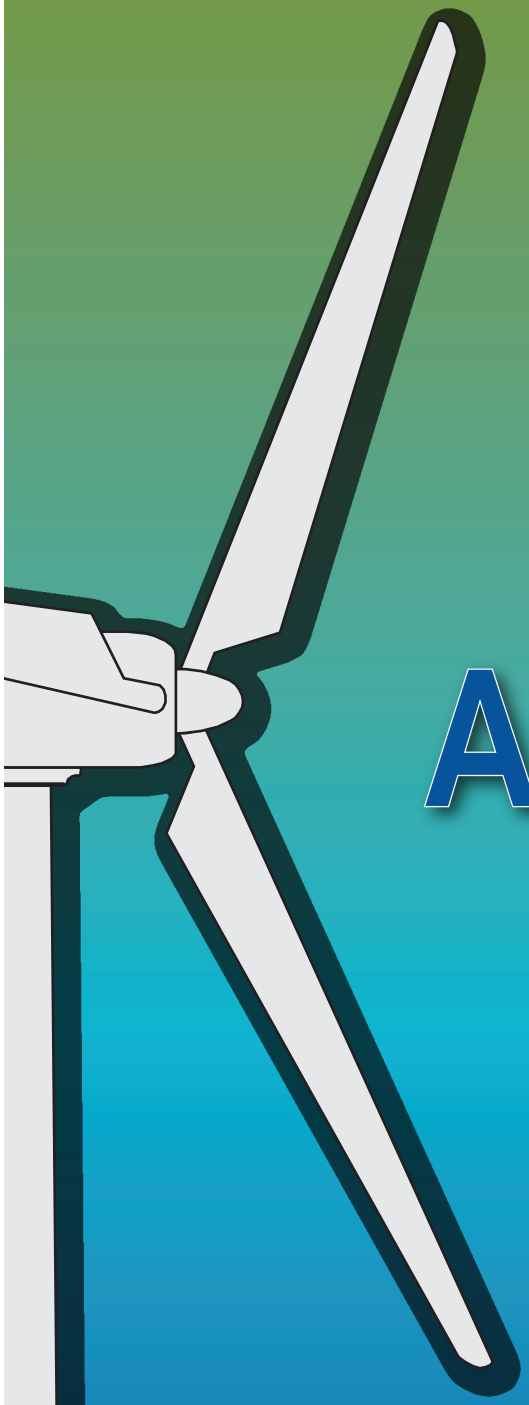

Annual report 2010

NOWITECH

Norwegian Research Centre for Offshore Wind Technology

www.NOWITECH.no

NOWITECH Annual Report 2010

March 2011

Editorial: Nils Arild Ringheim and John Olav Tande

Contribution from the following members of the Centre Management Group:
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SUMMARY

NOWITECH's vision is to contribute to large scale deployment of deep sea offshore wind turbines, and to be an internationally leading research community on offshore wind technology enabling industry partners to be in the forefront.

The objective is to provide pre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on "deep-sea" (+30 m) including bottom-fixed and floating wind turbines.

The research activities are organised into six work packages (WP):

- WP 1: Development of integrated numerical design tools for novel offshore wind energy concepts.
- WP 2: Investigation of new energy conversion systems for offshore wind turbines.
- WP 3: Analysis of novel substructures (bottom-fixed and floaters) for offshore wind turbines.
- WP 4: Assessment of grid connection and system integration of large offshore wind farms.
- WP 5: Development of operation and maintenance (O&M) strategies and technologies.
- WP 6: Assessment of novel concepts for offshore wind turbines by numerical tools and physical experiments, hereunder developing control systems and combining results from WP1 and WP5.

NOWITECH is organized with a General Assembly (GA), a Board, a Centre Director, a Scientific Committee (SC), a Committee for Innovation and Commercialisation (CIC) and a Centre Management Group (CMG).

Industry involvement is given high priority. The industry parties participate by in-kind supplies and direct involvement in WP and CIC activities. All industry parties are represented in the GA and the industry parties are active and in majority in the Board. The CIC is enhancing the industry involvement and making sure that results from NOWITECH are communicated to the industry parties, and that the possibilities for establishing new projects, products, services or processes with one or more partners are pursued. Commercialisation is by transfer of knowledge to the industry parties and their use of this in developing their business, through spin-off projects and creation of new industry. A number of spin-off projects have been created, and one new company is in planning.

The SC is developing a top quality PhD and post doc programme in collaboration with the CMG. A total of 18 PhD students and 3 post doc students have started. The SC has also started a research school to enhance the quality of education and research.

The main activities in 2010 were:

- Completing state-of-the-art reports on main issues in the work packages, more specialised publications and others; in total 97 publications.
- Software development and application for design and analyses of offshore wind technologies.
- Participating in national and international activities in order to influence future offshore wind research strategies, establish and maintain international R&D networks, and become a partner in new R&D projects on offshore wind energy.
- Collaboration with NORCOWE and CEDREN, incl. a joint application on Norwegian Offshore Wind Energy Research Infrastructure (NOWERI) has been granted by the Research Council of Norway.
- Preparation of industry meetings and workshops within all WPs, and organising, jointly with NORCOWE, an open Wind Power R&D seminar hosting some 200 delegates in Trondheim.

Two new industry parties joined NOWITECH in 2010; EDF R&D (France) and GE Wind (Norway).

The accumulated costs in 2010 was NOK 47,7 millions co-funded by the Research Council of Norway, the industry parties and the research parties.

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1 VISION AND OBJECTIVE

VISION

- Contribute to large scale deployment of deep sea offshore wind turbines
- Be an internationally leading research community on offshore wind technology enabling industry partners to be in the forefront.

OBJECTIVE

Provide pre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on “deep-sea” (+30 m) including bottom-fixed and floating wind turbines.

Figure 1 Illustration of offshore wind turbines with different sub-structures, from left: mono-pile, jacket and floating spar.

2 RESEARCH PLAN AND STRATEGY

2.1 CHALLENGE AND POTENTIAL

The EU 2020 target implies a massive installation of offshore wind. A ballpark estimate is investments of NOK 750 billions for installation of offshore wind farms in European seas during the next 10 years. Only about 2 GW of offshore wind farms have so far been installed in Europe, and with the exceptions of HyWind, Alpha Ventus and Beatrice, all relatively close to shore using what can be called on-shore wind technology. See also Figure 2.

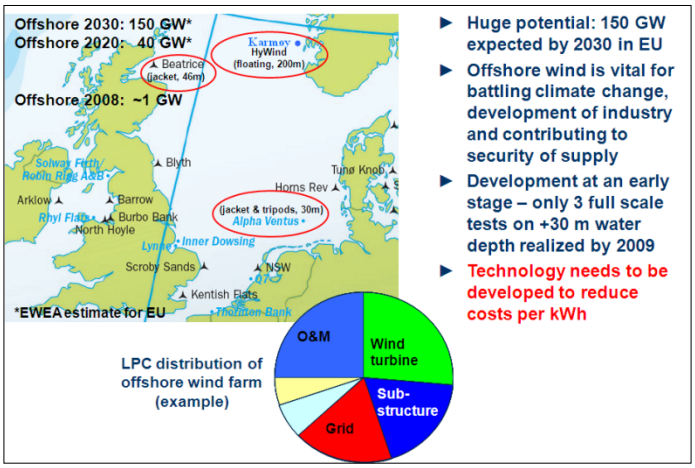


Figure 2 Strong motivation for research efforts on offshore wind technology.

The potential for wind farms at deeper water is huge provided that costs can be reduced to a competitive level. This requires development of offshore technology, and within this field Norwegian industry and research units are in the forefront. Examples are jacket design by Owec Tower for the Beatrice wind farm, manufacturing of tripods by Aker Solutions, and the floating concepts HyWind, SWAY and WindSea (see Figure 3). Considerable research efforts are needed to support this development.

New offshore wind farms are expected to be large, e.g. Dogger Bank is planned for 9 GW and located 125 to 195 km from shore. The environmental conditions here differ considerably from standard onshore conditions and new different design specifications have to be taken into account. This gives a basis for development of novel wind turbine concepts optimized for operation at rough off-shore conditions. The distant offshore location and size of installations further calls for development of new systems for maintenance, grid connection and system integration.

Figure 3 Floating concepts, from left: HyWind, SWAY and WindSea.

2.2 NOWITECH'S APPROACH

The Centre comprises interdisciplinary tasks that are required for successful development of offshore wind farms. Emphasis is on "deep-sea" (+30 m) including bottom-fixed turbines and floaters. The Centre will

- Combine wind technology know-how with offshore and energy industry experience to enhance development of offshore wind.
- Establish a recruitment and educational programme that provides for highly qualified staff at Master and PhD level for serving the industry.
- Build strong relations with selected top international research partners.
- Facilitate active involvement by industry partners to ensure relevance and efficient communication and utilization of results.
- Support to industry is through pre-competitive research – commercial development will come as a result and be run in separate projects.
- Actively pursue opportunities to increase R&D activity on critical issues.

The research is carried out in six work packages (WPs):

- WP 1: Development of integrated numerical design tools for novel offshore wind energy concepts. The goal is establishment of a set of proven tools for integrated design of deep-sea wind turbines, hereunder characterization and interaction of wind, wave and current.
- WP 2: Investigation of new energy conversion systems for offshore wind turbines. The goal is to contribute to the development of efficient, low weight and robust blade and generator technology for offshore wind turbines.
- WP 3: Identification and assessment of novel substructures (bottom-fixed and floaters) for offshore wind turbines. The goal is to pin-point cost-effective solutions for deep-sea wind turbines.
- WP 4: Assessment of grid connection and system integration of large offshore wind farms. The goal is to develop technical and market based solutions for cost-effective grid connection and system integration of offshore wind farms.
- WP 5: Development of operation and maintenance (O&M) strategies and technologies. The goal is to develop a scientific foundation for implementation of cost-effective O&M strategies and technologies for offshore wind farms.
- WP 6: Assessment of novel concepts for offshore wind turbines by numerical tools and physical experiments, hereunder developing control systems and combining results from WP1 and WP5. Assessment is by numerical tools and by utilizing "in-house" labs and results from full scale field tests (e.g. HyWind).

The WPs are closely interlinked (Figure 4) with a joint aim to provide new knowledge, tools and technologies as basis for industrial development of cost-effective offshore wind farms at deep sea. The research is mainly of pre-competitive nature including a strong PhD and post doc programme. Dissemination of results are through international conference papers, continuation and development of the established yearly wind R&D seminar in Trondheim, work-shops for industry and public bodies, newsletters and web.

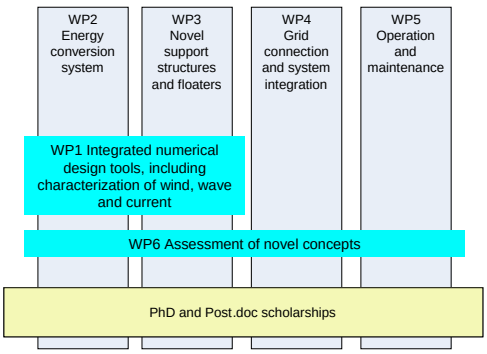


Figure 4 Interplay between work packages

Work is carried out in coordination with the two other CEERs (Centres for Environmental Energy Research; in Norwegian: FME) on offshore wind, CEDREN and NORCOWE. Together, the three centres contribute to a strong research effort on offshore wind, see Figure 5. There is, however, still need for further increase in the research efforts. NOWITECH will in coordination with CEDREN and NORCOWE continuously seek opportunities to establish new research projects, research infrastructure as well as test and demonstration projects.

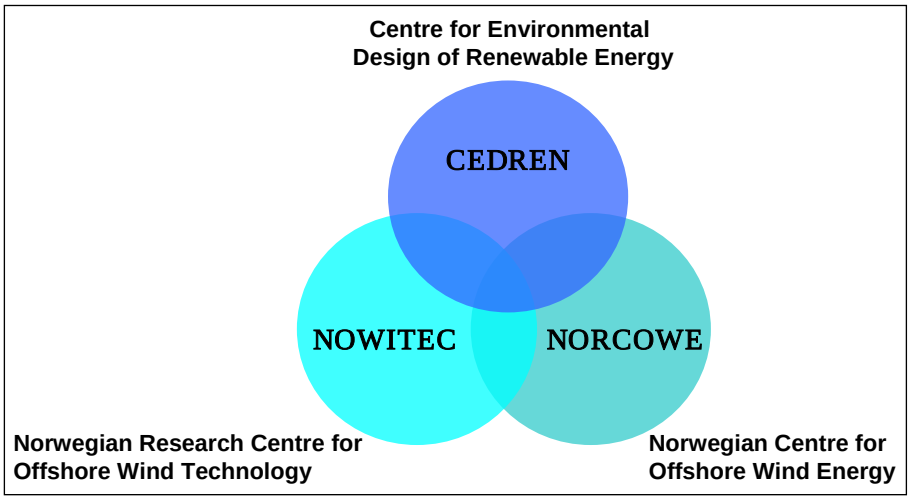


Figure 5 The three CEERs constitute a strong cluster on offshore wind.

3 ORGANISATION

3.1 GOVERNANCE STRUCTURE

NOWITECH is organised as shown in Figure 6.

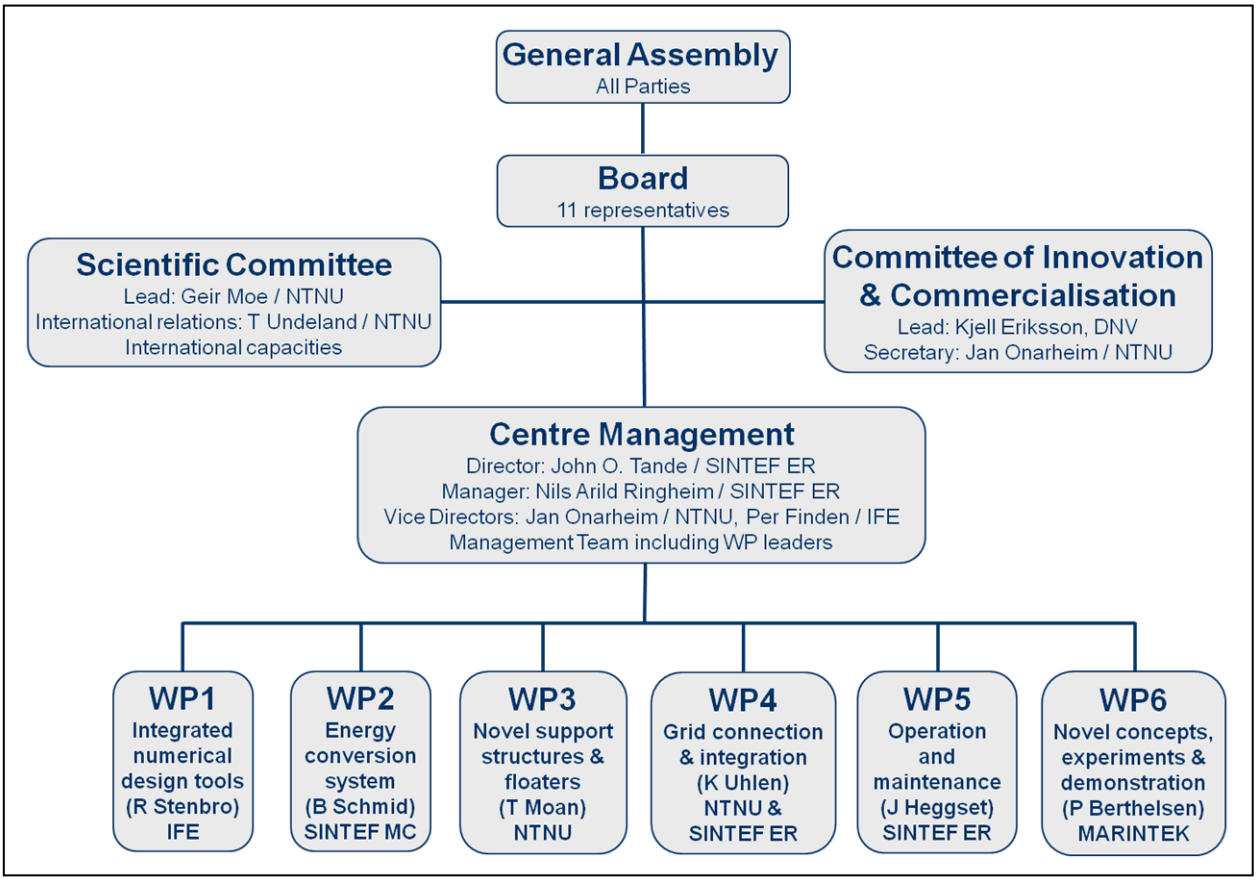


Figure 6 Outline of governance structure for the NOWITECH Consortium.

The General Assembly is the ultimate decision making body of the Consortium where all partners are represented.

The Board is the operative decision-making body for the execution of the Consortium with 11 members: 8 from industry, one from SINTEF, one from NTNU and one from IFE.

Industry partners are involved through representation in General Assembly and Board and through direct involvement in the Work Packages and their reference groups.

The host institution, SINTEF Energy Research, has John Olav Tande as the Centre Director.

NOWITECH is managed by the Centre Director in close cooperation with the Centre Management Group (CMG). The CMG consists of the Centre Director, Centre Manager, two Vice Directors, the Work Package leaders, representatives from the Scientific Committee and Committee for Innovation and Commercialisation and other staff appointed by the Centre Director. The CMG meets on a regular basis, at least once a month.

3.2 SCIENTIFIC COMMITTEE

The Scientific Committee (SC) is developing a top quality PhD and post doc programme in collaboration with CMG. This includes an active recruitment strategy, invitation of international capacities for giving lectures, arrangements of scientific colloquia and seminars, and exposing scholars to industry and leading international research groups. The members of the SC are listed below:

- NTNU-members
  - Geir Moe, (chairman)
  - Tore Undeland, NTNU (international relations)
  - O.G. Dahlhaug, NTNU
  - Trond Kvamsdal, NTNU
  - Torgeir Moan, NTNU
  - Marta Molinas, NTNU
  - Jan Onarheim, NTNU
  - SC Secretary, Debbie Koreman, NTNU
- Other Norwegian members
  - Tor Anders Nygaard, IFE
  - Ivar Langen, UiS
  - Finn Gunnar Nielsen, Statoil
  - Terje Gjengedal, Statnett
- Associated members
  - Paul Sclavounos, MIT, USA
  - Amy Robertson, NREL, USA
  - Peter Hauge Madsen, Risø-DTU, Denmark
  - Hans-Gerd Busmann, Fraunhofer IWES, Germany
  - William E. Leithead, Strathclyde University, UK
  - Gerard J.W. van Bussel, TU Delft – Aerospace Engineering Wind Energy (DUWIND)

Figure 7 Picture from meeting in SC with international experts.

3.3 COMMITTEE FOR INNOVATION AND COMMERCIALISATION

The Committee for Innovation and Commercialisation (CIC) enhances industry involvement, ensures industry relevance within the research of NOWITECH, pursues possibilities for establishing new projects, services or processes with partners and contributes to commercialisation of relevant ideas created in NOWITECH. The committee is industry driven and the members of the CIC are listed below:

- Chairman: Kjell Eriksson, DNV

- Secretary: Jan Onarheim, NTNU
- Other participants:
  - Jørn Holm, Dong Energy
  - Kjell Olav Skjølsvik, ENOVA
  - Inger Marie Malvik, Fugro OCEANOR
  - Kristian Holm, GE Wind Energy
  - Bergny Irene Dahl, Innovasjon Norge
  - Kurt Benonisen, NTE
  - Oddbjørn Malmo, NCE Instrumentation
  - Gard Hansen, NTNU
  - Marianne Ryghaug, NTNU
  - Per Arne Wilson, NTNU
  - Lars Øystein Widding, NTNU Entrepreneurship Centre
  - Annemarie Seterlund, Statkraft
  - Elly Karlsen, Statoil
  - Erik Wold, TTO/NTNU (representing SINVENT and Campus Kjeller)
  - Edgar Kvernevik, Vestavind Kraft

3.4 NOWITECH PARTNERS

The NOWITECH Consortium Partners in 2010 are listed below:

The Host Institution:	SINTEF Energy Research
Research Partners:	Norwegian University of Science and Technology (NTNU) Institute for Energy Technology (IFE) Norwegian Marine Technology Research Institute (Marintek) Stiftelsen SINTEF (SINTEF)
Industry partners:	Aker Solutions Devold AMT AS Det Norske Veritas AS (DNV) DONG Energy Power AS EDF R&D Division Fugro OCEANOR AS GE Wind Energy (Norway) AS Lyse Produksjon AS NTE Holding AS SmartMotor AS Statkraft Development AS Statnett SF Statoil Petroleum AS TrønderEnergi Kraft AS Vestas Wind Systems AS Vestavind Kraft AS

In addition NOWITECH has agreements on cooperation with the following associate partners:

Associate research partners:	Massachusetts Institute of Technology (MIT), USA National Renewable Energy Laboratory (NREL), USA Risø-DTU, Denmark Fraunhofer IWES, Germany University of Strathclyde, UK TU Delft, Netherlands
Associate industry partners:	Innovation Norway, Enova, NCE Instrumentation, NORWEA, NVE, Energy Norway, Navitas Network

4 SCIENTIFIC WORK AND RESULTS

This section presents the objectives and tasks of the existing work packages (WP) in NOWITECH as well as some of the results achieved in 2010.

4.1 MANAGEMENT AND COORDINATION (WP 0)

The objective is to manage and coordinate the activities of NOWITECH, ensuring progress and cost control according to approved plans.

The Work Package is divided into four tasks:
0.1 Start-up of centre (Completed)
0.2 Management
0.3 Outreach activities
0.4 Integration activity

The Management activity takes care of the day-to-day operation of the Centre. This includes follow up on administrative, financial and legal issues, meetings in the CMG with WP leaders and representatives from the SC and CIC, preparations for the GA and Board, reporting to the RCN etc.

CMG meetings have been held about once every month to a total of twelve for 2010. These are mainly for team-building, information exchange and strategic discussions. In addition web-based meetings are held between the WP leaders about every week for follow up on day-to-day business and administrative issues.

Two Board meetings were held in 2010, i.e. one in June and one in November. Both meetings were combined with a workshop the day before with presentations of the WPs. The Board generally recognised the good progress of NOWITECH. The work plans for 2011 were approved by the Board during the meeting in November.

A GA meeting was held in November 2010. This was held in combination with the Board meeting and workshop. During this meeting the GA decided that GE and EDF join the Board and replaces Aker Solutions and NTE from 1 January 2011.

Contact by e-mail and electronic voting have been applied between the Board and GA meetings for approval of new industry parties, etc.

The research parties of NOWITECH very much appreciate the active participation of the industry parties in the GA and the Board.

The Outreach activity includes preparing general presentations of the Centre, keeping contact with prospect new industry parties, overall coordination towards other projects and CEER's, in particular CEDREN and NORCOWE, and engagement in developing offshore wind projects and research strategies.

The activity on industry parties resulted in that EDF R&D (France) and GE Wind Energy (Norway) joined NOWITECH in 2010.

Examples of engagement in developing offshore wind projects and research strategies are:
- participation in the task force on wind energy in Energi21 suggesting future research strategy for wind energy in Norway,
- contributing to outlining the need for offshore wind demonstration projects suggesting Demo2020,
- participation in the European Technology Platform on Wind (TPwind) and
- taking a lead in developing the sub-programme on offshore wind energy in the European Energy Research Alliance (EERA) joint programme on Wind Energy.

International engagement is further described in section 5.

Close cooperation with CEDREN and NORCOWE is established. Examples of cooperation are:

- A joint application with NORCOWE and CEDREN on Norwegian Offshore Wind Energy Research Infrastructure (NOWERI) has been granted by the Research Council of Norway. The infrastructure will include a floating met-mast and a floating wind turbine as platform for open research. The project is now in a pre-engineering phase expecting installation in two years time.
- NOWITECH and NORCOWE jointly organized a Wind Power R&D seminar hosting some 200 participants in Trondheim, January 2010.
- Meetings between the management of NORCOWE, CEDREN and NOWITECH for overall coordination, information exchange, etc.
- Various joint workshops and meetings between the researchers as part of the activity of the scientific WPs.

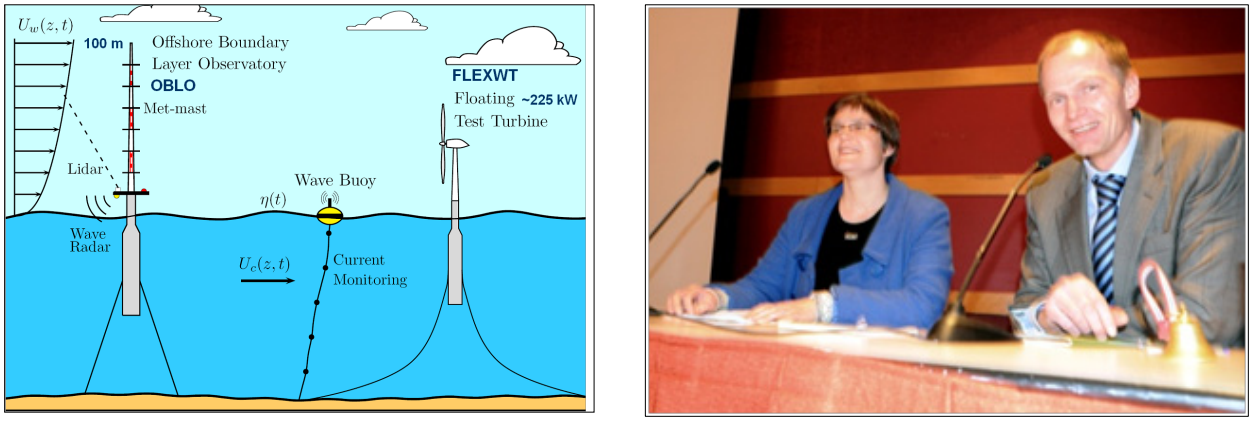


Figure 8 Examples of cooperation between NOWITECH and NORCOWE. Left: Sketch of joint research infrastructure (NOWERI). Right: Kristin Guldbrandsen Frøysa (NORCOWE) and John Olav G Tande (NOWITECH) were co-chairing the Wind Power R&D seminar in Trondheim, January 2010.

The integration activity is for enhancing cooperation between the WPs. This is expected to give significant added value compared to running the WPs as separate projects. It shall improve the common understanding of challenges and their interplay between the WPs, and may potentially lead to new innovative ideas and solutions that exist in the boarders of a traditional split between the engineering sciences. Whereas the regular management secure the general coordination and information exchange between the WPs, the integration activity is set-up to enhance this. This activity was initiated by the Board in mid 2010, and has been starting up with an internal strategic seminar, engagement of the SC on reviewing WP progress and initiation of cross WP publications.

Several spin-off projects have arisen from the NOWITECH consortium, see chapter 4.9.

4.2 INTEGRATED NUMERICAL DESIGN TOOLS (WP 1)

The objective is establishment of a set of proven offshore wind turbine simulation tools for integrated design of deep-sea wind turbines, hereunder enhanced knowledge of wake, wind, wave and current.
The WP is divided into two tasks.

1.1 Software development
1.2 Wake, wind, waves and ocean current

WP1 will develop software that accurately simulates the behavior of wind turbines. Such tools are vital to those doing research, development and engineering of whole wind turbines and its components. Tools for optimization of components and systems will also be developed. A research activity will be carried out on

the interaction of waves, current and wind, which is the origin of motion, loads and power output of an offshore wind turbine.

Major achievements/highlights:
- R&D in good progress with a strong involvement from both industry and research parties.
- First generation software for integrated simulations of offshore wind turbines developed and verified.
- Tools for optimization of spare type offshore wind turbines developed.
- Cooperating well with NORCOWE, including joint expert workshop on wakes at NTNU.

Three new PhD students have started in 2010 in addition to the one already engaged in 2009, see appendix A.1.3.

Both EDF and Fugro OCEANOR have industry in-kind contribution in WP1: EDF has delivered a report on modelling of the mechanical behaviour of offshore wind turbine structures in task 1.1 and Fugro OCEANOR has contributed to task 1.2 with report and software for offshore wind recourses.

Industry involvement is shown in section 4.8.

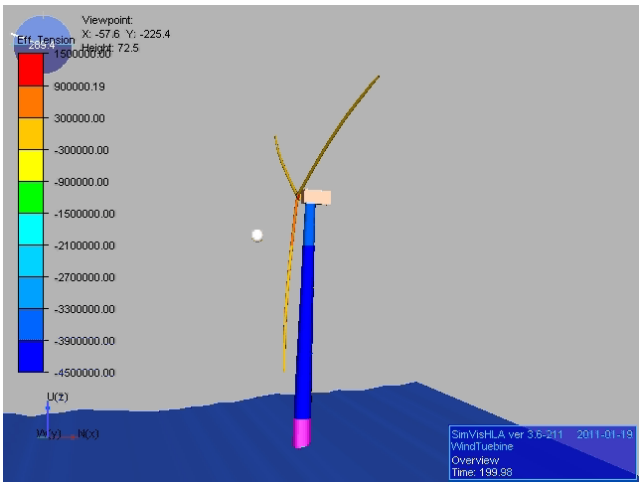


Figure 9 Example of simulation result from integrated numerical model of floating wind turbine.

4.3 ENERGY CONVERSION SYSTEM (WP 2)

The objective is to contribute to the development of efficient, low weight and robust blade and generator technology for offshore wind turbines.

WP2 is organised in two tasks:
2.1 Rotor blades
2.2 Generators

The energy conversion system of the offshore wind turbines being installed today are basically as for onshore wind turbines. The expectation is that significant life-cycle cost reductions can be achieved by developing an energy conversion system specifically for offshore conditions. The research activities given in WP2 are defined in order to “bridge” the competence gaps and to create a basis for innovation necessary to move beyond the today’s “show stoppers” that the industry is facing. Emphasis in WP2 is on the rotor blades (Task 2.1) and generators (Task 2.2), searching for lightweight and robust solutions.

A state of the art report on “Smart blades – adaptive technology for rotor blades” has been published. A workshop on “Generator design and experience based on Norwegian industry/research in hydroelectric power” was held in July 2010.

One PhD student on “Lift control of wind turbine blades” started in November 2010. A second PhD student on “Novel generator concepts” and a Post Doc on “Influence of material and process parameters on fatigue of wind turbine blades” proceeded with their work in 2010. A third PhD student on “Magnetic forces and vibrations in wind power generators” is expected to start in January 2011.

Devold AMT and SmartMotor are industry partners involved in WP2. Both companies spent their full NOWITECH contribution on WP2 in 2010.

Devold AMT participated in work meetings in task 2.1 “Rotor blades”. In addition the company has been supplying a huge variety of test samples. The samples have also been sent to different test institutes in Europe for comparison and benchmarking with NOWITECH results.

SmartMotor contributed with valuable information in task 2.2 “Generators”. Besides development of Computer Aided Engineering methods and tools for design of radial-flux PM generators, personnel were engaged in preparation of the generator workshop and contributed to the NOWITECH R&D seminar. Two conference contributions on design of permanent magnet generators for wind turbines were prepared for presentations at conferences in 2011.

Industry involvement is shown in 4.8.

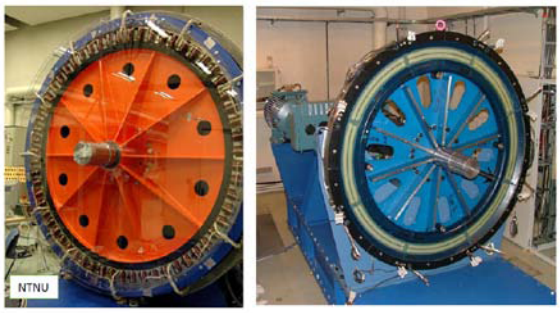


Figure 10 Lab-scale PM generators at NTNU (left) and SmartMotor (right).

4.4 NOVEL SUPPORT STRUCTURES AND FLOATERS (WP 3)

The objective is to develop novel, cost-effective support structures and floaters for deep-sea wind turbines.

Three tasks are defined:
3.1 Bottom-fixed support structures
3.2 Floating support structures
3.3 New coatings

WP3 deals with the analysis and design of bottom-supported and floating support structures for wind turbines. The purpose is in particular to assess design criteria, establish benchmark analysis procedures for evaluating the structural effects of wave, current and wind loads on different wind turbine concepts. This WP also includes assessment of existing and novel coatings for surface protection of offshore wind turbine support structures. This research in this WP will be based on experiences gained in other marine industries, especially the oil and gas industry in combination with land-based wind turbine technology to generate the unique information needed when the wind turbine industry moves offshore.

The work in 2010 included work on assessing tools applicable for design analyses of floating and bottom-fixed offshore support structures for wind turbines. This work involves engagements in the IEA Benchmark studies on Spar turbines and initial work on jacket turbines. In addition, NTNU partners on WP3 tasks 3.1 and 3.2 are involved in an EC FP7 project: The Orecca and Marina Platform project. The purpose of these projects is to investigate the synergy between wind and wave energy and they both had kick-off in the first quarter of 2010. The NTNU partners in Tasks 3.1 and 3.2 are also involved in the EC

project HiPRwind, which deals with design and testing of a floating wind turbine. The state of the art report on coatings for corrosion protection, erosion protection and anti-icing/anti-soiling properties has been completed.

A fourth PhD student was engaged on this WP in 2010. The fifth PhD candidate will start in August 2011, see appendix A.1.5.

Industry involvement is shown in Section 4.8.

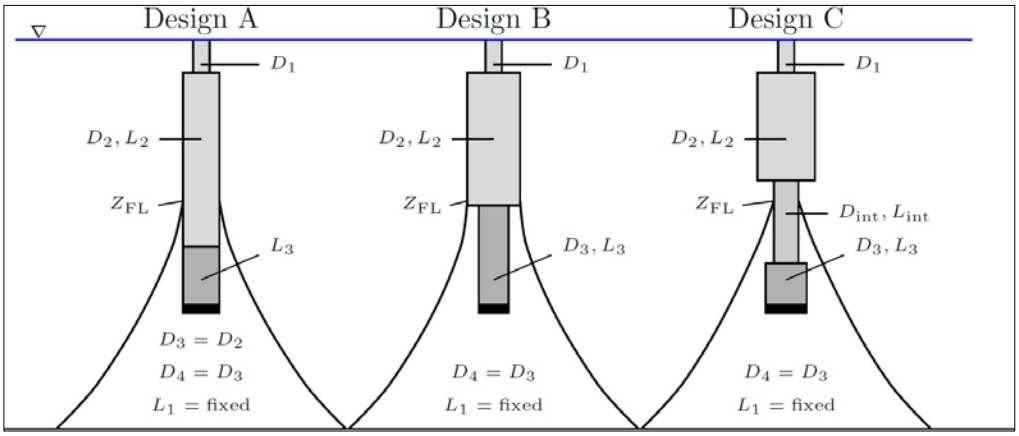


Figure 11 Example of different floating support structure designs for deep water wind turbines carried out in NOWITECH.

4.5 GRID CONNECTION AND SYSTEM INTEGRATION (WP 4)

The objective is to develop technical and market based solutions for cost effective grid connection and system integration of offshore wind farms.

The work is divided into three tasks:
4.1 Internal electrical infrastructure for offshore wind farms
4.2 Grid connection and control
4.3 Market integration and system operation

Offshore wind power is of little value unless the power plants are well integrated in the power system and able to compete successfully in the electricity market. This requires cost effective solutions on grid connection and system integration that will contribute to attract investments in offshore wind. The research activities in WP4 aim to remove barriers and close competence gaps on grid connection solutions, wind farm operation and control concepts, market design and regulatory issues. The main focus is on system analysis and model developments for simulation of wind farm operation and control. Moreover, models are developed for grid design and analysis in order to make recommendations on market adaptations and regulatory framework.

Main achievements in 2010 are related to wind farm measurements and model validations for power system studies, feasibility studies on integration of offshore wind farms with offshore platforms and further development and use of numerical tools for offshore grid design and analysis:

- Ongoing measurement campaigns have provided very good information about performance of existing wind farms related to power system behaviour, including power variations and voltage quality issues. Promising results have been obtained on wind farm model validation based on measurements.
- Promising results are obtained on modelling of a 100 MW offshore wind farm in an offshore grid connected to five oil and gas platform.
- Numerical tools for offshore grid design and power market analysis (PSST and Net-op) have been extensively used within related R&D projects (KMB and EU-projects). The PSST simulation tool has been further improved, including connections to SINTEF model EMPS and models from NTNU for

analysing the Northern European Regulating Power Market. Improved wind series are being implemented with assistance from Kjeller Vindteknikk AS (sub-contracted).

Two journal papers are written and accepted in 2010 ("Integrating wind power with offshore oil and gas platforms" /Wind Engineering and "Optimal design of a sub-sea power grids" /Wind Energy). In addition there have been several conference papers and presentations on offshore grid analysis and multi-terminal HVDC operation and control.

One Post doc has started in 2010, see appendix A.1.3 while another PhD student is appointed and will start early 2011.

The industry partners with main interests in this WP are primarily Statnett, Statkraft, Statoil, Vestavind Kraft, Dong Energy, GE, DNV and Aker Solutions. Industry involvement is shown in 4.8.

4.6 OPERATION AND MAINTENANCE (WP 5)

The objective is to develop a scientific foundation for implementation of cost-effective O&M concepts and strategies for offshore wind farms, taking into account the whole life cycle of the equipment. This will be achieved through the following secondary goals:

- Development and adaption of methods and tools for assessing optimal O&M strategies, with particular emphasis on condition based maintenance
- Assessment of low-cost and efficient surveillance and condition monitoring concepts
- Analyses of various access methods and assessing their impact on the maintenance opportunities and O&M costs
- Development and adaption of methods and tools for assessing optimal logistics strategies

The work is divided into four tasks:

5.1 Maintenance strategies
5.2 Surveillance and condition monitoring
5.3 Access and logistics techniques
5.4 Experience/data

Major achievements/highlights:

- A comprehensive review of models and tools for O&M decisions has been carried out and documented. A review paper on this topic to Journal of Wind Engineering has been accepted for publication. The LCP concept has been described.
- A prototype for remote inspection has been developed, and a state of the art document on condition monitoring methods has been published.
- State-of-the-art for maintenance of coatings and surface protection has been published.
- O&M experiences from the oil and gas industry are presented and the relevance for offshore wind farms has been discussed. The focus has been on materials, coatings and surface treatments.
- Data relevant for O&M of offshore wind turbines has been collected (from open sources), and challenges in RAMS data collection has been addressed.
- 6 conference papers have been published and presented, 2 journal papers have been published/accepted, and 1 more has been submitted for review.
- Joint collaborations/applications with European research institutes, see 5.2.

PhD status:
One PhD candidate started in 2009, and two in 2010. One more PhD position has been advertised and candidates are being reviewed for this.

Industry involvement is shown in Table 1 in Section 4.8.

Figure 12 A prototype of a robot system for remote inspection has been developed in WP5.

4.7 ASSESSMENT OF ALTERNATIVE DESIGN CONCEPTS (WP 6)

The objective is to develop and assess novel concepts of deep-sea wind turbines by numerical tools and physical experiments, hereunder developing control systems and combining results from WP1 to WP5. Assessment is by numerical tools and by utilizing "in-house" labs and results from full scale field tests.

The work is divided into three tasks:
6.1 Development of advanced control system
6.2 Assessment of alternative and novel design concepts
6.3 Experiments and demonstration

New improved concepts and technologies for offshore wind turbines should be developed by combining wind and offshore oil and gas experience. Robust and reliable technology is of paramount importance in order to keep repair and maintenance costs down. Conceptual design studies, exploring the interaction between the energy conversion, support structure and control system, should be carried out in order to minimize life cycle costs. Therefore, proper tools for these integrated design studies must be developed (WP1) and validated with experiments. Further, applying smart control systems for load mitigation and structural stabilization is also a key for cost reduction.

The 2010 work focused on assessment of novel concepts, including a tension-leg-buoy floating wind turbine and optimization of spar-type floating wind turbine. This work has resulted in two conference papers that will be presented in 2011. Further, a survey of previous ocean basin experiments of floating offshore wind turbines has been performed.

The work package has also been involved in:
- Workshop organized by Statoil to discuss access to data from Hywind Demo.
- Meetings with NORCOWE to discuss possible cooperation on control system and marine operations.
- EERA meeting on offshore wind technology in Trondheim, 20 September
- IEA Topical Expert Meeting #63 on offshore wind technology, Trondheim 21-22 September
- EU FP7-ENERGY-2010-FET: DeepWind. Exploration and evaluation of a simple floating vertical axed offshore wind turbine.
- EU FP7-OCEAN 2011: The ocean of tomorrow – Multi-use offshore platforms (application)

There are 4 PhD-students/Post Docs engaged in this work package. Two PhD students and one Post Doc started in 2010.

Industry involvement is shown in 4.8.

Figure 13 The ocean basin lab at MARINTEK.

4.8 INDUSTRY INVOLVEMENT

Industry involvement is given high priority. The industry parties participate by in-kind supplies and direct involvement in WP and CIC activities. All industry parties are represented in the GA and the industry parties are active and in majority in the Board.

An overview of the NOWITECH partners' meeting attendance is shown in Table 1.

Table 1 Overview of meeting attendance by NOWITECH industry partners in 2010.

Partner	GA	Board	WP1	WP2	WP3	WP4	WP5	WP6	CIC	SC
Aker Solutions										
Det Norske Veritas	X	XX	**		XX	X	XX	**	XX	
Devold AMT				X						
DONG Energy Power	X		X		XX			X	X	
EDF R&D	X		*					*		
Fugro OCEANOR		X	X						X	
GE Wind Energy (Norway)	X					X	X		X	
Lyse Produksjon	X		X		X			X		
NTE Holding	X	X					XX		X	
SmartMotor				X						
Statkraft Development	X	XX	XX		XX	XX	X	XX	XX	
Statnett SF	X					XX				
Statoil Petroleum	X	XX	XX		XX	X	XX	XX	XX	
Trønder Energi Kraft	X									
Vestas Wind Systems	X	XX								
Vestavind Kraft			X*		X	X		X*	XX	

X = Participated on meeting (X = one meeting, XX = two meetings)
* = Partner did not have the opportunity to participate on industry meeting, but has communicated suggestions previous to the meeting
= Not relevant

The CIC is enhancing the industry involvement and making sure that results from NOWITECH are communicated to the industry parties, and that the possibilities for establishing new projects, products, services or processes with one or more partners are pursued. Commercialisation is by transfer of knowledge to the industry parties and their use of this in developing their business, through spin-off projects and creation of new industry.

The CIC cooperates with NTNU's Entrepreneurship School (NEC) and NTNU Technology Transfer (TTO) in commercialisation of ideas created in NOWITECH, while Innovation Norway and Enova assist CIC in project development between SMEs and NOWITECH industry partners. Examples of SMEs that received assistance from the CIC in 2010 are Windflip, Re-Turn, limSIM and W2Power.

A number of spin-off projects have been created (see next section), and one new company is in planning.

Figure 14 Two important persons in CIC management: CIC leader Kjell Eriksson, DNV, (left) and secretary Jan Onarheim, NTNU, (right).

4.9 SPIN-OFF PROJECTS

Many NOWITECH partners have participated in applications for national and international research projects in 2010. Table 2 shows a selection of some relevant projects where NOWITECH partners are involved.

Table 2 Overview of some projects (ongoing or about to be started) in 2010 where NOWITECH partners are involved. Projects directly funded from industry are omitted due to confidentiality.

Project title	Project type	Partners	Status
ORECCA (**O**ff-shore **R**enewable **E**nergy **C**onversion platforms **C**oordination **A**ction)	EU	Coordinator: Fraunhofer IWES. Partners: NTNU, LyseEnergi etc	Ongoing
Autonome målinger av vindprofil, strømprofil og bølger for kartlegging av energipotensialet, design og operasjon av vindmøller til havs	BIP	Coordinator: Fugro Oceanor. Partners:, StatoilHydro, MARINTEK, CMR, UiB GFI	Ongoing
Marine Research Infrastructures Network for Energy Technologies: MARINET	EU	Coordinators: HMRC University College Cork. Partners: SINTEF ER, NTNU etc.	Ongoing
Design and testing of large wind turbine blades	BIP	Coordinator: GE Wind Energy. Partners: IFE, MARINTEK etc	Ongoing
Role of North Sea power transmission in realising the 2020 renewable energy targets	KMB	SINTEF ER	Ongoing

Project title	Project type	Partners	Status
Korea – offshore wind	Industry	SINTEF MK, MARINTEK	Ongoing
Marine Renewable Integrated Application Platform (MARINA platform)	EU	Coordinator: Acciona, Partners: NTNU etc	Ongoing
Future Deep Sea Wind Turbine Technologies (DeepWind)	EU	Coordinator: Risø DTU. Participants: Statoil, SINTEF ER, MARINTEK etc.	Ongoing
High power, high reliability offshore wind technology (HiPRwind)	EU	Coordinator: Fraunhofer. Participants: SINTEF ER, NTNU etc.	Ongoing
Operation and maintenance (monitoring) of Off-shore wind parks (OMO)	EU Aerto	Coordinator Fraunhofer. Partner: SINTEF ER etc.	Ongoing
Grid integration of offshore wind farms	EU Aerto	Coordinator: SINTEF ER. Partners: VTT, Fraunhofer	Ongoing
Offshore Grids	EU IEE	Coordinator: 3E; Partners: SINTEF ER, + more	Ongoing
Twenties	EU FP7	Coordinator: Red Electrica; Partners: SINTEF Energy R, + more	Ongoing
Improving the availability of offshore wind turbines	BIP	Coordinator: GE, Partners: Statoil, NTE, SINTEF ER, MARINTEK	Approved, to be started in 2011
RAWi, Radio Acoustic Wind Sensor	BIP	Coordinator: Triad. Partners: IFE, UIB, Kjeller Vindteknikk, NORBIT	Ongoing
WindSpeed	EU IEE	Coordinator: ECN; Partners: SINTEF ER, + more	Ongoing
BALANCE – Norwegian hydropower as balancing services in Europe – opportunities and challenges	KMB	SINTEF ER, NTNU	Approved, to be started in 2011
Development of Grid Code Testing Methods (Grid Code Test)	Nordic	Coordinator: Chalmers. Partners: DTU, VTT, NTNU, TU Tallinn,	Applied for
PowerUP – Effektive verdikjeder for offshore vindmøller	Regionale Forskningsfond Midt-Norge	Coordinator: SINTEF Partners: NTNU, Høgskolen i Molde, Møreforskning	Approved

5 INTERNATIONAL COOPERATION

This section outlines NOWITECH's international cooperation in 2010.

5.1 INTERNATIONAL COOPERATION THROUGH SCIENTIFIC COMMITTEE

The Scientific Committee (SC) is made up by
- NTNU members
- Other Norwegian members
- Associated research members

The associated members of the SC are international experts on relevant topics within offshore wind. The associated research partners are represented by:
- Paul Sclavounos, MIT, USA
- Amy Robertsen, NREL, USA
- Peter Hauge Madsen, Risø-DTU, Denmark
- Hans-Gerd Busmann, Fraunhofer IWES, Germany
- William E. Leithead, Strathclyde University, UK
- Gerard J.W. van Bussel, TU Delft – Aerospace Engineering Wind Energy (DUWIND)

The SC accomplished two meetings in 2010 where the associated research partners participated. Among their role are visiting lectures, exchange of PhD candidates and evaluation of scientific results in NOWITECH.

The SC, lead by NTNU, was responsible for planning and execution of the EAWE 6th International PhD Seminar on Wind Energy in 2010 in Trondheim that received very good response from the participants.

5.2 INTERNATIONAL COOPERATION THROUGH WORK PACKAGES

Engagement in international projects, networks and applications, IEA cooperation and IEC standardisation are considered important for enhancing the quality of research within the WPs. Basically all WPs are involved, though with varying degree. Examples of international cooperation are:

- EERA (European Energy Research Alliance) Joint Programme on Wind Energy, SINTEF Energy Research is heading Sub Program on Offshore Wind Energy.
- EU FP7-ENERGY-2010-FET: DeepWind. Exploration and evaluation of a simple floating vertical axis offshore wind turbine.
- EU FP7-ENERGY-2010: HiPRwind
- EU FP7: Twenties
- EU FP7: Marine Renewable Integrated Application Platform (MARINA platform)
- EU FP7: ORECCA (Off-shore Renewable Energy Conversion platforms Coordination Action)
- EU IEE: Offshore Grids
- AERTO project OMO (Operation and Maintenance (monitoring) of Offshore wind parks). A 2 year project is started (Fraunhofer, VTT, TNO, SINTEF), and a first workshop with industry has been held.
- AERTO project Grid integration of offshore wind farms (Fraunhofer, VTT, SINTEF)
- IEA Wind Task 25: System operation (grid integration)
- IEA Wind Task 29 Mexnext: Analysis of wind turbine measurements
- IEA Task 30 OC4: Comparison of Dynamic Computer Codes and Models for offshore Wind Energy
- EU FP7-OCEAN 2011: The oceans of tomorrow – Multi-use offshore platforms (application).
- EU FP7: EERA-DTOC (application)
- EU TPwind, www.windplatform.eu (John Tande is Chairman of Working Group 4 "Offshore")
- EAWE, European Academy of Wind Energy, www.eawe.eu (represented in board)
- IEC TC88, www.iec.ch (SINTEF Energy Research is heading the Norwegian sister-organization NK88, and representing Norway in TC88)

6 RECRUITMENT

Eleven PhD and two post doc candidates started in 2010 with funding from NOWITECH, thus in total eighteen PhD and three post doc candidates are funded by NOWITECH, see Appendix A.1.5 and A.1.3. In addition, NTNU has 21 PhD and 7 post doc candidates with funding from sources outside NOWITECH working on topics related to offshore wind and are associated to the NOWITECH research team. See appendix A.1.6 and A.1.4.

A research school for offshore wind power has been started by the Scientific Committee. The research school has the goal to improve the quality of research within the field of Offshore Wind Power. In 2010 a seminar on electrical issues (rotor, control system and grid) was organized. Furthermore, two international experts have given lectures on respectively wind turbine design and operation, and rotor design trends (Gerard J.W. van Brussel and Peter Jamieson).

During 2010, professors and scientific staff at NTNU with relations to NOWITECH were supervisors for 17 Master Degree theses. See appendix A.1.7.

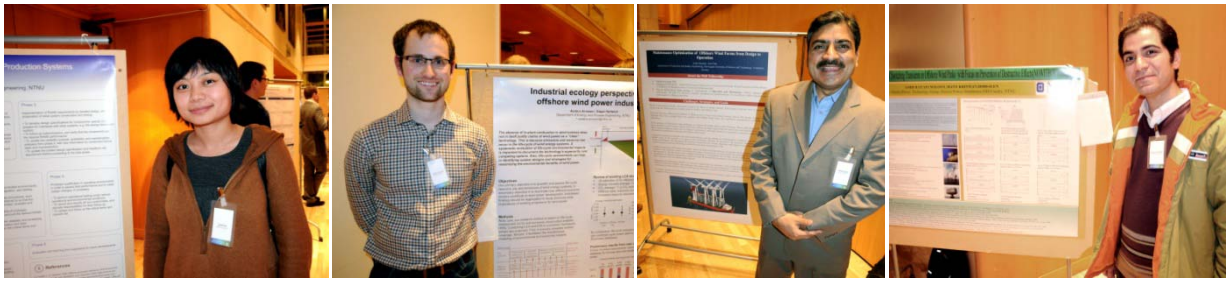


Figure 15 Four out of many PhD students with poster presentations during the Wind Power R&D seminar in 2010. From left: Lijuan Dai, Anders Arvesen, Zafar Hameed and Amir Hayati Soloot.

7 COMMUNICATION AND DISSEMINATION

NOWITECH publications include a total of 97 publications in 2010, whereof 3 journal paper, 23 conference papers, 31 conference presentations, 18 reports, 2 chapters in books and 20 media contributions (newspaper articles and feature articles). See appendix A.3.

NOWITECH partners have access to a project e-room, where all internal information and project results are presented. Further, NOWITECH has a web site (www.nowitech.no), where relevant NOWITECH news and information is presented to external interests.

An annual Wind Power R&D seminar is held in January in Trondheim. This seminar has been arranged every year since 2004 with SINTEF Energy Research as host in close cooperation with NTNU and IFE. It is established as an important venue for the wind sector in Norway and with international participation. The seminar is a mix of plenary presentations with broad appeal, and presentations in parallel sessions on specific technical themes. NOWITECH arranged the seminar in cooperation with NORCOWE in 2010. The seminar kept a strong focus on deep sea offshore wind and the PhD students working on projects in the centre were invited to give a poster presentation of their work.

Figure 16 Snapshots from Wind Power R&D seminar January 2010 in Trondheim. Right: Åslaug Haga, former member of the Norwegian Government and one of the main speakers at the seminar, representing The Federation of Norwegian Industries.

A.1 PERSONNEL

A.1.1 Key Researchers

#	Name	Institution	Main Research Area
1	Eek, Jarle	SINTEF Energy Research	WP4
2	Gustavsen, Bjørn	SINTEF Energy Research	WP4
3	Heggset, Jørn	SINTEF Energy Research	WP5, Management
4	Hernando, Daniel Huertas	SINTEF Energy Research	WP4
5	Hofmann, Matthias	SINTEF Energy Research	WP5
6	Korpås, Magnus	SINTEF Energy Research	WP4
7	Ringheim, Nils Arild	SINTEF Energy Research	Management
8	Svendsen, Harald	SINTEF Energy Research	WP4
9	Tande, John Olav Giæver	SINTEF Energy Research	Management, WP1-WP6
10	Trötscher, Thomas	SINTEF Energy Research	WP4
11	Warland, Leif	SINTEF Energy Research	WP4
12	Endegnanew, Atsede	SINTEF Energy Research	WP4
13	Berge Erik	IFE	WP1,
14	Finden Per	IFE	Management
15	Knauer Andreas	IFE	WP1, WP2, WP3, WP6
16	Nygaard Tor Anders	IFE	WP1, WP3
17	Rij Jennifer Van	IFE	WP1, WP2, WP3
18	Stenbro Roy	IFE	WP1, WP2, WP3, WP6, Management
19	Anders Valland	Marintek	WP5
20	Dag Fergestad	Marintek	WP3
21	Gro Baarholm	Marintek	WP3
22	Harald Ormberg	Marintek	WP1,
23	Ivar Fylling	Marintek	WP1, WP6
24	Jie Wu	Marintek	WP1
25	Joakim Taby	Marintek	WP3
26	Lars Magne Nonås	Marintek	WP5
27	Mateusz Graczyk	Marintek	WP1
28	Neil Luxcey	Marintek	WP1, WP3
29	Petter Andreas Berthelsen	Marintek	WP1,WP3, WP6, Management
30	Andreas Echtermeyer	NTNU	WP2
31	Geir Moe	NTNU	Management (including SC), WP3
32	Gerard Doorman	NTNU	WP4
33	Hans Kristian Høidalen	NTNU	WP4
34	Jan Onarheim	NTNU	Management (including SC, CIC)
35	Jørn Vatn	NTNU	WP5
36	Kjetil Uhlen	NTNU / SINTEF Energy Research	WP4, Management
37	Ole Gunnar Dahlhaug	NTNU	Management (including SC), WP1
38	Per Åge Krogstad	NTNU	WP6
39	Robert Nilssen	NTNU	WP2
40	Tore Undeland	NTNU	Management (including SC)
41	Torgeir Moan	NTNU	WP3, Management (including SC)
42	Trond Kvamsdal	NTNU/SINTEF ICT	WP1
43	Runar Holdahl	SINTEF ICT	WP1
44	Astrid Bjørgum	SINTEF MC	WP3, WP5
45	Bård Wathne Tveiten	SINTEF MC	WP2, Management
46	Christian R. Simon	SINTEF MC	WP3
47	Juan Yang	SINTEF MC	WP3
48	Monika Pilz	SINTEF MC	WP3
49	Ole Ø. Knudsen	SINTEF MC	WP3
50	Sergio Nieto Armada	SINTEF MC	WP3, WP5
51	Bernd Schmid	SINTEF MC	Management, WP2, WP3

A.1.2 Visiting Researchers

Name	Affiliation	Nationality	Sex	Duration	Topic

None

A.1.3 Postdoctoral Researchers with financial support from the Centre budget

Name	Nationality	Period	Sex	Topic
Anthonippillai Antonarulrajah	British	2009-2011	M	Influence of material and process parameters on fatigue of wind turbine blades in a marine environment (WP2)
Steve Völler	German	2010-2012	M	Balance management with large scale offshore wind integration (WP4)
Madjid Karimirad	Iranian	2010-2012	M	Alternative floating wind turbines for moderate water depths (WP6)

A.1.4 Postdoctoral Researchers working on projects in the Centre with financial support from other sources

Name	Nationality	Period	Sex	Topic
Muyiwa Adaramola	Nigerian	2008-2010	M	Deep sea wind turbine behaviour in extreme situations
Zhen Gao	Chinese	Started 2008	M	Reliability and stochastic response analysis of marine structures
Nilanjan Saha	Indian	2008-2010	M	Stochastic analysis of marine structures
Elisabetta Tedeschi	Italian	2009-2011	F	Design and control of energy conversion systems for the integration of offshore renewable energy sources into the electric grid
Paul Thomassen	Norwegian	Started 2008	M	Deep sea offshore structures
Rabah Zaimeddine	Algerian	Started 2008	M	Grid Integration Technologies of Offshore Wind
Michael Muskulus	German	Started 2010	M	Analysis and measurements of structural behaviour of offshore wind turbines

A.1.5 PhD Students with financial support from the Centre budget

Name	Nationality	Period	Sex	Topic
Knut Nordanger	Norwegian	2010-2013	M	Coupled fluid-structure interaction simulation of offshore wind turbines (WP1)
Lars Frøyd	Norwegian	2009-2012	M	Evaluation of the design criteria and dynamic forces on large floating wind turbines (WP1)
Martin Resell	Norwegian	2010-2014	M	Design wind and sea loads for offshore wind turbines (WP1)
Pål Egil Eriksen	Norwegian	2010-2014	M	Rotor wake turbulence (WP1)
Kevin Cox	American	2010-2013	M	Lift control of wind turbine blades by using smart composite materials manipulating aerodynamics rotor properties (WP2)
Mostafa Valavi	Iranian	2010-2013	M	Magnetic forces and vibrations in wind power generators (WP2)
Zhaoqiang Zhang	Chinese	2010-2013	M	Novel generator concepts for low weight nacelles. Integrated design of generator and mechanical structure for a maintenance free system (WP2)
Daniel Zwick	German	2009-2013	M	Design and production of offshore jacket structures (WP3)
Eric Van Buren	American	2009-2012	M	Bottom-fixed support structure for wind turbine in 30-70 m water depth (WP3)
Marit Irene Kvittem	Norwegian	2009-2012	F	Life cycle criteria and optimization of floating structures and mooring systems (WP3)
Mayilvahanan Chella	Indian	2010-2013	M	Wave forces on wind turbine structures (WP3)
Amir Hayati Soloot	Iranian	2009-2013	M	Analysis of switching transients in wind parks with focus on prevention of destructive effects (WP4)
Fahmi Mubarok	Indonesian	2010-2013	M	Novel coating and surface treatment for improved wear resistance (WP5)
Zafar Hameed	Pakistani	2009-2012	M	Maintenance optimization of wind farms from design to operation (models, methods, framework) (WP5)
Øyvind Netland	Norwegian	2010-2013	M	Cost-effective monitoring for remote environmental friendly O&M of offshore wind turbines (WP5)
Tania Bracchi	Italian	2009-2012	F	Assessment of benefits of downwind rotors due to weight savings using new and thinner airfoils and improved directional stability of turbine (WP6)
Kai Wang	Chinese	2010-2013	M	Comparative studies of floating concepts (WP6)
Morten Dinhoff Pedersen	Norwegian	2010-2013	M	Design of control systems for load mitigation and stabilization of floating wind turbines (WP6)

A.1.6 PhD Students working on projects in the Centre with financial support from other sources

Name	Funding	Nationality	Period	Sex	Topic
Thomas Pagaard Fuglseth	NTNU	Norwegian	2005-2010	M	Control of Wind Energy Plants
Alejandro Garces Ruiz	NTNU	Colombian	2008-2012	M	Electrical system for offshore wind parks: from the generator to the grid connection onshore
Anders Arvesen	NTNU	Norwegian	2008-2012	M	Assessment of environmental benefits and costs of a large-scale introduction of wind energy
Bing Lui	NTNU	Chinese	2008-2012	M	Offshore wind power electronics
Fabio Pierella	NTNU	Italian	2008-2012	M	Wind energy: Full scale and wind tunnel simulated measurements; consequential wind turbine design optimization, model construction and experimental testing
Fredrik Sandquist	NTNU	Austrian	2006-2010	M	Individual Pitch Control of Large Scale wind turbines
Ingrid Øverås	NTNU	Norwegian	2008-2012	F	Grid Integration Technologies of Offshore Wind
Lijuan Dai	NTNU	Chinese	2009-2013	F	RAMS engineering and management in the development and operation of offshore wind turbines
Madjid Karimirad	CeSOS	Iranian	2007-2011	M	Structural Dynamic Response of Floating Wind Turbine
Muhammed Jafar	NTNU	Pakistani	2008-2012	M	Electrical Conversion Systems for Offshore wind farms: from the generator to shore
Raed Khalil Lubbad	NTNU	Palestinian	2006-2010	M	Dynamic Response of Slender Offshore Structures
Raymundo Torres Olguin	NTNU	Mexican	2008-2012	M	Offshore Wind Farms Electrical System and grid Integration
Sverre Gjerde	NTNU	Norwegian	2009-2013	M	Integrated converter design with generator for weight reduction of offshore wind turbines
Temesgen Haileselassie	NTNT	Ethiopian	2008-2012	M	Grid Connection of Deep Sea Wind Farms
Tobias Aigner	NTNU	German	2008-2012	M	System impacts of large scale wind power
Gursu Tasar	NTNU	Turkish	2009-2012	M	Full Scale Measurements of Wind Conditions Relevant for Offshore Wind Turbines
Karl Merz	NTNU	American	2008-2011	M	Deep water offshore turbine structures
Mahmoud Valibeiglou	NTNU	Iranian	2009-2012	M	Area in Operation and Maintenance –in on-line monitoring and use o f on-line data for maintenance decision for offshore wind farms
Marit Reiso	NTNU	Norwegian	2009-2012	F	Design and analysis of downwind rotor for WT with jacket tower
Wenbin Dong	CeSOS	Chinese	2008-2011	M	Reliability of wind turbines
Sara Heidenreich	NTNU	German	2010-2014	F	Public engagement in offshore wind energy
Markus Steen	Geography	Norwegian	2010-2014	M	Commercialization and industrial development of new renewable energy with focus on offshore wind

A.1.7 Master Degrees

Name	Sex	Topic
Aina Crozier	F	Design of a 10 MW wind turbine
Dag Martin Frøystad	M	Norwegian hydropower and large scale wind production in the Northsea
Wei Gong	M	Design of transition element between tower top and nacelle on a wind turbine
Jon Guldsten	M	Influence on wind shear and turbulence in flow over obstacles
Maheshkumar Hadiya	M	Integration of offshore wind with offshore oil and gas platforms
Torbjørn Ruud Hagen	M	Measuring of wind field behind wind turbine tower and the effects on the rotor
Anders Kjetsaa	M	Offshore wind turbine substructures
Peng Li	M	Analysis and design of offshore jacket wind turbine
Kari Medby Loland	F	Wake behind yawed wind turbine
Øyvind Nygard	M	Study of wake behind tower
Stig Sund	M	Scaling characteristics of flow over bluff bodies
Lars J. Saaghus	M	Of offshore wind turbine substructures
Jørgen Tande	M	CFD analysis of a 10 MW wind turbine
Sigrid R. Vatne	F	Design of a 10 MW wind turbine
Camilla Volnes	F	Modelling of wind turbine
Yihan Xing	M	An inertia-capacitance beam substructure formulation based on bond graph terminology with applications to rotating beam and wind turbine rotor blade
Gaizka Zarraonandia	M	Influence on wind shear and turbulence in flow over obstacles

A.2 STATEMENT OF ACCOUNTS

(All figures in NOK 1000)

FUNDING

Name		Amount	Amount
The Research Council			20000
SINTEF Energi	(Host Institution)		2415
NTNU	(Research Partner)		5565
IFE	(Research Partner)		1357
Marintek	(Research Partner)		1805
SINTEF	(Research Partner)		1459
Aker Solutions		1874	
Det Norske Veritas		500	
Devold AMT		721	
DONG Energy Power		500	
EDF R&D		1078	
Fugro OCEANOR		1034	
GE Wind Energy (Norway)		1200	
Lyse Produksjon		500	
NTE Holding		1000	
SmartMotor		799	
Statkraft Development		1500	
Statnett		500	
Statoil		1150	
Trønder Energi Kraft		500	
Vestas Wind System		1200	
Vestavind Kraft		1000	
Transferred from 2009		2585	
Transferred to 2011		-2585	
	Subtotal		15056
Public Partners			
			47657

COSTS

Name		Amount	Amount
SINTEF Energi	(Host Institution)		9661
NTNU	(Research Partner)		15318
IFE	(Research Partner)		5428
Marintek	(Research Partner)		6596
SINTEF	(Research Partner)		5898
Aker Solutions		1874	
Devold AMT		721	
EDF R&D		328	
Fugro OCEANOR		1034	
SmartMotor		799	
	Subtotal		4756
Public Partners			
Equipment			
			47657

A.3 PUBLICATIONS

NOWITECH publications include a total of 97 publications in 2010, whereof 3 journal papers, 23 conference papers, 31 conference presentations, 18 reports, 2 chapter in books and 20 media contributions. Below you will find the papers, books and reports listed.

A.3.1 Journal Papers

Title	Author	Journal
The Potential of Integrating Wind Power with Offshore Oil and Gas Platforms	He, W.; Jacobsen, G.; Anderson, T.; Olsen, F.; Hanson, T.D.; Korpås, M.; Toftevaag, T.; Eek, J.; Uhlen, K.; Johansson, E.	Wind Engineering, Volume 34, No. 2, 2010
Impacts of large amounts of wind power on design and operation of power systems, results of IEA collaboration	Holttinen, H.; Meibom, P.; Orths, A.; Lange, B.; O'Malley, M.; Tande, J.O.; Estanqueiro, A.; Gomez, E.; Söder, L.; Strbac, G.; Smith, J.C.; van Hulle, F.	Wind Energy, 2010
Maintenance strategies for deep sea offshore wind turbines	Utne, I. B.	Journal of Quality in Maintenance Engineering, Volume 16, 2010

A.3.2 Published Conference Papers

Title	Author	Conference
Analysis of grid alternatives for North Sea offshore wind farms using a flow-based market model	Hernando, D.H.; Svendsen, H.G.; Warland, L.; Trötscher, T.; Korpås. M.	7th International Conference on the European Energy Market (EEM 10); Madrid; June 23 - 25, 2010
RAMS Engineering in the Development of Sustainable Energy Production Systems	Dai, L.; Rausand, M.; Utne, I.B.	PSAM; Seattle, USA; June 2010
Challenges in safety and reliability data collection for offshore wind turbines	Hameed, Z.; Vatn, J.; Velibeglio, M.	ESREL 2010; Rhodes, Greece; 5 - 9 September 2010
Offshore Wind Technology Research in Norway - An overview of National Research Programs	Tveiten, B.W.; Tande, J.O.; Haugen, P.M.; Frøysa, K.G.; Barstad, I.; Onarheim, J.	Renewable Energy 2010; Yokohama; Japan; 27 June - 2 July 2010
Offshore Code Comparison Collaboration within IEA Wind Task 23: Phase IV Results Regarding Floating Wind Turbine Modeling	Jonkman, J.; Larsen, T.; Hansen, A.; Nygaard, T.; Maus, K.; Karimerad, M.; Gao, Z.; Moan, T.; Fylling, I.; Nichols, J.; Kohlmeier, M.; Vergara, J.P.; Merino, D.; Shi, W.; Park, H.	EWEC; Warsaw, Poland; 20 April – 23 April 2010
A framework for the analysis of reliability and maintainability of offshore wind farms	Hameed, Z.; Vatn, J.	EAWE 6th PhD Seminar on Wind Energy in Europe; NTNU, Trondheim; 30 September-1 October 2010

Title	Author	Conference
Grouping of maintenance and Optimization by using Genetic Algorithm	Hameed, Z.; Vatn, J.	ESRA seminar; Pecs, Hungary; 4 - 5 May 2010
The Battery of Europe: Strategies for Norwegian Offshore Wind Energy	Lund, P.C.; Tveiten, B.W.; Tande, J.O.	Renewable Energy 2010; Tokyo, Japan; 27 June - 2 July 2010
Transmission Planning for Wind Energy: Status and Prospects	Smith, J.C. et al	9th International Workshop on Large Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants; Quebec, Canada; 18 -19 October 2010
Novel coating system for rotating parts in offshore wind turbines	Mubarok, F; Armada, S; Johnsen, R; Espallargas, N.	6th PhD Seminar on Wind Energy in Europe; NTNU; Trondheim; 30 September – 1 October 2010
Experimental Investigations of the Efficiency of Round-Sectioned Helical Strakes in Suppressing Vortex Induced Vibrations	Lubbad, R.K; Løset, S.; Moe, G.	OMAE2010; Changhai; China; 6 – 11 June 2010
Remote Presence, Cost-Effective Robotic Inspection and Maintenance of Offshore Wind Turbines	Netland, Ø.; Skavhaug, A.	6th PhD Seminar on Wind Energy in Europe; NTNU; Trondheim; 30 September - 1. October 2010
Primary Frequency Control of Remote Grids Connected by Multi-terminal HVDC	Haileselassie, T.; Uhlen, K.	IEEE PES 2010; Minnesota, USA; 25 - 29 July 2010
Effect of initial conditions on flow past grids of finite extension	Pierella, F.; Sætran, L.	17th Australasian Fluid Mechanics Conference; Auckland; New Zealand; 5 - 9 December 2010
Effect of Foundation Modeling Methodology on the Dynamic Response of Offshore Wind Turbine Support Structures	Van Buren, E.	EAWE 6th PhD Seminar on Wind Energy in Europe; NTNU, Trondheim; 30.September-1.oktober 2010
Fatigue reliability analysis of jacket-type offshore wind turbine considering inspection and repair	Dong, W.B.; Gao, Z.; Moan, T.	EWEC; Warsaw, Poland; 20 – 23 April 2010
Loads and dynamics in lattice tower support structures for offshore wind turbines	Zwick, D.; Moe, G.	EAWE 6th PhD Seminar on Wind Energy in Europe; NTNU, Trondheim; 30 September-1 October 2010
Dynamic analysis of offshore fixed wind turbines under wind and wave loads using alternative computer codes	Gao, Z.; Saha, N.; Moan, T.; Amdahl, J.	Torque2010; The Science of making Torque from Wind; FORTH, Heraklion, Crete; Greece; June 28 - 30, 2010
Organic coatings reinforced with ceramic particles: an erosion study	Armada, S., Bjørgum, A., Knudsen, O.Ø., Simon,C. and Pilz, M	EWEC2010 (Proceedings of the European Wind Energy Conference); Warsaw, Poland, April 20 - 23, 2010
Effect of Aerodynamic and Hydrodynamic Damping on Dynamic Response of a Spar Type	Karimirad, M.; Moan, T.	EWEC2010; Warsaw; Poland; April 20 – 23, 2010

Title	Author	Conference
Floating Wind Turbine		
Effect of initial conditions on flow past grids of finite extension	Pierella, F.; Sætran, L.	17th Australasian Fluid Mechanics Conference; Auckland; New Zealand; 5.-9. December 2010
Blade Response on Offshore Bottom-Fixed wind turbines with down-wind rotors	Reiso, M.; Moe, G.	OMAE2010; Shanghai, China, June 6 – 11, 2010
State of the Art on Generator Technology for Wind Power Plants	Zhaoqiang, Z.	EAWE 6th PhD Seminar on Wind Energy in Europe; NTNU, Trondheim; 30 September-1 October 2010

A.3.3 Books

Title	Author	Book
Impact of TradeWind offshore wind power capacity scenarios on power flows in the European HV network (Chapter in book)	Tande, J.O.; Korpås, M.; Warland, L.; Uhlen, K.; van Hulle, F.	Wind power; Alternative energy source
Wind Energy (Chapter in book)	Madsen; P.H.; Rasmussen, F.; Tande, J.O.; van Kuik, G.	Risø Energy Report 9 - Non-fossil energy technologies in 2050 and beyond

A.3.4 Reports

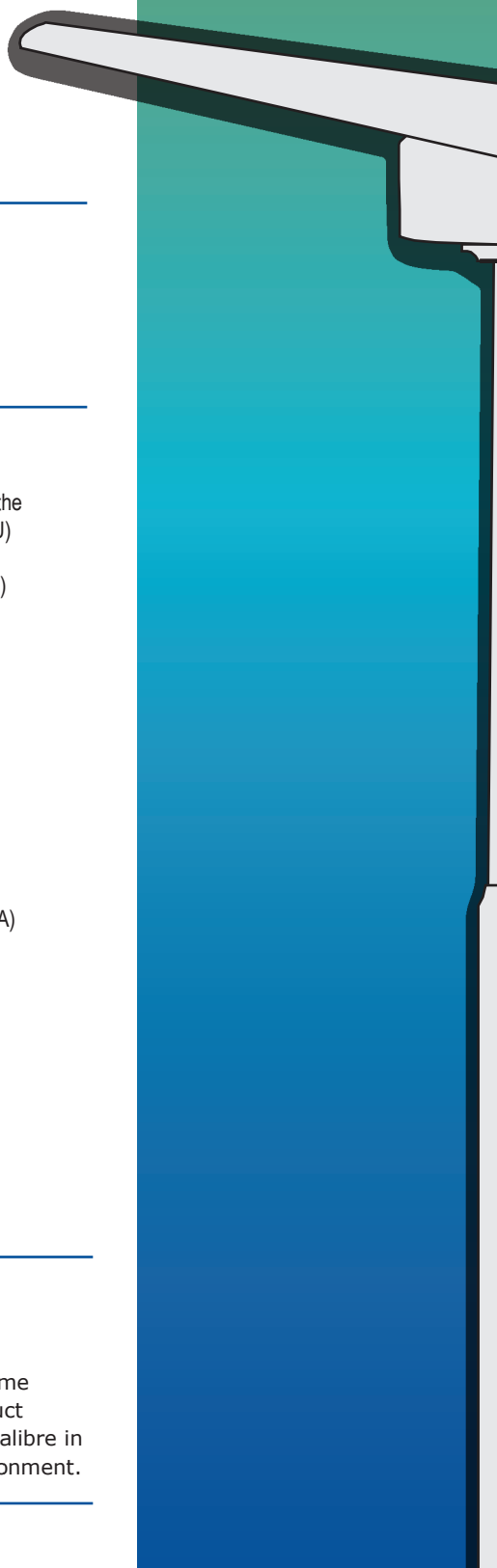
Title	Author	Institution
State-of-the-art for CFD analysis of wind turbine rotors	Rij, J.	IFE
State-of-the-art on coating systems for corrosion and erosion	Armada, S.; Bjørgum, A.; Johnsen, H.; Pilz, M.; Simon, C.; Yang, J.	SINTEF Materials and Chemistry
Work done by SmartMotor in 2009	Matveev, A.	SmartMotor
Use of WorldWaves Data for Assessment of Wind Speed and Wind	Mørk, G.; Malvik, I.M.	Fugro OCEANOR
Floating support structure for FLEXWT - Preliminary design of the spar buoy for the NOWERI application	Berthelsen, P.A.	MARINTEK
Resonant voltage magnification on a transformer low-voltage side caused by network initiated transients	Gustavsen, B.	SINTEF Energi AS
2009 Work and Achievements	Hillermeyer, R.	Devold Amt

Title	Author	Institution
reflecting in-kind contributions to project - NOWITECH WP2 Project		
State of the art of computational tools for integrated simulation of floating wind turbines	Nygaard, T.A.; Fylling, I.	IFE
Generatoren - Hva kan vi ta med oss fra den store vannkraftperioden over til vindkraftperioden? - Kompendium	Pleym, A. et al	SINTEF Energi AS
State-of-the-art on qualitative assessment of maintenance requirements regarding coatings and surface protection	Bjørgum, A.; Armada, S.	SINTEF Materials Technology
Relevant experiences in offshore oil & gas industry on degradation mechanisms in materials, coatings and surface treatments	Armada, S.; Bjørgum, A.	SINTEF Materials & Chemistry
Wind Power R&D Seminar - Deep Sea Offshore Wind	Tande, J.O.	SINTEF Energi AS
WINDOPT - A program for optimisation of floating wind turbines	Fylling, I.	MARINTEK
Offshore Wind Turbines : Mechanical Behaviour Model	Peyrard, C.	EDF
Evaluation of existing coatings for corrosion protection of structural components	Knudsen, O.Ø.	SINTEF Materials & Chemistry
State of the art of models for offshore wind farms with an emphasis on O&M Strategies	Hofmann, M.	SINTEF Energi AS
Description of a framework and structure for a life cycle cost and benefit model for offshore wind farms – NOWIcob	Hoffman, M.; Nonås, L.M.	SINTEF Energi AS, MARINTEK
Nanotechnology based coatings resistant to wear, erosion, soiling, icing as well as salt	Simon, C.; Pilz, M.; Adamczak, M.	SINTEF Materials & Chemistry

NOWITECH (Norwegian Research Centre for Offshore Wind Technology) is a centre for environment-friendly energy research started in 2009 co-funded by the Research Council of Norway.

The objective of NOWITECH is pre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on “deep-sea” (+30 m) including bottom-fixed and floating wind turbines. Work is focused on technical challenges including a strong PhD and post doc programme:

- Integrated numerical design tools for novel offshore wind energy concepts.
- Energy conversion systems using new materials for blades and generators.
- Novel substructures (bottom-fixed and floaters) for offshore wind turbines.
- Grid connection and system integration of large offshore wind farms.
- Operation and maintenance strategies and technologies.
- Assessment of novel concepts by numerical tools and physical experiments.



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The Centres for Environment-friendly Energy Research (CEERs) scheme is an initiative to establish time-limited research centres which conduct concentrated, focused and long-term research of high international calibre in order to solve specific challenges in the field of energy and the environment.