3571 - 3576.

Knudsen, T, Soltani, M & Bak, T (2009), 'Prediction Models for Wind Speed at Turbines in a Farm with Application to Control', In Extended Abstracts for Euromech Colloquium 508 on Wind Turbine Wakes, E.T.S.I. Industriales Universidad Politécnica de Madrid.

Soltani, M, Knudsen, T & Bak, T (2009), Simulation Models for Case Study - Aeolus - WP5, Aalborg Universitet.

Hansen, ST, Svenstrup, M, Andersen, HJ, Bak, T & Jensen, OB (2009), 'The SantaBot experiment: a pilot study of human-robot interaction', In Proceedings of the 4th ACM/IEEE international conference on Human robot interaction, ACM Conference on Computer-Human Interaction pp. 211-212.

Origo Engineering: Condition Monitoring Systems in Wind Turbine, Internal report, 23171-RA-0001.

Appendix D Presentations

- 20-21.04.2009 Offshore Wind Norway-Germany; Bremerhaven, Germany.
- 22-23.04.2009 Hannover Messe (trade fair), 22-23 April, Hannover, Germany.
- 18.05.2009, Meeting NORCOWE-NOWITECH-CEDREN; Kjeller: "Offshore Wind Energy Infrastructure"
- 19.05.2009, Meeting with NOWITECH (WP leaders); IFE, "NORCOWE presentation"
- 17.06.2009 Meeting with Troll WindPower; Bergen:, "Work package presentations"
- 23.06.2009, NORCOWE seminar with industry partners; Bergen: "Presentation of WP 5 and plans on infrastructure"
- 01.07.2009 Meeting with Storm; Bergen: "Work package presentations "
- 02.07.2009 Meeting with NOWITECH (SINTEF); Bergen "Work package presentations."
- 07.07.2009 Meeting with Siemens; Bergen :WP4 presentation
- 10.08.2009, NORCOWE meeting with IRIS and Lyse; Stavanger, "Presentation of NORCOWE"
- 11-12.08.2009 EnergiRike (conference); Haugesund; "NORCOWE presentation"
- 10.09.2009, TP wind meeting; Brussels: "Activities and plans for a Norwegian Offshore Wind Energy Infrastructure"
- 19.09.2009, Forskningsdagene; Bergen: "Offshore vindkraft"
- 23.09.09, Meeting with Scanmet; Bergen: "Presentation of WP 5 and plans on infrastructure"
- 29.09.2009 Presentation of NORCOWE at CEDREN kick-off; Trondheim
- 15.10.2009, IEA Topical Expert Meeting 59 on Remote Wind Speed Sensing Techniques using Sodar and Lidar; Boulder, USA: "Plans and activities for a Norwegian Offshore Wind Energy Infrastructure"

This list is not complete.

Appendix E Extract of work plans for 2010

E 1 WP1 - Wind and ocean conditions

WP1 has the following subtopics:
- WP1.1 Climatology met/ocean conditions
- WP1.2 Modelling marine boundary layer
- WP1.3 Short-term forecasting (1-2 days)

Work package 1 (WP1) will focus on setting up and running a model system that will describe forces acting on marine structures. This system will provide information on wind and waves at a large range of spatial and temporal scales. It will facilitate site assessment (climatology of mean and extreme wind and wave conditions), improve the accuracy of next-day energy output estimates (short-term forecasting), and aid in reducing structural strain and fatigue by quantifying the behaviour of the system of wind generators for various wind/wave regimes and power output requirements.

In order to achieve success in the endeavour outlined above, strengthening of our understanding of the marine boundary layer is required. In this work package, the enhanced understanding will go together with work on models and observations (existing and new acquirements). A better understanding of the marine boundary layer will speed up the process of developing the model system by making the correct choices in the design process for the new model system.

The products from numerical models and subsequent adjustment of the model results in WP1, will be combined with other information valuable for planning of offshore wind energy to form a new geographical information system (GIS) tool. Such other information will for example be geographical information of bird sanctuary, fish banks and vessel data. This data could be made available from other work packages such as WP5. The GIS tool will allow users to compile information to an overview of factors influencing decision-makings on wind parks issues. The tool will also try to incorporate different calculations such that it will be possible for users to adjust different parameters when compiling information. The system will use open source components to the extent possible.

The activity of model development and work in order to increase the understanding are concomitant activities. Work related to enhance understanding will first of all be conducted by PhD students in collaboration with their supervisor and co-supervisors. Thus several of the scientists are expected to work with PhD students on different topics.

We plan to start up 2 full PhD's within the first 3 years (and to support a 43% PhD position at met.no), supporting the efforts of atmospheric mesoscale, atmosphere-wave interaction, and microscale simulations including implementation of turbines within the models. One PhD (A Fitch) has already started (Aug. 2009). There will be additional PhD students working on peripheral activities among the WP 1 active partners.

E 1.1 WP1.1 Climatology met/ocean conditions

Since the depreciation time for offshore wind installation is comparable with currently predicted rapid climate changes, a sound assessment of wind power potential should include state-of-the-art information about future perspectives for offshore wind power potential. In 2009 and 2010, we have conduct several studies for offshore wind power potential for the future time period 2020-2060 based on existing data. Some of the efforts will put into investigation of variability of storm tracks and calm weather periods in the past, and address potential for such in the future. At the same time, we will map near-surface winds and wave fields from the new hindcast dataset. Maps (gridded to about 30km) of tendencies for the wind power potential will be presented.

Before the end of year 2010, a couple wave and mesoscale atmospheric model system should be ready for use, and we will set out to produce a new reanalysis (atmosphere and wave) with this system, resulting in a 3km gridded dataset covering at least 10 years. The area of focus will be relevant parts of the North Sea and Norwegian Sea. If necessary, we will furthermore downscale climate scenario using the same grid configurations.

In relation to loads on structures and building codes, there is obviously a need for investigation of the extreme value methodology. Large amount of data will be produced and from these data, return values etc. will be calculated.

E 1.2 WP1.2 Modelling marine boundary layer

The activity of model development and work in order to increase the understanding are concomitant activities. Work related to enhance understanding will first of all be conducted by PhD students in collaboration with their supervisor and co-supervisors. Thus several of the scientists are expected to work with PhD students on different topics.

We plan to start up 2 full PhD’s within the first 3 years (and to support a 43% PhD position at met.no), supporting the efforts of atmospheric mesoscale, atmosphere-wave interaction, and microscale simulations including implementation of turbines within the models. One PhD (A Fitch) has already started (Aug. 2009). There will be additional PhD students working on peripheral activities among the WP 1 active partners.

Ocean waves affect the airflow in the marine atmospheric boundary layer in a number of ways: by influencing the mean flow via the turbulent drag and aerodynamic roughness; by inducing wave-correlated oscillations which may have near-singular behaviour at critical levels; and by generating and suppressing turbulence via shear flow, flow separation, and the ejection of spray droplets. The study will be conducted using a selection from the following methods, and/or additional methods if found suitable

- Analysis of published data from the marine atmospheric boundary layer;
- Mathematical analysis of the flow field, including perturbation techniques;
- Numerical modelling: in one (vertical) and/or three dimensions, of the turbulent flow field, the wave-induced flow oscillations, and their Fourier spectra;
- Simulation of the effect of breaking crests and spray.

E 1.3 WP1.3 Short-range forecasting

Reliable prediction of power production for a time window from +12hrs to +48hrs is essential for optimizing the price of the produced energy. Knowledge about the uncertainties attached to the production estimates maybe used in a cost/loss-relation. Thus the former requires an accurate deterministic forecast and the latter a reliable ensemble forecast. For improvement of deterministic forecasts, identification of the source of errors is among the most important objectives. For ensemble forecasts, the initialization procedure has many challenges, and several methods should be investigated. Currently, ensemble forecasts is typically optimized for longer time windows (+48hrs and onwards) and is thus problematic to use. Assimilation of various observational data such as weather radar information and data from wind lidar may turn out to be important in short-range forecasting. This should be among the focus areas in future projects.

The reduction of budgets forced us to leave out some of the activities originally proposed, and the activity related to short-range forecasting has been cut.

Some initial activities will still be possible as resources have been moved from WP2. This part will include Artificial Intelligence (AI), which will be used to adjust model output to energy production at individual wind turbines. There is a natural link to WP4.1 (‘Nowcasting’) which will be exploited.

E 2 WP2 - Offshore wind technology and innovative concepts

The WP2 has the following sub-topics:
- WP2.1 Dynamic Response
- WP2.2 Innovative Concepts
- WP2.3 Component and Systems Development

E 2.1 WP2.1 Dynamic Response

The first sub-topic of this work package relates to the dynamical response of wind turbines and their operation in offshore wind farms. The objective is to improve the understanding of the dynamic response of a complete fixed or floating offshore wind turbine system subjected to wind, waves and current. A better understanding of the dynamical response will provide valuable information for design of single wind turbines; structures, mooring and anchoring; large wind parks; and instrumentation and control systems algorithms.

The environmental conditions due to wind, waves and currents need to be provided from observations and model simulations. The resulting loads on the structures and the dynamic response will be studied through development of comprehensive nonlinear models. The main goal is to understand the effect of gyroscopic loads, aerodynamic and hydrodynamic forces, and hence the dynamical behaviour of the systems in order to estimate load effects and instabilities.

E 2.2 WP2.2 Innovative Concepts

A number of ideas are expected to pop up within the industry, academia, as well as from private inventors. Promising new ideas should always be allowed to pass a first scientific evaluation, a so called *analytical proof of concept*, to actually classify how good the idea really is. NORCOWE gathers the expertise required for this sort of evaluation of all technological and operational elements. NORCOWE should therefore provide an arena for activities that stimulates and encourages the search for new and innovative solutions and concepts in the field of offshore wind technology. NORCOWE will be able through to look into new innovative concepts, and propose an appropriate development plan. This may include a first analytical proof of concept which involves the relevant expertise of the centre, formulation of a development plan, and participation in the further development by partners of NORCOWE as required.

E 2.3 WP 2.3 Component and Systems Development

This sub-task will focus on R&D activities related to existing technology and more mature concepts, i.e. solutions that have been through the initial proof of concept phase. We expect to work with a variety of promising technological solutions under this task over the coming years. One key challenge expected to be given much attention is the improvement of the stability of floating wind turbines through lighter gearbox design, hydraulic trasmission, new low speed generators, and possibly by positioning the gearbox and generator at, or below, sea level, but projects related to control systems and power transmission may also be included in this work package. The work will consider the interaction between the main components of the wind turbine, and the interaction between the main components and the surrounding environment (including the power grid, modes of operation, climatic conditions, and other factors).

E 3 WP3 - Offshore deployment and operation

WP3 is divided into the following tasks:

- WP3.1 Asset management
- WP3.2 Single turbine control systems
- WP3.3 Remote operation
- WP3.4 Marine operations

E 3.1 WP3.1 Asset management

Plan summary:

- Technical integrity through system design with focus on maintainability, operability, availability and supportability.

- Development of cost-optimal maintenance concepts based on real-time remote diagnostics and risk-based decisions.

- Technology for performing continuous maintenance based on measurements, failure modelling and signal processing.

- Technology for repairing and replacing damaged parts.

E 3.2 WP3.2 Single turbine control systems

Plan summary:

- Pitch and speed control based on model-based MIMO controller algorithms
- Effect of control algorithms on fatigue loading.

- Generic and time-averaged quasi-static flow modelling.

E 3.3 WP3.3 Remote operation

Plan summary:

- Communications infrastructure that is sufficiently flexible and a robust service platform that is sufficiently flexible, secure and easy to use.

- Optimisation of work processes, visualization and collaboration for remote operation for remote operations.

- Wind turbine management using decision support systems based on visualization techniques and performance predictions estimated from models and measurements.

E 3.4 WP3.4 Marine operations

Plan summary:

- Marine operations are connected to installation, interventions and decommissioning of offshore deep water wind energy concepts.

- Explore new technologies and operational concepts for these phases for present and new innovative concepts.

- In particular investigate the potential use of ballasting procedures combined with offshore service vessels.

- Risk and safety connected to these operations.

E 4 WP4 - Wind farm optimisation

The focus of WP4 is to optimize offshore wind farms with respect to turbine control systems, grid integration and farm layout; the main activities include:

- WP4.1 – Nowcasting (2-120 seconds)
- WP4.2 – Power system integration
- WP4.3 – Wind farm modelling

The modelling efforts focus on computational fluid dynamics (CFD), but other methods will also be employed.

E 4.1 WP4.1 Nowcasting

The measurements of the wind field upstream of the individual wind turbines may be carried out using Laser anemometry (Lidar). The technique provides a means to measure the line-of sight component of the wind speed via detection of the Doppler shift for light backscattered from natural aerosols (particles of dust, pollen, droplets) in the atmosphere. The basic underlying assumption that the aerosols accurately follow the flow is generally quite reliable, although precipitation represents a noteworthy exception.

Remote sensing information on upstream wind conditions and simultaneous wind speed and turbulence measurements locally at the turbines will be used for testing and calibrating realtime park-model calculations. Since the local measurements will be affected by the stagnation effect of the wind turbine rotor plane (the wind turbine thrust), detailed CFD simulations will be used to relate the locally measured wind speed and turbulent fluctuations to the free-stream velocity and turbulence viscosity needed in wake models for wind farm simulations.

Another approach that will be investigated involves the use of artificial intelligence (AI) to optimize systems for nowcasting.

E 4.2 WP4.2 Power systems integration

As many countries actively develop wind energy, the level of grid penetration for wind energy increases rapidly. The size of large-scale wind farms is generally increasing, and many largescale offshore wind farms are planned in Europe. A wind farm cluster may consist of dozens of integrated wind farms, with a total installed capacity of more than 1 TW. Massive implementation of wind energy will seriously impact the operation and control of the power grid, including stability and regulation of power, voltage, frequency, etc.

The overall aim of WP3.2 is to address these challenges and find technical solutions for the future. The approach adopted involves:

- Mathematical modelling and analysis
- Simulation models, system development and analysis
- Testing with the Real Time Digital Simulator (RTDS)

VSC-HVDC, FACTS technology and energy storage systems may provide effective ways of dealing with the challenges of large-scale wind farms integration. VSC-HVDC can for instance be used to improve the long-distance transmission capacity, and may simultaneously control the load flow in the grid. FACTS may be used to adjust voltage, impedance and phase angle, provide reactive power, etc. Energy storage devices can work as spinning reserves, to improve transient stability, to enhance transmission capacity and power quality management, etc.

E 4.3 WP4.3 Wind farm modelling

Each wind turbine in a wind farm generates a wake, and wind turbines within this wake experience lower wind speeds and increased turbulence intensity compared to unobstructed turbines. Power losses from wakes in wind farms are difficult to predict, and this effect is often underestimated with current models. The impact on the overall power output from a

wind farm is likely to be in the range 5-10 per cent or more.[2] Hence, there is an obvious need for improved predictive capabilities on the optimisation and layout of both onshore and offshore wind farms. This subtask is focused on developing and validating robust methods based on computational fluid dynamics (CFD) for modelling wake losses and power output from wind farms. Efforts will also be invested in bridging the gap between simpler engineering tools and CFD.
The CFD modelling will describe complex wake effects in offshore wind farms with multiple turbines (20-200), for various park layouts, and under changing wind and wave conditions.

This type of prediction is particularly valuable for offshore wind parks, because the performance of currently available analytical models is poor in the wake near the turbines, and because of the extended wake region in the marine boundary layer due to less intense turbulence offshore compared to onshore. On the scales that can be solved by using CFD for the entire wind farm, sub-models are needed for the wind turbines. Energy capture by wind turbines will be modelled with both the actuator disk approach and later the Blade Element Momentum (BEM) theory. The wake may be simulated directly by choosing a strategy for distribution of the velocity defect generated by the actuator disk or the blade elements downstream of the wind turbine, and by relating the turbulence production from the blades to the lift and drag coefficients of the blade elements as function of the local angles of attack and the relative velocities between blade elements and air and roughness of the blade element surfaces.

E 5 WP5 - Common themes

E 5.1 WP5.1 Education

A survey on relevant courses at the different university partners that could potentially be used for common interdisciplinary PhD education under all aspects of offshore wind energy research will be conducted. When the survey is completed, updating becomes part of Research School information centre and website. A one week summer school on LES simulation is scheduled in August 2010 and HAWC2 training course in Trondheim finished in March 2010 in cooperation with NOWITECH. A first joint meeting of all NORCOWE PhD students will be organized in May/June 2010 and a new seminar series "Geophysics of Renewable Energy" to be held at Geophysical Institute (UoB) in the autumn semester 2010.

National Research School on offshore wind energy applications will be organized in order to:

- Produce web overview of key and related course offerings and study councellors at participating partners
- Establish exchanges of students, teachers/supervisors and material with other institutions in Norway and abroad
- Develop new course offerings such as "Geophysics of wind energy", building upon strengths of staff at each institution and providing common background for PhD students from different institution.
- Establish forum for PhD students and supervisors

[2] EWEA (2009). *Wind Energy – the facts: a guide to the technology, economics and future of wind power*. European Wind Energy Association (EWEA). Earthscan, London. ISBN 978-1-84407-710-6.

E 5.2 WP5.2 Safety

A system for storage of ship drift data and relevant meteorological and oceanographic information will be developed, using GIS.

E 5.3 WP5.3 Environmental impact assessment

Vestavind Offshore was in September 2009 awarded the concession to build *Havsul 1*, a large offshore wind farm placed off Harøy in Sandøy municipality. Together with *Vestavind Offshore* and ecologists at CEDREN/NINA we are working to develop an Environmental Monitoring Plan (EMP) for the wind farm. It is anticipated that this EMP will set a standard for future offshore wind farms and that data generated by the EMP will be of great importance for research projects on short and long term environmental impact from Norwegian offshore wind farms.

An Offshore Wind Farm Marine Environment Impact Seminar to address research opportunities within the field of marine ecology is scheduled in May 2010. This is a one-day seminar with about 8 talks and a total of 30 participants.

E 5.4 WP5.4 Test facility and infrastructure

The turbulence structure in the marine atmospheric boundary layer, especially in the presence of ocean waves, is not well documented by measurements. The main goal of this project is therefore the development, test and operational deployment of a measurement system that will enable the direct measurement of the turbulence structure and the corresponding heat and momentum fluxes directly over the sea surface, by adapting a well established system of a sonic anemometer to a potentially moving platform, e.g. a buoy. To start with the system integration and corresponding laboratory tests as soon as possible the required instrumentation is highly prioritized.

Characterization of the marine boundary layer for offshore wind energy applications is supposed to be the main meteorological project; it includes the 4 year Post doc position at UoB and the purchase of a SODAR RASS system for measurements of wind, temperature and humidity profiles up to several hundredth of meters (in extreme cases above 1 km).. It will start with the collection and evaluation of archived met-ocean data, e.g. from platforms of the NORCOWE industrial partners or from other research data bases (e.g. the German FINO-platforms) with respect to offshore wind energy applications.

In this project available MBL data from various experiments and continuous measurement programs (including e.g. offshore wind and wave information from NORCOWES industrial partners measured in the past on oil or gas installations) will be collected, evaluated and analyzed with respect to their information content for mean wind and turbulence characterization relevant for wind energy applications. Based on these data the subproject will in close cooperation with WP1 identify the most obvious data gaps and work consequently towards targeted measurement campaigns and novel measurement strategies to close those gaps as far as possible.

In oceanic measurements we will utilize the primary measurement platform envisaged in NORCOWE to conduct oceanic measurements in the upper ocean boundary layer. The long-term goal of SP6 is to improve the understanding of the surface boundary layer and its representation in numerical models in the form of validated parameterizations. To this extent, we will use the available expertise at the Geophysical Institute on fine to small scale ocean measurements and theoretical and numerical methods in air-sea interaction.

The ocean surface is a complex boundary where air-sea fluxes of mass, momentum, and energy take place and its dynamics is of crucial importance for ocean circulation and ecosystems in general, and for the structural behaviour and fatigue of off-shore wind turbines in particular. It is a significant strength in WP5 that oceanic and atmospheric observations can be coupled to describe the complete boundary layers on both sides of the ocean surface. This subtask will address varying aspects of the ocean boundary layer dynamics and air-sea exchange in several projects throughout NORCOWE's duration, each with relevant objectives and scientific goals.

Movements of instruments and measurement platforms, which will be unavoidable on floating platforms which move with the waves, often bias the measurements, even if instantaneous motions of the platform are corrected for. These wave- and motion-induced effects may be allowed for by running full computational fluid dynamics (CFD) models, but it is also possible to correct field observations using simpler perturbation-based techniques which are valid to second-order in wave slope or platform displacement amplitude.

We plan to conduct dedicated turbulence and fine scale measurements in conditions covering calm to severe wind events in both fixed and moving platforms and analyze the data to describe the link between forcing and turbulent mixing in the surface boundary layer. For each relevant observed physical variable (current, turbulent kinetic energy, turbulent momentum/heat flux etc.), estimates of the effect of surface waves, wave-induced oscillatory currents, and platform motion will be calculated.