Annual report 2012

NOWITECH

Norwegian Research Centre for Offshore Wind Technology

www.NOWITECH.no

NOWITECH Annual Report 2012

April 2013

Editorial: John Olav Tande

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NOWITECH is an international precompetitive NOK 320 million (2009-2017) research cooperation on offshore wind technology co-financed by the Research Council of Norway, industry and research partners.

Vision

… to contribute to large scale deployment of deep sea offshore wind turbines,

… to be an internationally leading research community on offshore wind technology enabling industry partners to be in the forefront.

Objective

… to provide precompetitive 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.

Key issues

… are education, knowledge building and innovations aiming to reduce the cost of energy from offshore wind.

Organization

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). The research activities are organised into six work packages (WPs): integrated numerical design tools (WP1), blades and generators (WP2), bottom-fixed and floating substructures (WP3), grid connection and system integration (WP4), operation and maintenance (WP5), and assessment of novel concepts (WP6). Industry involvement has high priority: The industry parties participate by in-kind supplies, through participation at dedicated WP meetings, and in the CIC. All industry parties are represented in the GA and the industry parties are active and in majority in the Board.

Important benefits for Industry Partners are

- gaining knowledge giving reduced uncertainties and risks, reducing cost of energy from offshore wind farms and increasing profits
- the possibility to influence the direction of the research,
- to interact directly in the research, and network of knowledge
- possibilities for recruitment, new projects, and
- having the first access to detailed results for business development.

Results

NOWITECH finances 23 PhD students and 2 postdocs. The first students are now starting to finalize their theses. Publications since start-up include 64 peer-reviewed papers, 67 reports, 44 media contributions and 110 conference presentations of which 19 were invited keynotes. Two new business developments (Remote Presence and SiC coating) are in process based on research results of NOWITECH, and counting in a conservative way, sixteen innovations are in the research stage. The NOWITECH research partners are attractive: In total 31 new projects with an accumulated budget of NOK 950 millions are carried out with participation of one or more of the research partners in NOWITECH. These projects are with separate contracts external to NOWITECH, but carried out in alignment with NOWITECH.

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John Olav G. Tande, Director NOWITECH

An excellent scientific programme is established. In 2012, NTNU had 23 PhD students and two Postdoc positions fully funded by NOWITECH. In addition, 25 PhD students and 4 Postdocs are funded through other projects at NTNU, and professors and scientific staff at NTNU were supervisors for 30 MSc students specializing in wind energy during 2012. The start-up of the Erasmus Mundus European Wind Energy Master (EWEM) programme gives further weight to the MSc education at NTNU, in particular in the fields of electro and marine which are areas of NTNU engagement within the EWEM.

NOWITECH contributes to innovations by bringing forward relevant research results to a certain maturity at which further development is typically industry based towards more competitive and commercial application. The strategy to stimulate innovations was enhanced in 2012 through applying a Technology Readiness Level (TRL) methodology to relevant research activities, and through initiating a workshop process on idea search and development of ideas directed towards WP leaders, researchers and PhD students in NOWITECH. Strong and relevant R&D results with potential for value creation and cost reductions of offshore wind are achieved:

- Advanced methods and models are implemented in state-of-the-art integrated numerical design tools for offshore wind turbines.
- A first design of the NOWITECH 10 MW reference turbine is completed, and applied as a basis for testing innovative concepts, e.g. a full-height lattice tower, a new ironless direct-drive generator with HVDC output, and an adaptive blade technology with improved weight/strength ratio.
- An optimized spar design is identified reducing costs of materials by approx. 30 % compared to the initial case.
- Numerical simulation models, concepts and laboratory installations for grid connection and system integration of offshore wind farms are developed.
- Two new business developments (Remote Presence and SiC coatings) are in process. Remote Presence applies a low-cost robot with camera, microphone and other sensors inside the nacelle with monitoring and control from on-shore, increasing the operational time of the turbine and reducing the need for offshore service visits. SiC coating is a new patent pending coating that can increase the lifetime of bearings and gears.
- A patent is granted for a control scheme for load mitigation and minimization of motions of floating wind turbines.

The results are disseminated efficiently. In 2012 NOWITECH prepared 104 publications including 39 peer-reviewed papers, 20 conference presentations, 18 reports and 10 media contributions. The use of web, newsletters and organization of workshops and conferences enhance the communication:

- The seminar series "Industry meets Science" was started in 2012 in cooperation with Access Mid-Norway and WindCluster Mid-Norway to facilitate improved interaction between the research in NOWITECH and relevant industry, also those that are not partner in NOWITECH.
- The annual offshore wind R&D conference in Trondheim has developed into an international event with call for papers, peer-review and publication in the open access journal Energy Procedia (Elsevier). DeepWind'2012 had about 200 delegates from 14 countries, mainly Europe, but also from USA, China, Singapore and Japan.

Participation in relevant national and international forums is emphasised. These include participation in Energi21 suggesting future research strategy for wind energy in Norway, active participation in IEA Wind research collaboration, IEC TC88 wind turbine standardization working groups and taking leading positions within the European Technology Platform on Wind (TPwind), the European Energy Research Alliance (EERA) joint programme on Wind Energy and the

European Academy of Wind Energy (EAWE). The forums are important networks for improving quality of research, developing R&D strategies and new projects. The NOWITECH research partners are attractive: A total of four EU research projects and five Research Council of Norway projects were started in 2012 with participation of one or more of the research partners in NOWITECH. These projects are with separate contracts external to NOWITECH, but carried out in alignment with NOWITECH.

The existing strong research infrastructure is expanded with funding from RCN; namely ETEST (8 MVA short-circuit emulator) and NOWERI (met-ocean measurements and floating research turbine) jointly with NORCOWE. ETEST is in procurement expecting installation in 2013, while NOWERI is an initial stage preparing contracts between RCN and the research parties. NTNU is the contract partner for the floating test turbine and University of Bergen for the met-ocean measurements.

The accumulated costs for NOWITECH in 2012 were NOK 44.2 million co-funded by the Research Council of Norway, the industry parties and the research parties. The Centre is however not unaffected by the international financial crisis and the demanding market situation for manufacturers in particular; hence the budget for NOWITECH is expected to be somewhat reduced for 2013, possibly down to NOK 37 millions. The market outlook for offshore wind is still positive. The European plans to develop offshore wind are firm, indicating continued large investments in offshore wind farms to reach 2020 targets and beyond. The Fukushima accident brought strong political incentives in Japan to develop offshore wind, in particular floating, and markets for offshore wind are also emerging in USA, South-Korea and China. NOWITECH will continue to deliver within this international market, assuming Europe as the home market, but also following up on opportunities in the emerging markets. IEA[1] suggests in their 2 degree scenario (2DS) for 2050 that wind energy will provide for 15 % of the global electricity generation. This calls for annual installations in the order of 100 GW of on-land and offshore wind farms during the next decades. Land areas will be in high demand; hence an increasing proportion will be offshore. It seems rational then to keep up R&D on offshore wind technology.

Figure 1: A delegation of about 40 Japanese stakeholders in ocean energy visited NOWITECH at 5 September 2012 as part of a round tour in Norway inviting for cooperation.

[1] IEA Energy Technology Perspectives 2012

1 NOWITECH PARTNERS

The NOWITECH Partners in 2012 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:	Det Norske Veritas AS (DNV) Devold AMT AS (Associated industry partner since 2012-09) DONG Energy Power AS EDF R&D Fedem Technology AS Fugro OCEANOR AS GE Wind Energy (Norway) AS Kværner Verdal (former Aker Verdal AS, Aker Solutions) NTE Holding AS SmartMotor AS Statkraft Development AS Statnett SF Statoil Petroleum AS Vestas Wind Systems AS Vestavind Offshore AS

Fugro, GE, Kværner, Vestas and Vestavind Offshore noted their withdrawal from NOWITECH by 2012-12-31, all due to conditions outside the Centre. This withdrawal of some industry parties is unfortunate, but not critical for NOWITECH. There are significant interest from new industry parties to join, hereunder Kongsberg Maritime were accepted during fall of 2012 to join NOWITECH from 2013-01-01.

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 DTU, Denmark Fraunhofer IWES, Germany University of Strathclyde, UK TU Delft, Netherlands Nanyang Technological University (NTU), Singapore
Associate industry partners:	Access Mid-Norway Hexagon Devold AS Enova Energy Norway Innovation Norway Norwegian Wind Energy Association (NORWEA) Norwegian Centres of Expertise Instrumentation (NCEI) NVE WindCluster Mid-Norway

2 ORGANISATION

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). The research activities are organised into six work packages (WPs): integrated numerical design tools (WP1), blades and generators (WP2), bottom-fixed and floating substructures (WP3), grid connection and system integration (WP4), operation and maintenance (WP5), and assessment of novel concepts (WP6). The organization of NOWITECH is shown in Figure 2.

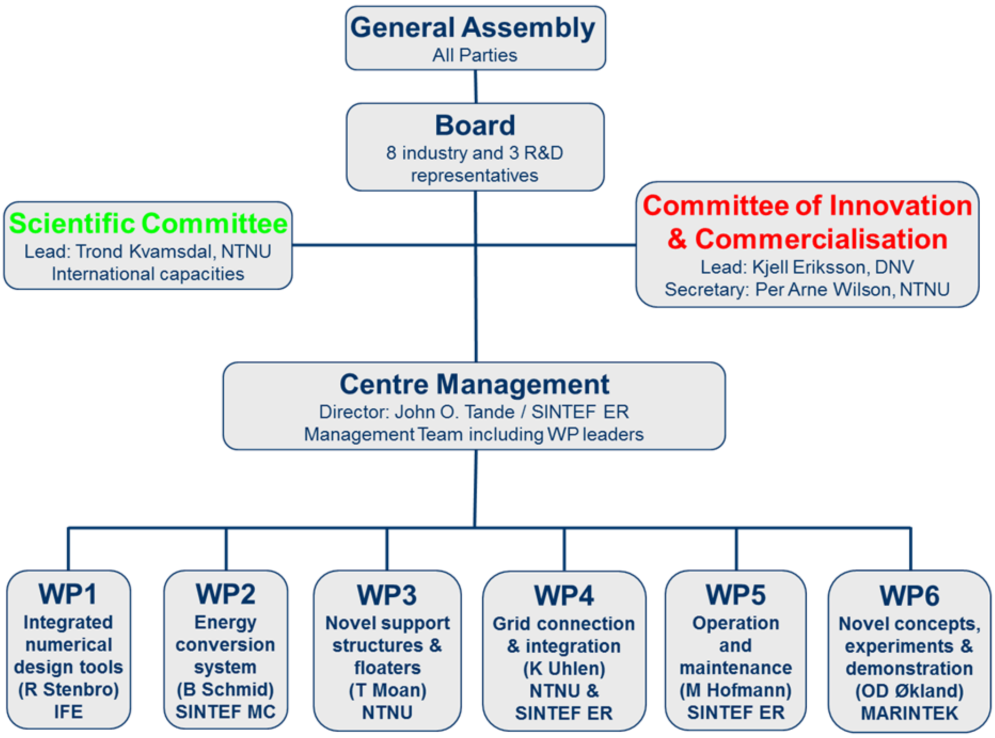


Figure 2 Outline of governance structure for NOWITECH (2012).

The scientific leadership is carried out by the Centre Director and CMG in close collaboration with the SC. Decisions as regards scientific direction, contents and prioritisation are executed by the CMG. The SC has the responsibility for the educational part and provides strategic advices on scientific focus and priorities.

Industry involvement has high priority: The industry parties participate by in-kind supplies, through participation at dedicated WP meetings, and in the CIC. All parties are represented in the GA and the industry parties are active and in majority in the Board. Eight out of eleven representatives in the Board are from the industry.

Accounts of the Board, CMG, CIC and SC set-up and activities in 2012 are given in section 3, 5, 6 and 7 respectively.

3 THE BOARD

The Board is the operative decision-making body for the execution of the activities within the Centre. It consists of eleven members whereof eight are representatives of the industry partners and three are from the research partners. The board shall report to and be accountable to the General Assembly (GA). The Board monitors the implementation of the Centre and approves the annual working plans and budgets. The Board ensures that the activities described in the annual working plans are completed within the defined time frame, hereunder that the In-kind contributions are delivered as specified.

Two Board meetings were held in 2012, i.e. one in June and one in November. Both meetings were combined with a workshop the day before. The June workshop discussed NOWITECH strategy and was combined with the NOWITECH day, with researchers, PhD and post doc scholars presenting key results. The November workshop presented results from the work packages and was combined with the annual GA meeting. The work plans for 2013 were approved by the Board during the meeting in November, and also Kongsberg Maritime was welcomed as a new Industry Partner to join by start of 2013.

The Board members in 2012 were Sverre Aam / Knut Samdal (chairman), SINTEF Energy Research, Kjell Eriksson, DNV AS, Jean Benoit-Ritz, EDF, Martin Degen, GE, Martin Kirkengen, IFE, Olav B. Fosso, NTNU, Sigurd Øvrebø, SmartMotor, Jørgen Krokstad, Statkraft, Gudmund Per Olsen, Statoil, Jens Jakob Wedel-Heinen, Vestas, Dag T Breistein, Vestavind Offshore.

Research Director Knut Samdal took over as new chairman of the Board appointed by SINTEF Energy Research during fall 2012 after Sverre Aam stepped back due to other commitments.

The GA approved Statnett, Fedem and NTE to join the Board by start of 2013 replacing GE, Vestas and Vestavind Offshore.

The strong commitment and competence of the Board is highly appreciated.

Figure 3 Engaged discussions during the Board meeting June 2012. From left: Jean Benoit-Ritz, Martin Degen, Harald Rikheim (RCN), Jørgen Krokstad and Dag T Breistein.

4 RESEARCH PLAN

NOWITECH is an international precompetitive NOK 320 million (2009-2017) research cooperation on offshore wind technology co-financed by the Research Council of Norway, industry and research partners.

The 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 precompetitive 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.

Important elements in the research strategy are listed below:

- 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.

Key issues in NOWITECH are education, knowledge building and innovations aiming to reduce the cost of energy from offshore wind. Emphasis is on “deep-sea” (+30 m) including bottom-fixed and floating turbines.

The research methodology includes a mix of analytic work, numerical simulations and development of such tools, laboratory experiments and field measurements. The mix will vary depending on the task addressed, though the main portion of the budget is for scientific staff, while additional funding are sought for any significant investments in experiments or research infrastructure, see section 8.8. The general idea is to align research in NOWITECH with other open research activities carried out by the research partners, and by this maximize benefits of funding, see section 8.9.

The research is prepared through activities at SINTEF, IFE and NTNU and with in-kind contributions for industry partners. The educational activity forms part of the research programme with engagement of MSc students and funding of 25 PhD and post doc students at NTNU. Phd and post doc students at NTNU working on offshore wind, but funded through other sources, are affiliated with NOWITECH.

The research is organized 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.

The interaction between the WPs is enhanced through dedicated integration activities. This includes joint development of the NOWITECH 10 MW reference wind turbine serving as a focal point and baseline case for research activities within the Centre. The activity brings researchers together across traditional fields of engineering science facilitating team building and innovations. The preparation of joint workshops and research strategies further strengthen the team building.

Dissemination of results are through international journals, conference papers and presentations, also continuation and development of the established yearly offshore wind R&D conference in Trondheim (DeepWind), work-shops for industry and public bodies, newsletters and web.

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. The Centres are complementary to each other and contribute to a strong research effort on offshore wind. 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.

5 CENTRE MANAGEMENT

The Centre Management Group (CMG) is led by the Centre Director and consists of a management team including Centre Manager, the Work Package leaders, the SC lead, vice-lead and secretary, the CIC secretary and the project secretary of NOWITECH. The CMG meets regularly about once per month, or more frequent if required. Management staff is appointed to follow up on administrative, financial and legal issues supporting the Centre Director in the day-to-day operation of NOWITECH, including administration of the information sharing system (e-room) where status report, deliverables, minutes of meetings and presentations are shared between the partners of NOWITECH.

The Centre Director is responsible for progress and cost control of the project according to approved Working Plans. The Centre Director has the responsibility and the authority to execute management tasks in accordance with the Working Plan, the Consortium Agreement and the Contract and monitor Parties' compliance with their obligations.

The objective is to manage and coordinate the activities of NOWITECH, ensuring progress and cost control according to approved plans. The work is divided into Management, Outreach and Integration.

The Management activity takes care of the day-to-day operation of the Centre, scientific leadership and strategy development.

The day-to-day operation 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 on a monthly basis during 2012. These are mainly for team-building, information exchange and strategic discussions. In addition telephone, e-mail and web-based meetings are prepared as required. Three main activities for the management during 2012 outside the day-today business were the preparation of NOWITECH's international strategy, implementation of the TRL methodology and preparations for the mid-term evaluation by RCN.

The international strategy considers Europe as home market. The Board gave positive feedback on this strategy during the November meeting.

The TRL methodology was implemented with guidance from DNV facilitated through CIC (see section 6).

The mid-term evaluation by RCN required preparation of reports that was supplied during fall 2012, including:

- research plan for the second three-year period and beyond,
- self-evaluation of the Centre including sections on research accomplishments, important industrial or social results and potential for innovation, network, internationalisation, recruitment, financial aspects and organisation. What additional effects have been accomplished through establishing a FME?
- a report and self-evaluation from the host institution
- a short report and self-evaluation from each of the industry partners
- a short report and self-evaluation from each of the research partners
- fact sheets including CV for the management team, data for the staff working in the Centre, list of publications, PhDs. candidates, financial data and selected indicators
- report from Scientific Committee

The reports constitute background material for the evaluation that will be carried out by an international committee for the RCN to conclude by fall 2013.

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

The dissemination activities by the management in 2012 included key-note presentations at international conferences, e.g. DeepWind'2012 (Trondheim, 19-20 January), Technoport (Trondheim, 16 - 18 April), RAVE'2012 (Bremerhaven, 8 - 10 May), and OREC'2012 (Singapore, 24-25 October), presentations at industry oriented events in cooperation with Innovation Norway (e.g. Korea (Seoul, 15 May) and Japan (Tokyo, 11 May)), hosting numerous delegations visiting NOWITECH, preparation of media contributions, keeping web and e-room updated, preparation of newsletters, workshops and the annual offshore wind R&D conference in Trondheim DeepWind'2012. The new workshop series "Industry meets Science" was introduced in 2012, and DeepWind'2012 was developed to a truly international R&D conference, see Figure 4. Further accounts of the dissemination activity of NOWITECH are given in section 11.

Contact with prospect industry partners resulted in Kongsberg Maritime was approved to join as a new industry partner by start of 2013. Further CD-Adapco is expected to be approved as new industry partner during 2013.

Engagement in developing offshore wind projects and research strategies in 2012 included both national and international engagement:

- Participation in Norwegian Climate Foundation and SFFE (www.sffe.no) task force on offshore wind energy, producing the pamphlet "Et hav av muligheter".
- Participation in the European Technology Platform on Wind (TPwind) heading the working group on offshore wind.
- Leading 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 9.

Figure 4 DeepWind 2012 19-20 January in Trondheim was accomplished in excellent manner with 200 delegates from 12 countries, and with about 50 oral presentations and 25 posters. From left: plenary session audience, poster award winner Signe Schløer, PhD stud, Technical Univ. of Denmark and poster award winner Daniel Zwick, PhD stud, NTNU with Prof Ole Gunnar Dahlhaug presenting the award.

The cooperation with CEDREN and NORCOWE is continued in 2012:

- 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.
- Preparation of the research infrastructures EFOWI and NOWERI jointly between NORCOWE and NOWITECH, see section 8.8.
- The DeepWind'2012 Offshore Wind R&D conference was organized by NOWITECH in cooperation with NORCOWE, see also section 11.
- A common workshop on wake effect was arranged by NOWITECH and NORCOWE in October 2012, see section 8.1.

The integration activity 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. The integration activities include joint development of the NOWITECH 10 MW Reference Turbine, preparation of joint workshops and research strategies. The activity brings researchers together across traditional fields of engineering science facilitating team building and innovations. The Reference Turbine is already applied as a basis for testing innovative concepts, e.g. the full-height lattice tower, new ironless direct-drive generator with HVDC output, and adaptive blade technology with improved weight/strength ratio through incorporating bend-twist coupling in the composite layup. Section 8.7 gives a summary account of the Reference Turbine progress supplementing the reporting of the individual WPs (section 8.1-8.6).

Arrangement of the NOWITECH Day and preparation of Centre Management Group (CMG) seminars are other integration activities carried out in 2012.

The NOWITECH Day was prepared in June 2012 back-to-back with the Board meeting as an internal seminar for all NOWITECH partners with researchers, PhD and post doc scholars presenting key results.

The CMG seminars were prepared for strategy development, SWOT analysis (May 2012) and introduction of the TRL methodology (August 2012).

6 INNOVATION AND COMMERCIALISATION

Kjell Eriksson, DNV, Chair CIC

Per Arne Wilson NTNU, Secretary CIC

The Committee for Innovation and Commercialisation (CIC) is enhancing the industry involvement and assures 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 the creation of new industry. The committee is industry driven, with chairman Kjell Eriksson (DNV) and secretary Per Arne Wilson, NTNU. Activities in 2012 include:

- A Technology Readiness Level (TRL) guideline is adapted to the Centre activities and a first iteration of the method has been implemented in the working plans. The method is suggested to be a useful communication platform between researchers and industry partners as regards contents and maturity of WP results, and in particular to identify the next steps for taking an innovation closer to the market. A report with the title "Guideline for assessing technology readiness level" has been published.

- CIC in cooperation with NTNU Technology Transfer have started a workshop process "Idea search and development of ideas" directed towards WP leaders, researchers and PhD students in NOWITECH. The program is identifying ideas relevant for patenting, commercialisation and industrialisation. In addition to intercepting new ideas, the workshop series have an important consciousness-raising effect on idea generation and commercialisation to the NOWITECH researchers. The intention is to run the workshop process annually.

- Two new business developments (Remote Presence and SiC coating) are in process based on research results of the Centre, and the CIC has together with other key resources in NOWITECH assisted in their business developments.

NOWITECH assists also external parties in developing ideas. A strong link to relevant SMEs is made through NOWITECH's close cooperation with Windcluster Mid-Norway (WMN) and Access Mid-Norway (AMN), and a number of innovators and SMEs have been assisted in validation of ideas and linking with relevant partners and public bodies for further development, e.g. WindFlip, Limsim and SubHydro.

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 partners.

7 SCIENTIFIC COMMITTEE

Trond Kvamsdal
NTNU, Chair SC

Michael Muskulus
NTNU, Vice-chair SC

The scientific leadership is carried out by the Centre Director and CMG in close collaboration with the Scientific Committee. Decisions as regards scientific directions, contents and prioritisation are executed by the CMG. The SC has the responsibility for the educational part and provides strategic advices on scientific focus and priorities.

The Scientific Committee (SC) consists of a core group with relevant NTNU professors and the Centre Director meeting on a monthly basis or more frequent if required. The associated research partners are included in the extended SC, which has two annual meetings. The meetings involve an evaluation of the scientific content of NOWITECH's results. In addition, SC is doing an evaluation of the scientific content of the annual working plan to the different work packages as input to the Board meeting where the annual working plans are to be approved.

The SC accomplished two full meetings in 2012 where the associated research partners participated. Besides, the SC organised the attendance of visiting lectures, the exchange of PhD candidates, and the review and evaluation of scientific activities and results within NOWITECH.

The NOWITECH Mobility Programme for promoting the exchange of students and researchers between NOWITECH and associated partners offers support for travel and housing costs, and some applications were received in 2012 for mobility in 2013. The SC also provided some "seed" funding and initiatives to facilitate increased national and international collaboration:

- The SC provided the funds for NOWITECH to join the IEA Wind Task 26 “Cost of Energy”. The provision of participation fees through the SC allows researchers from all of Norway to join the activities of the task.
- The SC co-funded a second "blind test" workshop on wake effects jointly organized by NOWITECH and NORCOWE in Trondheim October 2012. Further accounts of the workshop are given in Section 8.1.
- The Vice-Chairman of the SC, Michael Muskulus, was elected Vice-President of the European Academy of Wind Energy (EAWE http://www.eawe.eu/), further strengthening the presence of NOWITECH in international research networks and opening up new possibilities for international cooperation.
- A number of meetings regarding a closer collaboration were organised with NORCOWE. Common tasks of interest were identified, e.g., Operation & Maintenance. SINTEF and Aalborg University expressed their interest.

Nanyang Technological University (Singapore) became a new associated research partner in NOWITECH, and was visited three times during 2012 by members of the SC, participating in workshops and the Offshore Renewable Energy Conference (OREC’2012). NOWITECH was represented at OREC'2012 with its director John Tande giving a key note and participating in the panel debate concluding the conference, and the vice chair of SC prof. Michael Muskulus led the session on substructures and advanced materials.

The Scientific Committee (SC) has the overall responsibility for developing the PhD and Postdoc programme. This include an active recruitment strategy, organization of joint PhD forums and training, exposing them to industry and leading international research groups by organising the PhDs and Postdocs in groups contrary to the unfortunate ivory tower model. A challenge for the next years is to obtain additional funding to keep up the momentum in the PhD and Postdoc education. The PhD and postdocs financed by NOWITECH are all due to finish before 2015. The first PhD student already graduated, and 10 to 15 PhD students are expected to conclude their study in 2013. Thus, to keep up the momentum significant additional funds for a next wave of

PhD students need to be secured. This is high on the agenda in the management of NOWITECH and in the SC in particular. A solution is sought in dialogue with the Board and the RCN. Section 10 gives further details on recruitment and the PhD and post doc programme within NOWITECH.

The members of the SC as per end of 2012 are listed below:

- NTNU-members
  - Trond Kvamsdal (Chairman), NTNU
  - Michael Muskulus (Vice-Chairman), NTNU
  - Debbie Koreman (SC Secretary), NTNU
  - Jan Onarheim, NTNU
  - Torgeir Moan, NTNU
  - Lars Sætran, NTNU
  - O.G. Dahlhaug, NTNU
  - Karl Merz, NTNU
  - Tore Undeland, NTNU
  - O.B. Fosso, NTNU
  - Marta Molinas, NTNU

- Other Norwegian members
  - Finn Gunnar Nielsen, Statoil / UiB
  - Terje Gjengedal, Sogn og Fjordane Energi
  - Jørgen Ranum Krokstad, Statkraft
  - Tor Anders Nygaard, IFE
  - Ivar Langen, UiS

- Associated members
  - Paul Sclavounos, MIT, USA
  - Senu Sirnivas, 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)
  - Seri Lee, Nanyang Technological University (NTU), Singapore

The Michigan Technological University (USA), represented by Bruce Mork, has approached NOWITECH to become an associated research partner. The expectation is that they will be welcome to join during 2013.

NOWITECH and NORCOWE are also collaborating through their Scientific Committees (SC). Trond Kvamsdal / Michael Muskulus is representing NOWITECH in NORCOWE's SC, while Ivar Langen / Finn Gunnar Nielsen represents NORCOWE towards NOWITECH's SC.

8 RESEARCH 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 2012.

8.1 INTEGRATED NUMERICAL DESIGN TOOLS (WP 1)

Roy Stenbro,
Head of WP1

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 develops 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 their components. Tools for optimization of components and systems are also part of the scope. The research activity includes the interaction of waves, current and wind, which is the origin of motion, loads and power output of an offshore wind turbine.

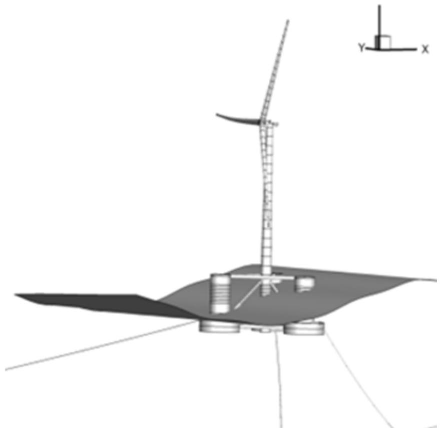


Figure 5 The FUGRO LIDAR based met-ocean buoy (left). Integrated simulations of semi-submersible offshore wind turbines with NOWITECH developed software performed well in the international comparison IEA Annex 30 OC4 (right).

Major achievements/highlights in 2012:

- WP1 is up and running well with a strong group of people from the both industry and R&D partners, and generally high productivity of deliverables.
- First generation software from both MARINTEK (SIMO/RIFLEX) and IFE (3DFloat) for integrated simulations of slender floating offshore wind turbines is developed and verified
- Second generation integrated models 3DFloat from IFE for turbines with bottom fixed jacket foundation are verified in IEA OC4. The tool now also supports tension leg buoy concepts (TLB) which have been extensively investigated.
- Both Integrated models now well under way of being validated for semi-submersibles.
- The development of the novel iso geometry based elements fluid/structure simulation tool by SINTEF ICT progressing well.
- A software tool for the optimization of spare type offshore wind turbines and one general tool that can be used with most numerical models have been developed. They have been applied to spare horizontal axis, spare vertical axis, TLB and 5 MW 1-, 2- and 3-bladed rotors.
- Good results with full 3D CFD wake simulations of a wind turbine park and single rotor are provided.

- A second "blind test" workshop on wake effects was jointly organized by NOWITECH and NORCOWE in Trondheim 4-5 October 2012. This was a follow-up on the first held in Bergen October 2011. The workshop assessed results from 7 research groups including research parties from NOWITECH and NORCOWE, DTU in Denmark, and participants from the Nordic Consortium on Optimization and Control of Wind Farms, led by Gotland University. The workshop participants estimated the performance of a model turbine and the wake formed by the rotor. The methods ranged in complexity from standard Blade Element Momentum methods to Large Eddy Simulations. While the first workshop conducted in 2011 focused on a single turbine, this year's Blind Test 2 considered two turbines in a row. The workshop started with a review of the results from the previous workshop, giving the participants the possibility to improve their results. The overall conclusion of the workshop was that a large uncertainty in the prediction of the turbulence field in the wake remains, which increases with the complexity of the methods used.

The post doc and the four PhDs are all progressing well and have started to deliver R&D results. Lars Frøyd successfully defended his PhD thesis at NTNU on 17 October 2012 with title "Wind Turbine Design: Evaluation of Dynamic Loads on Large Offshore Wind Turbines". Lars Frøyd is the first NOWITECH PhD to finish; the two next in WP1 are expected to finish in 2013 and the fourth in 2016, see A.1.4

Both Fugro OCEANOR and Fedem Technology have industry in-kind contribution in WP1: Fugro OCEANOR has contributed to task 1.2 with in-kind in the form of reports. FEDEM has contributed with software licenses in task 1.1. FUGRO have very high commercial interest in their floating LIDAR met-ocean buoy which was initiated by their involvement in NOWITECH.

8.2 ENERGY CONVERSION SYSTEM (WP 2)

Bernd Schmid, Head of WP2

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

In 2012 WP2 was divided in three tasks:

2.1: Fatigue properties of composites in rotor blades and rotating machinery
2.2: Ironless generators for direct-drive wind turbines
2.3: Sensor technology for condition monitoring of composite components

The energy conversion system of the offshore wind turbines being installed today are basically the same 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 to “bridge” the competence gaps and to create a basis for innovations necessary to move beyond the today’s “show stoppers” the industry is facing.

Two main conceptual topics have been treated in Task 2.1 Rotor blades:

- Smart blade technology involving passive control concepts.
- Influence of material and process parameters on fatigue of composites.

Generator design has been approached in Task 2.2 by modelling and understanding the thermal and electromagnetic conditions in new design and superconducting materials.

Task 2.3 focused on the application of sensors for condition monitoring of components made of composite material and possibly also feedback control during operation of wind turbine.

Examples of major achievements/highlights:

Task 2.1: Composite material technology

The development of multi-megawatt adaptive wind turbine blades is driven by the potential for reducing maximum loads and fatigue damage. Load mitigation, created by pitching a blade towards feather, lessens the strength requirements for the blade and elsewhere in the turbine. This allows for lighter components throughout the system. In addition, adaptive blades react to wind turbulence more quickly than active pitching of the full blade and thus can provide a more steady torque to the generator.

The study was performed on a blade of the NOWITECH 10 MW reference turbine. The goal was to determine the degree of twisting achieved at various wind speeds and to find what affects the induced twisting had on power collection and bending loads. The analyses predicted a flap load reduction of 15.9% at the design wind speed with a 7% drop in C_p as compared to the reference blade. During the EOG (assuming no control system, 0 pitch), the C_p decreased by 2% and the flap loads by 10.3%.

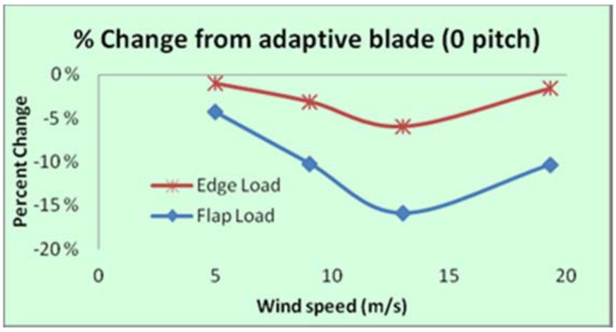


Figure 6 Influence of adaptive wind turbine blades on edge and flap load

A nonlinear buckling simulation was performed during the EWM condition corresponding to the worst-case condition for this blade. Due to the load reduction from the coupled blade the critical buckling load increased by 8.7%. This allowed for a removal of material reducing the blade weight by 2.2%. Overall, adaptive blades reduce loads and show potential for saving weight. In addition, the control system can be simplified.

Task 2.2: Generator technology
The mass of generator generally consists of two parts: the active part which directly produces the torque and the inactive part which holds the active material in position and keeps the air-gap clearance. Normally, the larger the rating of the generator, the heavier and bigger the machine is.

However, as the power rating grows, the mass of the active and the inactive part increases differently. For example, 20% of inactive mass in a 1.5 MW machine turns into more than 70% in a 10 MW machine.

The huge mass of inactive material makes the application of conventional generators at a power level over 10 MW not feasible since the generator gets very heavy and expensive.

Figure 7 Lab setup with ironless permanent magnet machine.

In NOWITECH, the ironless technology is under investigation and development (Figure 7). Because of no iron in the stator, there is reduced tension between the stator and the rotor, hence less need for the strength of the inactive part. An ironless design has less mass than current technology frontier. In addition, this generator technology is intrinsically friendly to the high voltage transformer-less generator drive for direct connection to HVDC grid (see NOWITECH newsletter published in April 2012), which can further decrease the nacelle weight and increase the turbine availability. By enabling the lightweight turbine, ironless technology makes the floating turbine concept (>10MW) more viable.

Task 2.3: Sensor technology
A report on innovative sensors and their potential for establishing a reliable, cost-effective condition monitoring/ structural health monitoring system has been compiled.

The report focused on two of the most promising sensor technologies available, and the researchers from SINTEF MC and ICT worked together to establish a roadmap in order to achieve the ultimate goal of a SHM system: A strategy for the identification of failures in terms of existence, location, type and extent and their effect on the overall reliability of the structure.

The roadmap includes the following steps:
- Determine and qualify mounting (surface/embedding) procedures
- Determine number of sensors and positions

- Data storage and transfer issues (wireless monitoring systems are an inevitable part of the future)
- Combine measurements with FE analysis and smart algorithms in order to determine the relation between measured data and condition of structure.

The report concludes that: "The key to a successful system is providing information and decision support, not just data".

An efficient structural health monitoring system is an important sub-system in the future "Cost-effective Integrated Operations for Offshore Wind Turbines". In the near future, the operation and maintenance of offshore wind turbines will be managed remote-controlled using highly automated onshore monitoring systems in combination with high value resources where they are most critically needed. Inspiration and valuable lessons are learnt from the development of Integrated Operations for offshore oil and gas recovery.

The three PhD students in WP2 all started in 2010 and are progressing well, expecting to finalize in 2013, see also A.1.4.

8.3 NOVEL SUPPORT STRUCTURES AND FLOATERS (WP 3)

Trogeir Moan, Head of WP3

The objective is to develop novel, cost-effective support structures for deep-sea wind turbines. This goal is addressed by the following three tasks:

3.1: Bottom-fixed support structures
3.2: Floating support structures
3.3: New coatings

The first two tasks deal with the analysis and design of alternative concepts for bottom-supported and floating support structures for wind turbines by assessing design criteria, establishing benchmark analysis procedures for evaluating the structural effects of wave, current and wind loads on different wind turbine concepts. The third task addresses existing and novel types of coatings for corrosion protection of offshore wind turbine support structures.

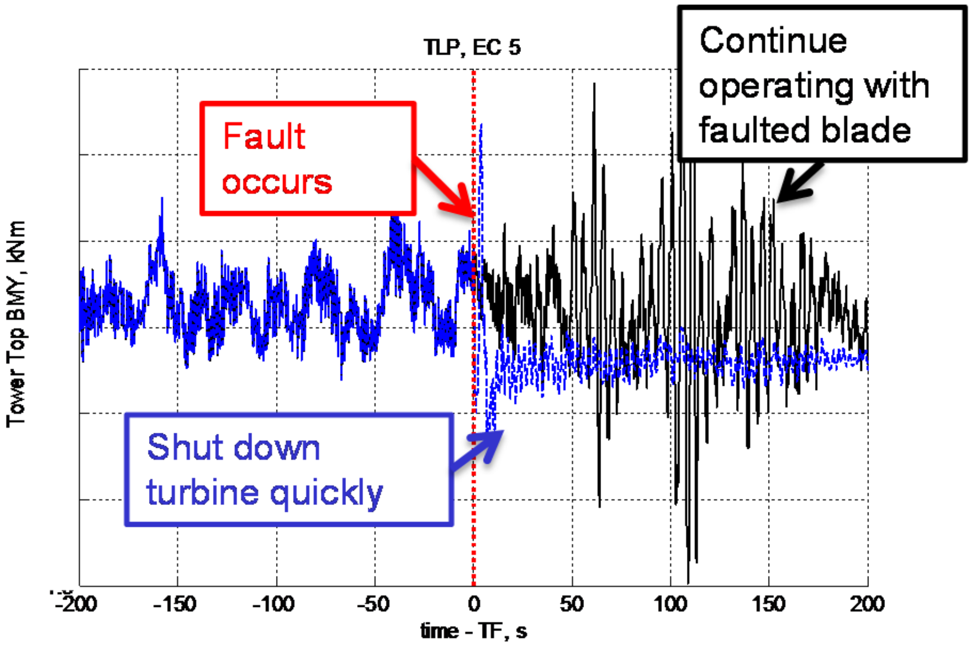


Figure 8 Snapshot of bending moment at the top of the tower in a tension-leg wind turbine during the occurrence of fault (blocked actuator of pitch control). Mean wind speed= 20 m/s; Hs =4.8 m and Tp =10.8 s with the rotor in normal operation. Two alternative conditions after fault are considered: shut-down and continued operation with faulty blade.

Major achievements/highlights:

- A milestone deliverable on the design of the support structure of the 10 MW reference turbine was completed in 2012 (NTNU BAT).This reference turbine has also served as basis for other studies in WP3, e.g. on pile-soil foundations and fabrication methods.

- Advances on assessing analysis tools applicable to floating and fixed offshore structures supporting wind turbines have been made. These include the integration of the Aerodyn and SIMO/Riflex codes and applying it to semi-submersible and tension-leg wind turbines (by MARINTEK and NTNU CeSOS), as documented in several papers

- A comparative study of various floating wind turbines under environmental and fault conditions have been conducted to assess the vulnerability of such turbines to faults, relative to land based wind turbines

- IFE and NTNU CeSOS have carried out analyses in the IEA OC4 benchmark study of software for wind turbines with semi-submersible support structures.

- NTNU partners in WP3 tasks 3.1-2 have been involved in an EC FR7 project: the Marina Platform, Mare-Wint and Orecca as well as the HiPRwind project in 2012.

- SINTEF MC made the following achievements regarding corrosion protection systems for the support structure:
  - It is found that coating systems with thermally spayed zinc (TSZ) seems to have excellent field performance, even with a very simple paint system on the top
  - The ISO 20340 ageing test is unable to predict the performance of duplex coating systems, while laboratory tests can reproduce field performance for coating systems without TSZ

- SINTEF MC has assessed the Technology Readiness Level of their novel protective coating systems for offshore wind turbines based on maintenance-free coating systems comprising thermally sprayed zinc (TSZ) with paint with self-healing properties on top.

The results are documented in the publications listed in section A.3. While 4 of the PhD candidates are well underway with their research, the fifth PhD candidate by EDF in-kind, was engaged in February 2012, see A.1.4.

8.4 GRID CONNECTION AND SYSTEM INTEGRATION (WP 4)

Kjetil Uhlen, Head of WP4

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.

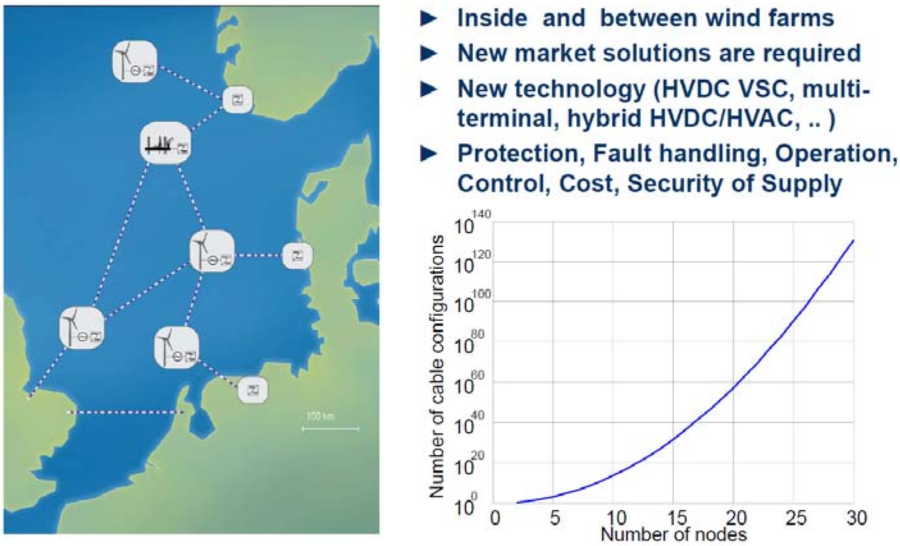


Figure 9 A main topic in WP4 is the optimization of offshore grids and grid connections.

Main achievements in 2012 are related to model developments and research to identify innovations in wind farm and wind cluster grid design adapted for:

- Offshore applications (Tasks 1 and 2)
- Control design for secure operation of offshore grids (Task 2)
- Power system analysis tools for cost benefit assessment of offshore wind and grids (Task 3).

Highlights in 2012:

- The work up to now in NOWITECH WP4 has resulted in many high quality publications this year. In addition to several conference publications and reports 16 journal papers have been accepted for publication in 2012.
- There has been high focus on alternative design of wind farm internal grids. This work is closely coordinated with the EU FP7 projects HiPRwind and EERA-DTOC “offshore cluster”. The work includes the adaptation of the existing tool, Net-Op, for optimized grid design to be used for studies on grid connection of wind farm clusters and internal wind farm grids.

There has been a close collaboration with EERA (European Energy Research Alliance) on grid connection and offshore wind. Several on-going Nordic and EU-projects are closely coordinated with the in WP4.

All three PhD students financed by NOWITECH under WP4 have started. The Postdoc period of Steve Völler has ended, and he is continuing offshore wind related research at SINTEF Energy Research. Among the associated PhDs at NTNU four have completed in 2012 and four more are expected to complete in the course of 2013 (see Appendices A.1.4 and A.1.6). Recruitment of new PhDs and researchers is therefore identified as a main challenge for the upcoming period.

The industry partners closely connected to WP 4 are primarily Statnett, Statkraft, Statoil, DONG Energy and DNV.

8.5 OPERATION AND MAINTENANCE (WP 5)

Matthias Hofmann, Head of WP5

The objective is to develop a scientific foundation for the 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, including remote presence
- Analyses of access techniques and assessing their impact on maintenance opportunities and O&M costs
- Development and adaption of methods and tools for assessing optimal logistics strategies
- Develop new materials/coatings with improved Life Cycle Costs (LCC)

The work is divided into three tasks:

5.1 Maintenance strategies
5.2 Surveillance and condition monitoring
5.3 Access and logistics techniques

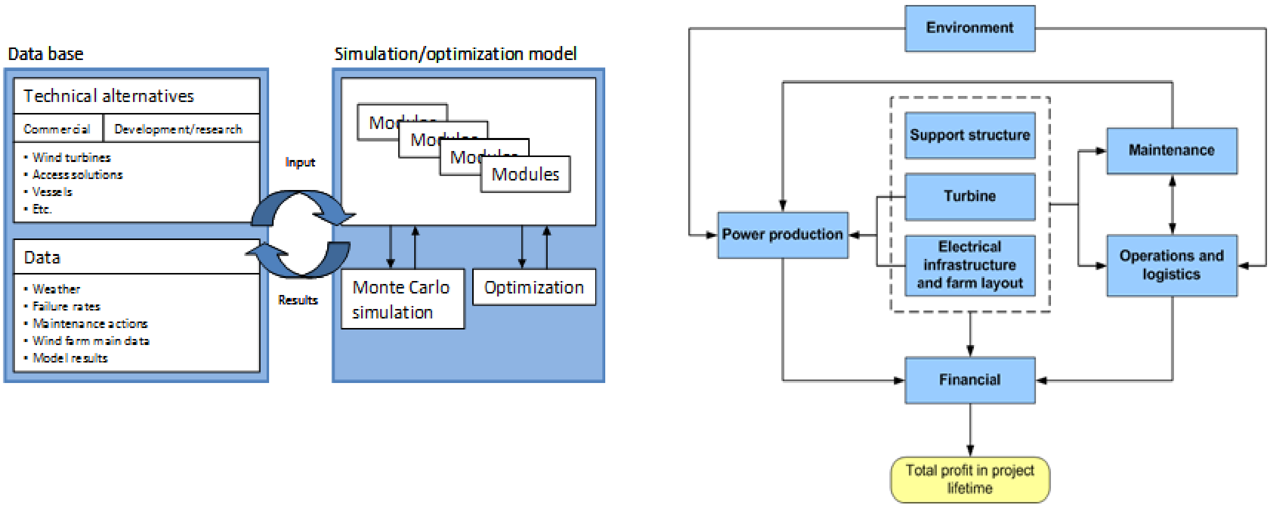


Figure 10 Holistic/ integrated model concept for Life Cycle Profit analysis of an offshore wind farm, including all phases from design to decommissioning (Task 5.1).

Major achievements/highlights:

- A second version of a holistic life-cycle profit (LCP) software for offshore wind farms and a model for optimizing the vessel fleet are finalized, and is being utilized in a spin-off project (FAROFF) (T5.1)
- A spin-off project (WINDSENSE) has been launched on instrumentation of wind turbines (T5.2)
- Wear and erosion resistant plasma spray coatings for wind turbines have been tested with promising results. A patent application is submitted (T5.3)
- 15 peer-reviewed papers have been submitted/ completed in 2012, out of which 5 are journal papers.
- Joint collaborations/applications with European research institutes:
  - EU FP7-ENERGY-2010: HiPRwind (O&M activities).
  - Cooperation with Tampere Univ. of Technology on development of thermal spray technology
  - Participation in EERA working group on O&M of offshore wind power

  - Participation in IEA Task 26 on cost of wind energy
  - Participation in coming IEA Task 33 on standardization of reliability data
  - Participation in Nordic wind power O&M network, so far together with Chalmers Univ. of Technology, VTT, DTU, Elforsk and Energi Norge
  - Member of Reference groups in Vindforsk's "Wind Power Asset Management" and "Wind Power RAMS-Database" projects
- Two meetings for closer collaboration with NORCOWE on O&M research.

One PhD candidate started in 2009, and two in 2010. A new PhD candidate has been employed in 2012 with focus on condition monitoring of gearboxes. In addition, three PhD students are associated with WP5, but financed by other sources than NOWITECH (see Appendices A.1.4 & A.1.6).

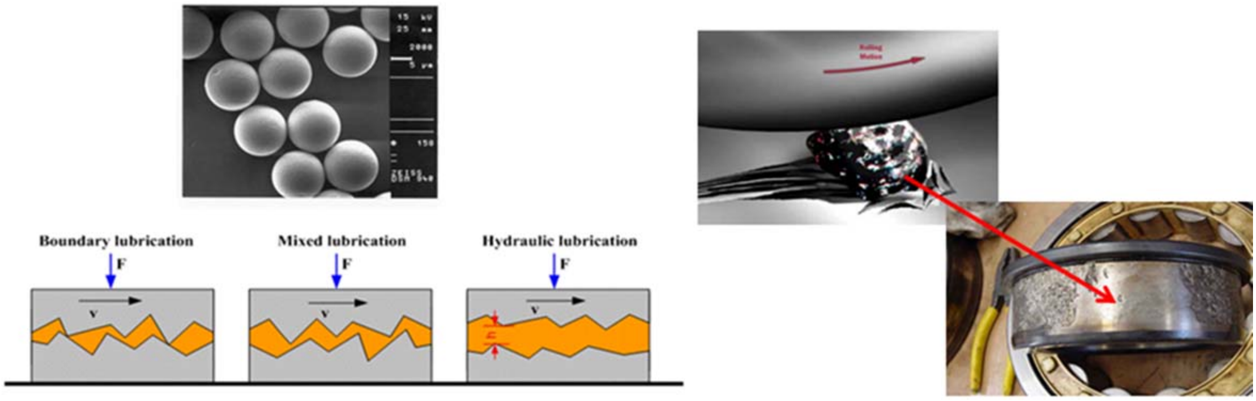


Figure 11 New, cost-effective methods for production and maintenance of low friction surfaces and surface protection (Task 5.3).

8.6 ASSESSMENT OF ALTERNATIVE DESIGN CONCEPTS (WP 6)

Ole David Økland,
Head of WP6

The objective is to develop and assess novel concepts of deep-sea wind turbines by numerical tools and physical experiments and the development of control systems combining the results from WP1 to WP5. The concepts are assessed 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.

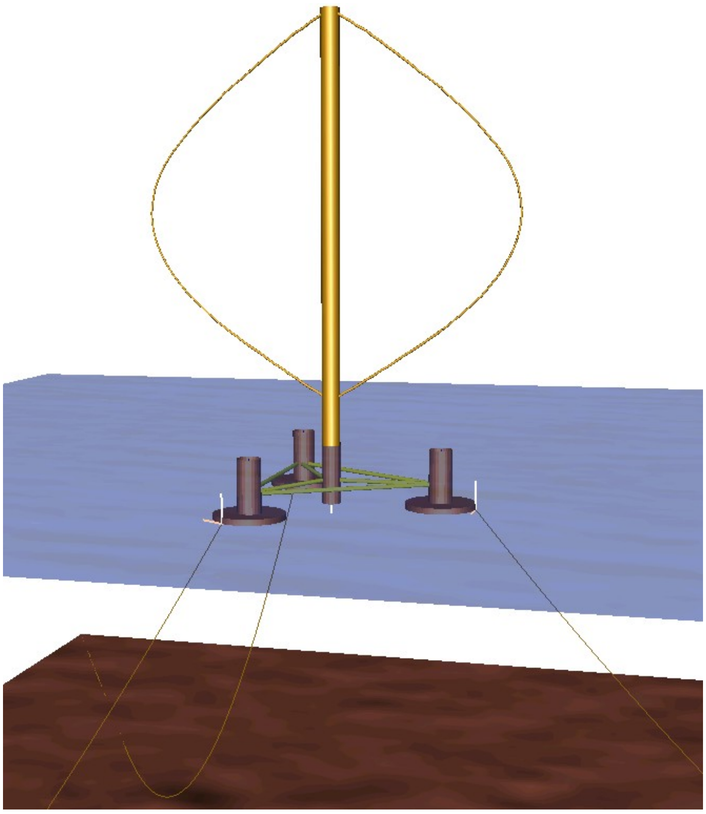


Figure 12 Visualization of FVAWT in post-processing SIMVIS

The 2012 work lead to reports and scientific publications on control-oriented modeling of floating offshore wind turbines (see Appendix A.3). These publications also constitute one of the milestone deliveries in NOWITECH for 2012- *Control scheme for load mitigation and minimization of motions of floating wind turbine*. A patent on methods for the suppression of oscillations in wind turbine towers was also granted in 2012. The work on exploring alternative concepts such as short spar type floating wind turbines for intermediate water depths and floating vertical axis wind turbines was continued. The second phase of experiments in the CWT-facility at MARINTEK with focus on scale effects has been carried out.

Results from the work package have been presented at several international conferences in 2012, including EWEA2012, 9th Wind R&D, MATHMOD2012, ISOPE 2012 and OMAE 2012. Several publications based on results from 2012 are planned to be presented at international conferences in 2013.

The work package has also been involved in:

- NOWERI full scale project
- NOWITECH integration activity – structural model for NOWITECH Reference Turbine
- EU DeepWind status meeting at EWEA2012
- NOWITECH Software Workshop, April
- IEA Experts Meeting on Computer Code Validation for Offshore Wind System Modelling, May 15-16, 2012, Boulder, CO, USA

There are presently 4 PhD-students engaged in this work package. All PhD candidates have now finished their courses and are able to fully focus on their research tasks. Madjid Karimirad was engaged as Postdoc until summer 2012. PhD student Morten Pedersen will finish his thesis in 2013. A list of all PhD students financed through NOWITECH or by other sources can be found in the Appendices A.1.4 & A.1.6.

8.7 NOWITECH 10 MW REFERENCE TURBINE


Karl Merz, Head NRT

The NOWITECH 10 MW Reference Turbine (NRT) is intended to serve as a focal point and baseline case for research activities within NOWITECH. If a version of the design is completed, then it will be the only full definition of a large wind turbine available in the public domain, and thus there is also potential for international impact[2]. Since start of the activity in 2011, the NRT has developed from an idea into a conceptual design. Publications in 2012 document the status:

- Dahlhaug et al. [3] provides general design specifications for the NRT. The specifications include global dimensions, environmental conditions, the electrical system topology, and so forth: this is the information needed to begin the design, but is not sufficient to build an analytical model.
- Cox [1] gives a detailed description of the composite layups used in the blades.
- Zwick [9], Muskulus [6], and Van Buren [8] described methods to be employed in the design of the tower and foundation.
- Other articles present alternate concepts, outside of the design specifications: Frøyd [4] describes a hydraulic blade pitch drive and looked at a grid fault load case, and Gjerde [5] introduces a modular, high-voltage generator and converter concept that allows the transformer to be eliminated.
- The master's thesis by Smith [7] provides a detailed design of the nacelle frame. This consists of a turret mounted atop the yaw bearing, and a cylindrical nose bolted to the turret. The main shaft sits inside the nose, and the generator stator is mounted outside.
- Cox [2] shows how bend-twist coupling can be introduced to the NRT blades in order to reduce loads, albeit at the cost of reduced energy production.

[1] Cox K, Echtermeyer A; "Structural design and analysis of a 10 MW wind turbine blade"; Energy Procedia 24 (2012) 194-201

[2] Cox K, Echtermeyer A; "Load alleviation from an adaptive 10 MW wind turbine blade"; DEWEK (German Wind Energy Conference), Bremen, Germany, 7-8 November, 2012

[3] Dahlhaug OG, et al.; "Specification of the NOWITECH 10 MW Reference Wind Turbine"; NOWITECH Report, January 2012

[4] Frøyd L, Dahlhaug OG; "Effect of pitch and safety system design on dimensioning loads for offshore wind turbines during grid fault"; Energy Procedia 24 (2012) 36-43

[5] Gjerde SS, Underland TM; "A modular series connected converter for a 10 MW, 36 kV, transformer-less offshore wind power generator drive"; Energy Procedia 24 (2012) 68-75

[6] Muskulus M; "The full-height lattice tower concept"; Energy Procedia 24 (2012) 371-377

[7] Smith EB; *Design of a Nacelle for a 10 MW Wind Turbine*; MS Thesis, Department of Engineering Design and Materials, NTNU, 2012

[8] Van Buren E, Muskulus M; "Improving pile foundation models for use in bottom-fixed offshore wind turbine applications"; Energy Procedia 24 (2012) 363-370

[9] Zwick D, Muskulus M, Moe G; "Iterative optimization approach for the design of full-height lattice towers for offshore wind turbines"; Energy Procedia 24 (2012) 297-304

3D CAD Model

During the summer of 2012, a student (E. Agnalt) was employed by NTNU to develop a 3D CAD model of the NRT. Figure 13 shows a cutaway view of the nacelle. Here the tower legs and braces, nacelle turret and nose, and blades are "real", based on at least preliminary engineering calculations. The other components – the hub, pitch drives, main shaft, tower-to-nacelle

[2] The DOWEC study (http://www.ecn.nl/nl/units/wind/projecten/dowec/) comes close to a complete definition. So does the NREL 5 MW reference turbine. However, both of these omit important parts of the electrical system.

transition piece, and secondary structures – are conceptual. The generator width and diameter are based on engineering data, while the structural design of the rotor and stator is conceptual.

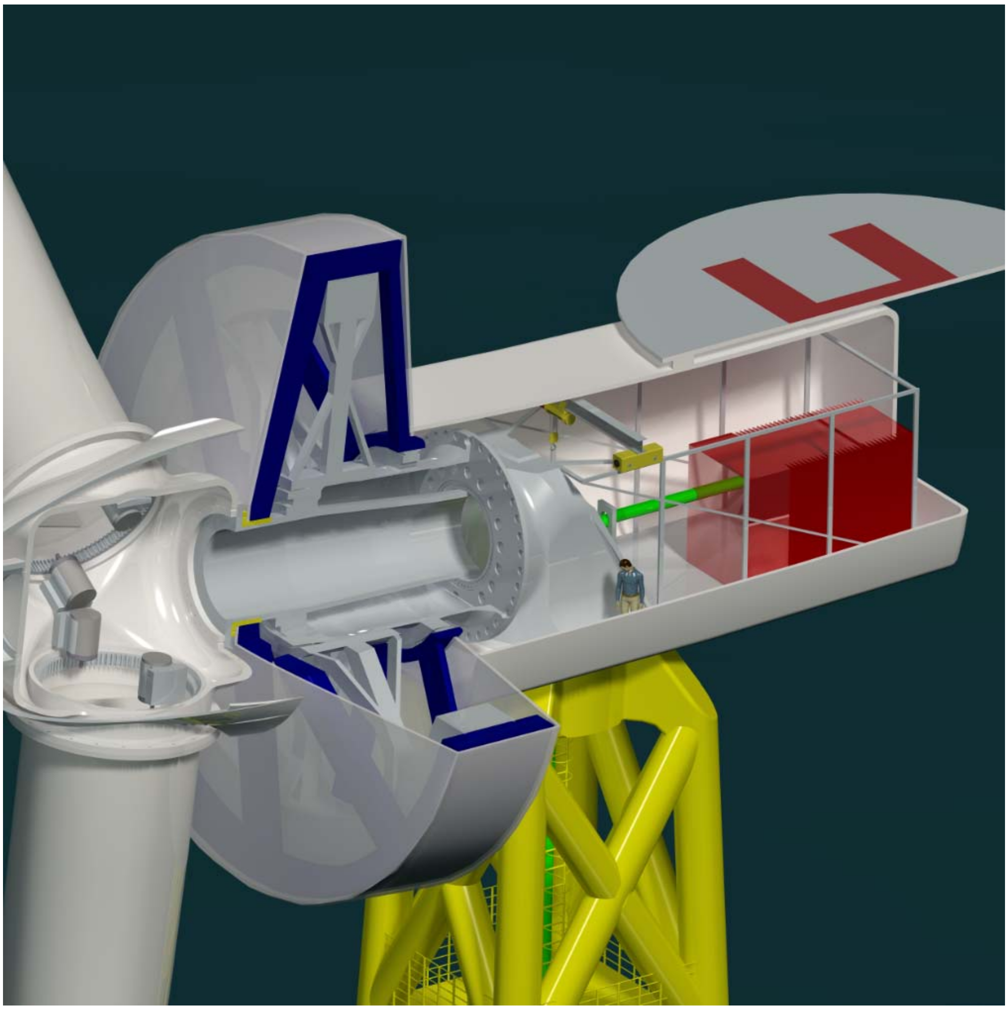


Figure 13: A cutaway view of the nacelle, from the 3D model of E. Agnalt

In-Kind Contributions

Fedem Software is implementing a model of the blades, tower, and foundation of the NRT in their FEM code. The tower and foundation designs are preliminary, and will need to be updated.

Summary of Status

There are two perspectives from which to view the NRT. The first is "the NRT as a theme in research". That is, if a research activity within NOWITECH involves application of a new technology to a wind turbine, then the NRT is to be chosen as an example. In this sense, the NRT has been successful.

The second perspective is "the NRT as a test-bed". Here we should talk of a specific, baseline Version 0 of the turbine, NRT0. A full-system loads model would enable

1. a reliable determination of the mechanical and electrical loads seen by a given component on the turbine, and
2. a scientific evaluation of new ideas, via perturbation studies: NRT0 → NRTx.

A loads model is a beam (equivalent mass and stiffness distribution) model of the mechanical load path from blades to ground, plus an equivalent circuit model of the electrical system from generator to point of common coupling with the grid.

To provide an obvious example of the importance of a fully-defined test-bed, NTNU is designing a novel full-height lattice tower for the NRT0. This requires an accurate estimate of lifetime mechanical loads – both extreme loads and fatigue cycles – at the yaw bearing located at top of the tower. Currently there is no main shaft design, nor is there a baseline blade pitch control system. Therefore it is not possible to obtain an accurate estimate of lifetime mechanical loads at the yaw bearing.

A similar problem arises in most other fields as well. Take as an example corrosion protection technology. To determine the potential benefits from, say, a new coating, one must know the geometry of the structure that is being protected.

Figure 14 summarizes the status of the NRT0. Green means "done", yellow means "something has been done", and blank is "nothing" or "no data". The NRT0 is ready to be released when most of or all the loads model is completed.

	Specifications	Planned	Preliminary sizing	Analysis/ Loads model	3D CAD	Notes
Blades						Default OK, ideally one more design iteration
Pitch mechanism						Need basic parameters for loads model
Hub						
Main shaft and brake						
Generator (structural)						Mass estimate from SmartTool and industry trends
Main bearings						Selected from catalog
Bed frame						Need dynamic and fatigue analysis; actual base BC
Yaw drive						
Transition piece						
Tower						Need analysis with full set of load cases
Pile sleeves						
Piles						Design tool ready, awaiting loads
Controls						NREL model; need specific gains and load reduction loops
Generator (electrical)						
Converter						Typical architecture, need specific values for parameters
Converter controls						Typical architecture, need specific values for parameters
Transformer						Typical architecture, need specific values for parameters
Documentation						Need to document mechanical and electrical loads models explicitly.

Figure 14: Status of the NRT0 test-bed

8.8 RESEARCH INFRASTRUCTURE

The research partners have access to strong research infrastructures in form of in-house labs and field facilities, e.g. test station for wind turbines at Valsneset, four met-masts at Frøya, EFOWI (lidars and met-ocean buoys) together with NORCOWE, wind tunnel at NTNU (11x3x2 m), ocean basin lab at MARINTEK (80x50x10 m) and SmartGrid lab at NTNU/SINTEF.

Further infrastructure are being developed with funding from RCN, namely ETEST (8 MVA short-circuit emulator) and NOWERI (offshore met-ocean measurement station and floating 225 kW research turbine) jointly with NORCOWE. ETEST is in procurement expecting installation in 2013, while NOWERI is an initial stage preparing contracts between RCN and the research parties. NTNU is the contract partner for the floating test turbine and UiB for the met-ocean measurements. The plan is to have the floating research turbine installed off the coast of Mid-Norway within 2014.

In 2012 an extension of the SmartGrid lab was applied for, expecting a decision on funding or not by the RCN within 2013.

An EU infrastructure project was also started in 2012 with participation from NOWITECH. This is WindScanner.eu being a European Strategy Forum on Research Infrastructures (ESFRI) preparatory phase (PP) project (2012-2015). The objective is to provide catalytic and leveraging support towards the construction of the facility, in order to bring the project to the level of legal, organizational, technical and financial maturity required to establish and operate the facility by 2016 onwards. The operational European WindScanner Facility – once established – is expected to become a distributed and mobile research infrastructure.

The research infrastructures are developed with separate contracts external to NOWITECH, but prepared in alignment with NOWITECH.

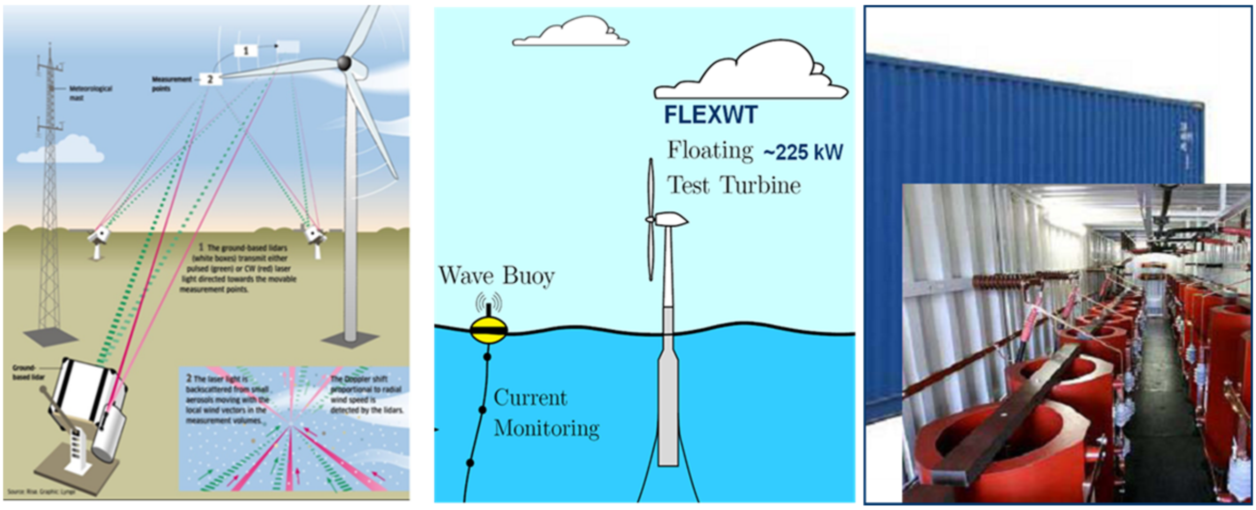


Figure 15 Research infrastructure in preparation, from left: WindScanner.eu, NOWERI floating test turbine and ETEST 8 MVA short-circuit emulator.

8.9 SPIN-OFF PROJECTS

The NOWITECH research partners are attractive: A total of four EU research projects and five Research Council of Norway projects were started in 2012 with participation of one or more of the research partners in NOWITECH. Since start-up the count is 31 new projects with an accumulated budget of NOK 950 millions. The projects are with EU or Nordic funding (11), or by the Research Council of Norway (RCN) divided into competence building projects (KPN, KMB etc. 10), industry driven (IPN, BIP 7) and research infrastructure (3). A selection of the projects is listed in Table 1. A number of bilateral projects directly for industry come in addition. The projects are with separate contracts external to NOWITECH, but carried out in alignment with NOWITECH.

Table 1 Selection of projects (started, on-going or finished in 2012) with participation of one or more of the research partners in NOWITECH.

Project title	Type	Partners	Status
WindScanner.eu	EU ESFRI	DTU, Fh IWES, ECN, ForWind, CENER, SINTEF ER, LNEG, University of Porto and CRES	Started
EWEM: European Energy Master (Erasmus Mundus programme)	EU	TU Delft, DTU, NTNU, Universität Oldenburg	Started
FAROFF: Far offshore operation and maintenance vessel concept development and optimization	RCN IPN	Statkraft, MARINTEK, Fred Olsen, Odfell, SINTEF ER	Started
WINDSENSE: Add-on instrumentation system for wind turbines	RCN IPN	Kongsberg Maritime, Statoil, NTE, SINTEF ER, Marintek, NTNU, WCMN	Started
ProOfGrids: Protection and Fault Handling in Offshore HVDC Grids	RCN KPN	SINTEF ER, NTNU, RWTH Aachen University, Statnett, Statoil, NationalGrid, EDF, GE Power Conversion, NVE, Siemens, Statkraft	Started
Fluid Structure Interactions for Wind Turbines	RCN KPN	SINTEF IKT, Statoil, TrønderEnergi, Kjeller Vindteknikk, FFI, NTNU, SINTEF	Started
MARE-WINT: new Materials and Reliability in offshore WINd Turbines technology	EU FP7	NTNU, Marintek	Started
InnWind: Innovative wind conversion systems (10-20MW) for offshore applications	EU FP 7	Risø DTU, SINTEF ER, etc.	Started
EERA-DTOC: EERA Design Tools for Offshore Wind Farm	EU FP 7	DTU Risø, SINTEF ER, etc	On-going
MARINET: Marine Research Infrastructures Network for Energy Technologies	EU	HMRC University College Cork, Risø DTU, NTNU, Universityof Strathclyde, Fraunhofer IWES, SINTEF ER, etc	On-going
MARINA: Marine Renewable Integrated Application Platform	EU	Acciona, Partners: NTNU etc.	On-going

Project title	Type	Partners	Status
Mitigation measures and tools to reduce bird-associated conflicts in space and time for onshore and offshore wind-power plants	RCN KMB	NINA, NTNU, SINTEF M&C, SINTEF ICT, Statkraft etc.	On-going
DeepWind: Future Deep Sea Wind Turbine Technologies	EU	Risø DTU, Statoil, SINTEF ER, MARINTEK etc.	On-going
HiPRwind: High Power, high Reliability offshore wind technology	EU	Fraunhofer. SINTEF ER, NTNU etc.	On-going
Twenties (www.twenties-project.eu)	EU	Red Electrica, SINTEF ER etc	On-going
Offshore DC: DC grids for integration of large scale wind power	Nordic	Risø DTU, AAU, Chalmers, SINTEF, VTT, Dong, Vestas, ABB, Energinet.dk	On-going
Offwind: Prediction tools for offshore wind electricity generation	Nordic	IRIS, SINTEF, FFI, WindSim, Storm Geo etc.	On-going
PowerUP: Effektive verdikjeder for offshore vindmøller	RCN Mid-Norway	SINTEF,NTNU, Høgskolen I Molde, Møreforskning	On-going
Nordic wind power O&M network	Nordic	Energi Norge, SINTEF ER, VTT, Vindforsk, Chalmers, Risø DTU	On-going
RAWi: Radio Acoustic Wind Sensor	RCN BIP	Triad, IFE, UIB, Kjeller Vindteknikk, NORBIT	On-going
NOWERI (offshore met-ocean measurements and floating wind turbine)	RCN	CMR, UiB, NTNU, SINTEF, IFE etc.	On-going
ETEST	RCN	SINTEF ER	On-going
Role of North Sea power transmission in realising the 2020 renewable energy targets	RCN KMB	SINTEF ER, Statnett, Statkraft, EDF R&D, Siemens, NVE etc	Finished
High frequency solutions for Wind power conversion	RCN SUP	NTNU, MTU (USA)	Finished
EFOWI (lidars, met-ocean buoys) research infrastructure	RCN	UiB, CMR, NTNU, IFE, SINTEF, etc	Finished

9 INTERNATIONAL COOPERATION

NOWITECH participates in relevant international activities with significant efforts in the following international entities:

- European Energy Research Alliance (EERA) joint programme (JP) on wind energy, www.eera-set.eu; SINTEF, NTNU and IFE participate in EERA JP Wind Energy developing network, scientific work programmes, workshops and project proposals. John Tande (SINTEF Energy Research) coordinates the sub-programme on Offshore Wind Energy.

- European Technology Platform for wind energy (TPwind), www.windplatform.eu; John Tande (SINTEF Energy Research) is Chair of the offshore working group within TPwind, and a member of the TPWind Steering Committee.

- European Academy of Wind Energy (EAWE), www.eawe.eu; SINTEF, NTNU and IFE participate. Michael Muskulus (NTNU) is Vice President of EAWE. Tor Anders Nygård (IFE) is member of the Executive Committee.

- Erasmus Mundus European Wind Energy Master (EWEM), www.windenergymaster.eu. NTNU has together with three other European universities (TU Delft, DTU and University of Oldenburg) jointly been awarded an Erasmus Mundus European Wind Energy Master (EWEM) programme starting September 2012. TU Delft and DTU are also associate research partners to NOWITECH. The programme aims to educate 120-150 MSc graduates per year in Wind Energy technology.

- IEA Wind, www.ieawind.org; The research partners of NOWITECH are active in all relevant tasks of IEA Wind, including:
    - IEA Wind Task 25: System operation (grid integration)
    - IEA Wind Task 26: Cost of wind energy
    - 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

- IEC TC88, www.iec.ch. The research partners of NOWITECH are active in all working groups with relevance for offshore wind turbines, e.g. PT 61400-3 developing a technical specification for the design requirements for floating offshore wind turbines. SINTEF Energy Research is heading the Norwegian sister-organization NK88 and represents Norway in TC88.

The research partners in NOWITCH participate in eleven EU projects related to offshore wind. These projects have separate contracts external to NOWITECH but are carried in alignment with NOWITECH.

10 RECRUITMENT

The Centre includes a strong PhD and Postdoc programme. Three PhD candidates started in 2012 with funding from NOWITECH, leading to an overall number of 23 PhD scholars and two Postdoc at NTNU fully funded by the Centre. In addition, another 29 PhD and Postdoc students are associated to the Centre in 2012. These are doing research within the thematic area of the Centre at NTNU, and participate in relevant Centre activities, but their grants are funded outside the Centre. The PhD and Postdoc positions are carried out as an integrated part of the work packages. The Scientific Committee (SC) has the overall responsibility for developing the PhD and Postdoc programme. This include an active recruitment strategy, organization of joint PhD forums and training, exposing them to industry and leading international research groups by organising the PhDs and Postdocs in groups contrary to the unfortunate ivory tower model. A list of all PhD students and Postdocs financed through NOWITECH or by other sources can be found in the Appendices A.1.3 - A.1.6.

Figure 16 Three new PhD students started up in 2012. From left: Phen Chiak See, Amir Rasekhi Nejad and Lars Morten Bardal.

An overview of all NOWITECH PhD and Postdoc projects has been published in the form of a booklet entitled 'PhD and Post-doc projects 2012'. The Scientific Committee distributed 150 copies to partners and at relevant events. The booklet is also available for download at www.nowitech.no. NOWITECH also participated in the organization of the NorRen (The Norwegian Research School in Renewable Energy) summer school 2012.

A challenge for the next years is to obtain additional funding to keep up the momentum in the PhD and Postdoc education. The PhD and postdocs financed by NOWITECH are all due to finish before 2015. The first PhD student already graduated, and 10 to 15 PhD students are expected to conclude their study in 2013. Thus, to keep up the momentum significant additional funds for a next wave of PhD students need to be secured. This is high on the agenda in the management of NOWITECH and in the SC in particular. A solution is sought in dialogue with the Board and the RCN.

MSc students are engaged in summer jobs with the research partners, and the partners are also active in proposing relevant subjects for their final projects and thesis. The MSc education on wind energy has been enhanced at NTNU through NOWITECH, with the PhD and Postdocs assisting in the education, and the engaged professors cooperating through the SC and other NOWITECH activities across faculties.

As part of the MSc education in Energy and Environment at NTNU, in 2012 about 120 students divided in teams and built 22 complete machines with turbine and generator, all from scratch and with up to a one metre rotor diameter. A championship was organized in which the turbines were tested in a wind tunnel (Figure 17). The winner was the one generating the highest output power.

Figure 17 NTNU MSc students compete in building the best wind turbine as part of their education in Energy and Environment during fall 2012. Pictures by Prof Tore Undeland. From left: an engaged Prof Lars Sætran organizing the championship; a proud student with the winning turbine, and detail of the turbine with generator.

During 2012, professors and scientific staff at NTNU, with relations to NOWITECH, were supervisors for 30 Master Degree theses (see Appendix A.1.7). The start-up of the Erasmus Mundus European Wind Energy Master (EWEM) programme gives further weight to the MSc education at NTNU, in particular in the fields of electro and marine which are areas of NTNU engagement within the EWEM.

Studies on offshore wind energy are generally popular among the students. A search at http://ntnu.diva-portal.org/smash/searchlist.jsf?searchId=2 gives more than hundred MSc theses at NTNU with the keyword "wind".

Increased recruitment of women is promoted by active profiling of female candidates specializing within the field of offshore wind energy. In hiring students for summer job, PhD or Postdoc positions, women are especially invited to apply, and will be selected over male candidates if otherwise equally qualified.

11 COMMUNICATION AND DISSEMINATION

NOWITECH publications include a total of 104 publications in 2012, whereof 39 journal papers or peer-reviewed papers, 13 conference papers, 20 conference presentations, 18 reports and 10 media contributions. See Appendix A.3.

NOWITECH partners have access to a project e-room, where all internal information and project results are presented. The main channels for open communication of activities and results in NOWITECH are listed below:

- www.nowitech.no gives open information about NOWITECH, short news on offshore wind and announcements of relevant seminars etc. The site is mainly for the interested professional.
- Popular articles, adverts, media contributions and interviews are generally important means for raising public education and opinion.
- The NOWITECH newsletters give short teasers of results. The newsletters are distributed through e-mail and public web; they are open and shall be understandable also for the educated non-expert. Links for further reading are however to the NOWITECH e-room that is for partners only. Two news letters were produced during 2012.
- In 2012 the seminar series "Industry meets Science" was introduced in cooperation with Access Mid-Norway and Wind cluster Mid-Norway. The aim of the seminar is facilitate an improved interaction between the research in NOWITECH and relevant industry, also to those that are not partner in NOWITECH. http://www.sintef.no/Projectweb/Industry-meets-science/
- The scientific results of the Centre are disseminated efficiently and achieving international recognition. Publications since start-up include 64 peer-reviewed papers, 67 reports, 44 media contributions and 110 conference presentations of which 19 were invited keynotes.
- The annual offshore wind R&D conference in Trondheim has developed into an international event with call for papers, peer-review and publication in the open access journal Energy Procedia (Elsevier). DeepWind'2012 had about 200 delegates from 14 countries, mainly Europe, but also from USA, China, Singapore and Japan. www.sintef.no/deepwind_2012

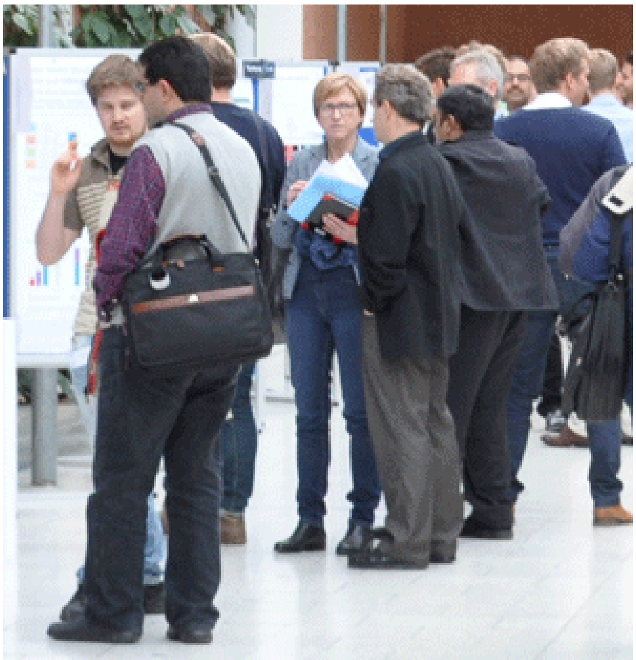


Figure 18 Poster session at NOWITECH's 'Industry meets Science' seminar 20 Sept. 2012.

A.1 PERSONNEL

Centre Management and Committees


John Olav G. Tande, Centre Director


Nils Arild Ringheim, Centre Manager


Tobias Aigner, Centre Manager (since 01.04.13)


Roy Stenbro, Head WP1


Bernd Schmid, Head WP2


Torgeir Moan, Head WP3


Kjetil Uhlen, Head WP4


Matthias Hofmann, Head WP5


Ole David Økland, Head WP6


Trond Kvamsdal, Chair SC


Michael Muskulus, Vice-chair SC


Kjell Eriksson, Chair CIC


Per Arne Wilson, Secretary CIC


Karl Merz, Head Reference Turbine


Debbie Koreman, Higher Executive Officer


Randi Aukan, Centre Secretary


Jørn Heggset Head WP5 (until 31.10.12)


Petter Andreas Berthelsen Head WP6 (until 31.06.12)

Further key researchers are listed in A.1.1.

NOWITECH Postdoctoral Researchers


Madjid Karimirad, Post-Doc


Mukesh Kumar, Post-Doc

NOWITECH PhD students


Tania Bracchi


Lars Morten Bardal


René Alexander Cárdenas


Valentin Chabaud


Mayilvahanan Chella


Kevin Cox


Pål Egil Eriksen


Lars Frøyd


Hameed Zafar


Marit Irene Kvittem


Luan Chenyu

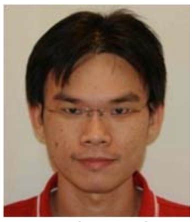

Amir Nejad


Øyvind Netland


Knut Nordanger


Morthe Dinhoff Pedersen


Martin Resell


Phen Chiak See

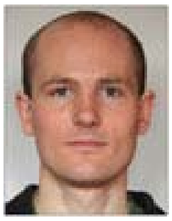

Amir Hayati Soloot


Mostafa Valavi


Eric Van Buren


Kai Wang


Zhaoqiang Zhang


Daniel Zwick

Details of topics and further list of associated postdoctoral researchers and PhD students are listed in A.1.3-A.1.6. Master students are listed in A.1.7.

A.1.1 Key Researchers

#	Name	Institution	Main Research Area / Role
1	Armada, Sergio	SINTEF MC	WP3, WP5
2	**Berthelsen, Petter Andreas**	**Marintek**	**Head WP6 (until 31.06.2012)**
3	Bjerkan, Leif	SINTEF MC	WP2
4	Bjørgum, Astrid	SINTEF MC	WP3, WP5
5	Dahlhaug, Ole Gunnar	NTNU	WP1, SC, Management
6	Delhaye, Virgile	SINTEF MC	WP2
7	Echtermeyer, Andreas	NTNU	WP2
8	Foques, Sebastien	Marintek	WP1, WP3
9	Fosso, Olav	NTNU	WP4, Board
10	Fylling, Ivar	Marintek	Wp1, WP6
11	Gao, Zhen	NTNU	WP3
12	Hals, Jørgen	Marintek	WP1
13	Halvorsen-Weare, Elin	Marintek	WP5
14	**Heggset, Jørn**	**SINTEF Energy Research**	**Head WP5 (until 31.10.2012)**
15	**Hofmann, Matthias**	**SINTEF Energy Research**	**Head WP5 (started 01.11.2012)**
16	Holdahl, Runar	SINTEF ICT	WP1
17	Høidalen, Hans Kristian	NTNU	WP2
18	Jørgensen, Jens Kiær	SINTEF MC	WP2
19	Krasilnikov, Vladimir	Marintek	WP6
20	Krogstad, Per Åge	NTNU	WP1,WP6
21	**Kvamsdal, Trond**	**NTNU/SINTEF ICT**	**Chair SC**
22	Luxsacumar, Sivakanes	SINTEF MC	WP2
23	Maus, Karl Jacob	IFE	WP1
24	**Moan, Torgeir**	**NTNU**	**Head WP3**
25	**Muskulus, Michael**	**NTNU**	**Vice-chair SC**
26	Muthanna, Chittiappa	Marintek	WP6
27	Nilssen, Robert	NTNU	WP2
28	Nonås, Lars Magne	Marintek	WP5
29	Nygaard, Tor Anders	IFE	WP1, WP2, WP3, WP6
30	Nysveen, Arne	NTNU	SC, WP4
31	Oggiano, Luca	IFE	WP1
32	Ong, Muk Chen	Marintek	WP3
33	Ormberg, Harald	Marintek	WP1, WP3
34	Passano, Elizabeth	Marintek	WP3
35	**Ringheim, Nils Arild**	**SINTEF Energy Research**	**Centre Manager**
36	**Schmid, Bernd**	**SINTEF MC**	**Head WP2**
37	Skavhaug, Amund	NTNU	WP5
38	Stansberg, Carl Trygve	Marintek	WP3, WP6
39	**Stenbro, Roy**	**IFE**	**Head WP1**
40	Stålhane, Magnus	Marintek	WP5
41	Svendsen, Harald	SINTEF Energy Research	WP4, WP6
42	**Tande, John Olav Giæver**	**SINTEF Energy Research**	**Centre Director**
43	**Uhlen, Kjetil**	**NTNU/SINTEF Energy Research**	**Head WP4**
44	Valland, Anders	Marintek	WP5
45	Vatn, Jørn	NTNU	WP5
46	**Økland, Ole David**	**Marintek**	**Head WP6 (started 01.07.2012)**
47	Østbø, Niels Petter	SINTEF ICT	WP2

A.1.2 Visiting Researchers

#	Name	Affiliation	Nationality	Sex	Duration	Topic
	-	-	-	-	-	-

A.1.3 Postdoctoral Researchers with financial support from the Centre

	Name	Nationality	Period	Sex	Topic
1	Karimirad, Madjid	Iranian	2010-2012	M	Alternative floating wind turbines for moderate water depths (WP6)
2	Kumar, Mukesh	Indian	2011-2013	M	Adaptive methods for accurate CFD-simulations of aerodynamic loads of offshore wind turbines (WP1)

A.1.4 PhD Students with financial support from the Centre

	Name	Nationality	Period	Sex	Topic
1	Hameed ,Zafar	Pakistani	2009 - 2012	M	Maintenance optimization of wind farms from design to operation (models, methods, framework) (WP5)
2	Frøyd, Lars[3]	Norwegian	2009 - 2012	M	Evaluation of the design criteria and dynamic forces on large floating wind turbines (WP1)
3	Zwick, Daniel	German	2009 - 2013	M	Design and production of offshore jacket structures (WP3)
4	Van Buren, Eric	American	2009 - 2013	M	Bottom-fixed support structure for wind turbine in 30-70 m water depth (WP3)
5	Kvittem, Marit Irene	Norwegian	2009 - 2013	F	Life cycle criteria and optimization of floating structures and mooring systems (WP3)
6	Soloot, Amir Hayati	Iranian	2009 - 2013	M	Analysis of switching transients in wind parks with focus on prevention of destructive effects (WP4)
7	Bracchi,Tania	Italian	2009 - 2013	F	Assessment of benefits of downwind rotors due to weight savings using new and thinner airfoils and improved directional stability of turbine (WP6)
8	Resell, Martin	Norwegian	2010 - 2012	M	Design wind and sea loads for offshore wind turbines (WP1)
9	Nordanger,Knut	Norwegian	2010 - 2013	M	Coupled fluid-structure interaction simulation of offshore wind turbines (WP1)
10	Cox, Kevin	American	2010 - 2013	M	Lift control of wind turbine blades by using smart composite materials manipulating aerodynamics rotor properties (WP2)
11	Valavi, Mostafa	Iranian	2010 - 2013	M	Magnetic forces and vibrations in wind power generators (WP2)
12	Zhang, Zhaoqiang	Chinese	2010 - 2013	M	Novel generator concepts for low weight nacelles. Integrated design of generator and mechanical structure for a maintenance free system (WP2)
13	Chella, Mayilvahanan	Indian	2010 - 2013	M	Wave forces on wind turbine structures (WP3)
14	Netland, Øyvind	Norwegian	2010 - 2013	M	Cost-effective monitoring for remote environmental friendly O&M of offshore wind turbines (WP5)
15	Wang, Kai	Chinese	2010 - 2013	M	Comparative studies of floating concepts (WP6)
16	Pedersen, Morten Dinhoff	Norwegian	2010 - 2013	M	Design of control systems for load mitigation and stabilization of floating wind turbines (WP6)

[3] Lars Frøyd successfully defended his PhD thesis at NTNU on 17 October 2012.

	Name	Nationality	Period	Sex	Topic
17	Eriksen, Pål Egil	Norwegian	2010 - 2014	M	Rotor wake turbulence (WP1)
18	Cárdenas, René Alexander Barrera	Columbian	2011 - 2014	M	Multi-domain optimization model for the evaluation of power density and efficiency of wind energy conversion systems (WP4)
19	Chabaud, Valentin	French	2011 - 2015	M	Experimental investigation of coupled hydrodynamic and aerodynamic performance of floating wind turbines (WP6)
20	Luan, Chenyu	Chinese	2011 - 2015	M	Efficient stochastic dynamic response analysis for design of offshore wind turbines (WP3)
21	Nejad, Amir	Romanian	2012 - 2015	M	Condition monitoring of the mechanical system of a wind farm (WP5)
22	See, Phen Siak	Malaysian	2012 - 2015	M	Development of market models incorporating offshore wind farms and offshore grids (WP4)
23	Morten, Lars	Norwegian	2012 - 2016	M	Design wind and sea loads for offshore wind turbines (WP1)

A.1.5 Postdoctoral Researchers working on projects aligned with the Centre with financial support from other sources

	Name	Nationality	Period	Sex	Topic
1	Thomassen, Paul	Norwegian	2008 - 2012	M	Deep sea offshore structures
2	Adaramola, Muiwa	Nigerian	2010 - 2012	M	Resource optimization and recovery in the materials industry
3	Langhamer, Olivia	German	2010 - 2013	F	Renewable offshore energy and the marine environment: biofouling and artificial reefs
4	Merz, Karl	American	2011 - 2013	M	Offshore Wind Turbines

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

	Name	Nationality	Period	Sex	Topic
1	Fuglseth, Thomas Pagaard	Norwegian	2005 - 2011	M	Control of Wind Energy Plants
2	Dong, Wenbin	Chinese	2008 - 2011	M	Reliability of wind turbines
3	Liu, Bing	Chinese	2008 - 2012	M	Offshore wind power electronics
4	Pierella, Fabio	Italian	2008 - 2012	M	Wind energy: Full scale and wind tunnel simulated measurements; consequential wind turbine design optimization, model construction and experimental testing
5	Øverås, Ingrid	Norwegian	2008 - 2012	F	Grid Integration Technologies of Offshore Wind
6	Jafar, Muhammed	Pakistani	2008 - 2012	M	Electrical Conversion Systems for Offshore wind farms: from the generator to shore
7	Olguin, Raymundo Torres	Mexican	2008 - 2012	M	Offshore Wind Farms Electrical System and grid Integration
8	Haileselassie, Temesgen	Ethiopian	2008 - 2012	M	Grid Connection of Deep Sea Wind Farms
9	Aigner, Tobias	German	2008 - 2012	M	System impacts of large scale wind power
10	Ruiz, Alejandro Garces	Colombian	2008 - 2012	M	Electrical system for offshore wind parks: from the generator to the grid connection onshore
11	Arvesen, Anders	Norwegian	2008 - 2013	M	Understanding the Environmental Implications of Energy Transitions. A Case Study for Wind Power
12	Pierella, Fabio	Italian	2008 - 2013	M	An experimental investigation of wind turbine wakes
13	Tasar, Gursu	Turkish	2009 - 2012	M	Full Scale Measurements of Wind Conditions

	Name	Nationality	Period	Sex	Topic
					Relevant for Offshore Wind Turbines
14	Valibeiglou, Mahmoud	Iranian	2009 - 2012	M	Area in Operation and Maintenance –in on-line monitoring and use of on-line data for maintenance decision for offshore wind farms
15	Reiso, Marit	Norwegian	2009 - 2012	F	Design and analysis of downwind rotor for WT with jacket tower
16	Dai, Lijuan	Chinese	2009 - 2013	F	RAMS engineering and management in the development and operation of offshore wind turbines
17	Gjerde, Sverre	Norwegian	2009 - 2013	M	Integrated converter design with generator for weight reduction of offshore wind turbines
18	Vrana, Kristian	Norwegian	2009 - 2013	M	Development and Operation of the North Sea Super Grid
19	Heidenreich, Sara	German	2010 - 2014	F	Public engagement in offshore wind energy
20	Steen, Markus	Norwegian	2010 - 2014	M	Commercialization and industrial development of new renewable energy with focus on offshore wind
21	Mubarok, Fahmi	Indonesian	2010 - 2014	M	Novel coating and surface treatment for improved wear resistance (WP5)
23	Holtsmark, Nathalie	Norwegian	2010 - 2014	F	Wind Energy Conversion using high frequency transformation and DC collection
24	Fuchs, Ida	German	2010 - 2014	F	Planning power transmission for wind power integration
25	Slimacek, Vaclav	Czech	2011 - 2015	M	Reliability analysis of offshore wind turbines/plants and their connection to Smart Grids (WP5)

A.1.7 Master Degrees during 2012 affiliated with NOWITECH

	Name	Sex	Topic
1	Abildgaard, Elisabeth Nøkleby	F	Exploring the properties of a modular multilevel converter based HVDC link with focus on voltage capability, power system relations, and control system
2	Aksønov, Sergei	M	Embedded Control of a Wind Turbine Based on Model Driven Development
3	Andersen, Camilla Eikeland	F	Numerical simulation for installation of offshore monopile wind turbines
4	Azurmendi, Inigo	M	Instrumentation for measuring wind conditions relevant for wind power
5	Bastiko, Arya Priambodo	M	Mechanical properties of coatings for offshore wind turbines
6	Bastiko, Arya Priambodo	M	Mechanical properties of coatings for offshore wind turbines
7	Berntsen, Eivind	M	Development of a Predictive Display Interface to assist control of a Robot Arm in a Telepresence System
8	Berre, Tommy Skjeldnes	M	Wind turbine emulator for power conversion and grid connection studies
9	Briatore, Marco	M	Validation of the CFD TAU DLR CODE for Large and Small Scales Wind Turbines
10	Cheynet, Étienne	M	Wear properties of polymeric coatings for wind turbine blades, Master Thesis (ENSCI, France)
11	Eide, Arne Olav	M	Fatigue of Unbalanced hybrid composites
12	Fossum, Peter Kalsaas	M	Aeroelastic analysis of an offshore wind turbine: Design and fatigue performance of large utility-scale wind turbine blades
13	Gundegjerde, Christian	M	Vessel fleet size and mix for maintenance operations of offshore wind farms
14	Halvorsen, Ina Blomseth	F	Vessel fleet size and mix for maintenance operations of offshore wind farms

	Name	Sex	Topic
15	Husby, Marte Asbøll	F	Integrasjon av vindkraft i regionalnett med begrenset overføringskapasitet
16	Keppler, Robert Max	M	Operation and Maintenance Cost Modelling for Offshore Wind Farms
17	Mesquita, Mario	M	Winding losses calculation
18	Molde, Håvard	M	Simulation-based optimization of lattice support structures for offshore wind energy
19	Moy, Inge	M	Parameter Sensitivity of Short-term Damage of Spar-type Wind Turbine Tower
20	Moy, Ørjan Fredheim	M	Fatigue Analysis of Column-Brace Connection in a Semi-submersible Wind turbine
21	Nes, R.N.	M	Life cycle assessment of an offshore electricity grid interconnecting Northern Euope
22	Nes, Rasmus Nikolai	M	Life cycle assessment of an offshore electricity grid interconnecting Northern Europe
23	Nyhus, Toril	F	Effect of marine environment on the tribology performance of materials used in rotating parts of offshore wind turbines
24	Pons, Jeremias Moragues	M	Practical Experiments on the Efficiency of the Remote Presence
25	Sachithanathamoorthy, Kumaravalavan	M	Design and analysis of tension leg anchor systems for floating wind mills
26	Salvesen, Lise Fevåg	F	Influence of marine growth on support structure design for offshore wind turbines
27	Schumann, Heiner	M	An Experimental Investigation of Turbine Wakes in Wind Farms
28	Smith, Ebbe Berge	M	Design av nacelle for en 10 MW vindturbin
29	Tiwari, Raghbendra	M	Application of AC Superconducting Windings in Large PM Synchronous Generators for Wind Power
30	Tyrhaug, Magnus	M	Coatings and modelling leading edge erosion of wind turbine blades

A.2 STATEMENT OF ACCOUNTS

(All figures in NOK 1000)

FUNDING

Name		Amount	Amount
The Research Council of Norway			20000
SINTEF Energi	(Host Institution)		2083
NTNU	(Research Partner)		5789
IFE	(Research Partner)		1059
Marintek	(Research Partner)		1733
SINTEF	(Research Partner)		1808
Kværner Verdal (former Aker Solutions)		0	
Det Norske Veritas		500	
Devold AMT		0	
DONG Energy Power		500	
EDF R&D		1466	
Fedem Technology		668	
Fugro OCEANOR		1044	
GE Wind Energy (Norway)		1200	
NTE Holding		1000	
SmartMotor		523	
Statkraft Development		1500	
Statnett		500	
Statoil		1150	
Vestas Wind System		1200	
Vestavind Offshore		500	
Transferred from 2011		3161	
Transferred to 2013		-3160	
	Subtotal		11752
Public Partners			0
			44224

COSTS

Name		Amount	Amount
SINTEF Energi	(Host Institution)		8333
NTNU	(Research Partner)		14283
IFE	(Research Partner)		4237
Marintek	(Research Partner)		6933
SINTEF	(Research Partner)		7237
Kværner Verdal (former Aker Solutions)		0	
Devold AMT		0	
EDF R&D		966	
Fedem Technology		668	
Fugro OCEANOR		1044	
SmartMotor		523	
Subtotal			3201
Public Partners			0
Equipment			0
			44224

A.3 PUBLICATIONS

NOWITECH publications include a total of 104 publications in 2012, whereof 39 journal papers or peer-reviewed papers, 13 conference papers, 20 conference presentations, 18 reports and 10 media contributions. The papers, books and reports are listed below.

A.3.1 Journal and Peer-reviewed Papers

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1. Frøyd, Lars; Dahlhaug, Ole Gunnar: Effect of pitch and safety system design on dimensioning loads for offshore wind turbines during grid fault, Energy Procedia, 2012, Volume 24
2. Thomassen, P.; Bruheim, P.I.; Suja, L.; Frøyd, L.: A Novel Tool for FEM Analysis of Offshore Wind Turbines With Innovative Visualization Techniques, ISOPE 2012 22nd International Offshore (Ocean) and Polar Engineering Conference Proceedings
3. Cox, K.; Echtermeyer, A.: Structural design and analysis of a 10MW wind turbine blade; Energy Procedia, 2012, Volume 24
4. Van Buren, E.; Muskulus, M.; Improving pile foundation models for use in bottom-fixed offshore wind turbine applications; Energy Procedia, 2012, Volume 24
5. Muskulus, M.; The full-height lattice tower concept; Energy Procedia, 2012, Volume 24
6. Zwick, D.; Muskulus, M.; Moe, G.; Iterative optimization approach for the design of full-height lattice towers for offshore wind turbines; Energy Procedia 2012, Volume 24
7. Kvittem, M.; Bachynski, E.; Moan, T; Effects of hydrodynamic modelling in fully coupled simulations of a semi-submersible wind turbine; Energy Procedia 2012, Volume 24
8. Karimirad, M.; Moan, T.; Wave- and Wind-Induced Dynamic Response of a Spar-Type Offshore Wind Turbine; Journal of Waterway, Port, Coastal, Ocean Eng., 2012, Vol 138, Issue 1
9. Kvittem, M.I.; Moan, T.; Effect of Mooring Line Modelling on Motions and Structural Fatigue Damage for a Semisubmersible Wind Turbine; Proceedings of the Twenty-second (2012) International Offshore and Polar Engineering Conference
10. Alagan Chella, M.; Tørum, A.; Myrhaug, D.; An Overview of Wave Impact Forces on Offshore Wind Turbine Substructures; Energy Procedia, 2012, Technoport RERC Research 2012
11. Myhr, A.; Nygaard, T.A.; Load Reductions and Optimizations on Tension-Leg-Buoy Offshore Wind Turbine Platforms; ISOPE 2012, Rhodos, Greece, June 2012, Proceedings
12. Gjerde, S.; Undeland, T.; A modular Series Connected Converter for a 10 MW, 36 kV, Transformer-Less offshore Wind Power Generator Drive; Energy Procedia, 2012, Volume 24
13. Tande, J.O.; Korpås, M.; Uhlen, K; Planning and Operation of Large Offshore Wind Farms in Areas with Limited Power Transfer Capacity Wind Engineering, 2012, Volume 36, Issue 1
14. Acker, T.; Robitaille, A.; Holttinen, H.; Piekutowski, M.; Tande, J.O.; Integration of Wind and Hydropower Systems: Results of IEA Wind Task 24; Wind Engineering, 2012, Volume 36, Issue 1
15. Korpås, M.; Warland, L.; He, W.; Tande, J.O.; A Case-Study on Offshore Wind Power Supply to Oil and Gas Rigs; Energy Procedia, 2012, Volume 24
16. Endegnanew; A.; Øyslebø, E.V.; Huertas-Hernando, D.; Bakken, B.H.; Coordinated Control between Wind and Hydro Power Systems through HVDC Links; Energy Procedia, 2012, Volume 24
17. Tande, J.O.; Korpås, M.; Impact of OffshoreWind Power on SystemAdequacy in a Regional Hydro-based Power System with Weak Interconnections; Energy Procedia, 2012, Volume 24
18. Marvik, J.I.; Endegnanew; A.; Wind turbine model validation with measurements; Energy Procedia, 2012, Volume 24
19. Årdal, A.R.; Undeland, T.; Sharifabadi, K.; Voltage and frequency control in offshore wind turbines connected to isolated oil platform power systems; Energy Procedia, 2012, Volume 24
20. Ljøkelsøy, K.; D'Arco, S.; Tande, J.O.; Challenges and rationale for laboratory research of offshore grids; Energy Procedia, 2012, Volume 24
21. Soloot, A.H.; Høidalen, H.K.; Gustavsen, B.; The Assessment of Overvoltage protection Within Energization of Offshore Windfarms; Energy Procedia, 2012, Volume 24
22. Farahmand, H.; Aigner, T.; Doorman, G.; Korpås, M.; Huertas-Hernando, D.; Balancing Market Integration in the Northern European Continent: A 2030 Case Study; IEEE Transactions on Sustainable Energy, Special Issue: Wind Energy, 2012, Volume 3, issue 4
23. Cardenas, R.B.; Holtsmark, N.; Molinas, M; Comparative study of the efficiency and power density of offshore WECS with three-phase AC-link; IEEE Conference Proceedings, 2012, ISBN: 978-1-4673-2023-8
24. Barrera-Cardenas, R.; Molinas, M; A simple procedure to evaluate the efficiency and power density of power conversion topologies for offshore wind turbines; Energy Procedia, 2012, Volume 24
25. Barrera-Cardenas, R.; Molinas, M.; Comparative study of the converter efficiency and power density of power conversion topologies for offshore wind turbines; IEEEConference proceedings, 2012, ISBN:978-1-4673-1300-1

26. Barrera-Cardenas, R.; Molinas, M.; Optimal LQG Controller for Variable Speed Wind Turbine Based on Genetic Algorithms; Energy Procedia, 2012, Volume 20
27. Barrera-Cardenas, R.; Molinas, M.; Optimized design of wind energy conversion systems with single-phase AC-link; IEEE Conference Proceedings, 2012, ISBN: 978-1-4244-9373-9
28. Albrechtsen, E.; Occupational safety management in the offshore wind industry – status and challenges; Energy Procedia, 2012, Vol 24
29. Hameed, Z.; Vatn, J.; Important challenges for 10MW reference wind turbine from RAMS perspective; Energy Procedia, 2012, Vol 24
30. Scheu, M.; Matha, D.; Hofmann, M.; Muskulus, M.; Maintenance strategies for large offshore wind farms; Energy Procedia, 2012, Vol 24
31. Scheu, M.; Matha, D.; Muskulus, M.; Validation of a Markov-based Weather Model for Simulation of O&M for Offshore Wind Farms; Proceedings of the Twenty-second (2012) International Offshore and Polar Engineering Conference
32. Karimirad, M.; Moan, T.; Feasibility of the Application of a Spar-type Wind Turbine at a Moderate Water Depth; Energy Procedia, 2012, Vol 24
33. Lindeberg, E.; Svendsen, H.G.; Uhlen, K.; Smooth transition between controllers for floating wind turbines; Energy Procedia, 2012, Vol 24
34. Karimirad M; Moan T.; A simplified method for coupled analysis of floating offshore wind turbines; Journal of Marine Structures
35. Paulsen, U.S.; Vita, L.; Madsen, H.A.; Hattel, J.; Ritchie, E.; Leban, K.M.; Berthelsen, P.A.; Carstensen, S.; 1st DeepWind 5 MW baseline design; Energy Procedia, 2012, Vol 24
36. Dai, L.; Dai, L, Ehlers, S., Rausand, M., Utne, I.B. (2013), Risk of collision between Service Vessels and Offshore Wind turbines; Reliability Engineering & Safety Systems 109, pp. 18-31
37. Knudsen, O.Ø.; Bjørgum, A.; Døssland, L.T.; Low maintenance coating systems for constructions with long lifetime; Corrosion 2012; Salt Lake City; Utah; USA; 11 - 15 March 2012
38. Graczyk, M.; Sandvik, P.C.; Study of landing and lift-off operation for wind turbine components on a ship deck; Proceedings of the 31st International Conference on Ocean, Offshore and Arctic Engineering (OMAE); Rio de Janeiro; Brazil; 1 – 6 July 2012
39. Hameed, Z.; Wang, K.; Exploring the synergy between Wind turbine and manufacturing industry to improve their reliability and maintainability by using artificial neural networks; IWAMA 2012; NTNU; Trondheim; 21 - 22 June 2012

A.3.2 Published Conference Papers

1. Ormberg, H.; Bachynski, E.; Global analysis of floating wind turbines: Code Development, Model Sensitivity and Benchmark Study; Twenty-second (2012) International Offshore and Polar Engineering Conference; Rhodes; Greece; 17 - 22 June 2012
2. Gao, Z.; Nygaard, T.A. et al ; Offshore Code Comparison Collaboration Continuation (OC4), Phase I – Results of Coupled Simulations of an Offshore Wind Turbine with Jacket Support Structure Twenty-second(2012) International Offshore and Polar Engineering Conference Rhodes; Greece; June 17–22; 2012
3. Myhr, A.; Nygaard, T.A.; Load Reductions and Optimizations on Tension-Leg-Buoy Offshore Wind Turbine Platforms; Twenty-second (2012) International Offshore and Polar Engineering Conference; Rhodes; Greece; 17 - 22 June 2012
4. Knudsen, O.Ø.; Schnars, H.; van der Mijle Meijer, H.; Protective coatings for offshore wind farms; Eurocorr 2012; Istanbul; Turkey; 9 - 13 September 2012
5. Årdal, A.R; Marvik, J.I.; Svendsen, H.G.; Tande, J.O.; Offshore Wind as Power Supply to Oil and Gas Platforms Offshore Technology Conference; Houston 2012; 30 April - 3 May 2012
6. Adaramola, M.S.; Krogstad, P.Å.; Tande, J.O.; Anaya-Lara, O.; Uhlen, K..; Power output optimisation from an offshore wind farm; EWEA Offshore Conference and Exhibition; Amsterdam, The Netherlands; 29 November to 2 December 2011
7. Hameed, Z.; Vatn, J.; Importance of reliability data analysis to estimate the parameters for the maintenance optimization of offshore wind turbines; 42nd ESReDA Seminar on Risk and Reliability for Wind Energy and other Renewable Sources; 15th and 16th May 2012; University of Strathclyde, Glasgow
8. Valland, A.; Integrated operations - A success story from the oil & gas industry; EWEA 2011; Amstedam; 29 November - 1 December 2011
9. Svendsen,H.G.; Merz, K.; , Endegnanew, A.; Control of floating vertical axis wind turbine; EWEA; Copenhagen; April 2012
10. Pedersen; M.D.; Fossen, T.I.; Efficient Nonlinear Wind-Turbine Modeling for Control Applications; Mathmod 2012; 7th Vienna International Conference on Mathematical Modelling; Vienna; 15 – 17 February 2012

11. Bracchi, T.; Krogstad, P.-Å.: Yaw moments of a three-axis wind turbine with yaw error; Proc. 22nd International Offshore and Polar Engineering Conference, ISOPE, Rhodes, 17-22 June, 2012
12. Krogstad, P.-Å.; About the NTNU wind turbine data base and its use for prediction method verification; Invited key note speaker; 15th Nordic Pilot Centre conference; Porvoo; Finland; 28-29 August 2012
13. Krogstad, P.-Å.; Eriksen, P.E.; "Blind test" predictions of the performance and wake development for a model wind turbine; 18 Australasian Fluid Mechanics Conference; Launceston; Australia; December 2012

A.3.3 Books

1. Frøyd, L.; Wind Turbine Design: Evaluation of Dynamic Loads on Large Offshore Wind Turbines; Doctoral Thesis; NTNU; 2012
2. Tande, J.O.; Power quality standards for wind turbines; Chapter 12 in Wind Power in Power Systems; Second edition 2012

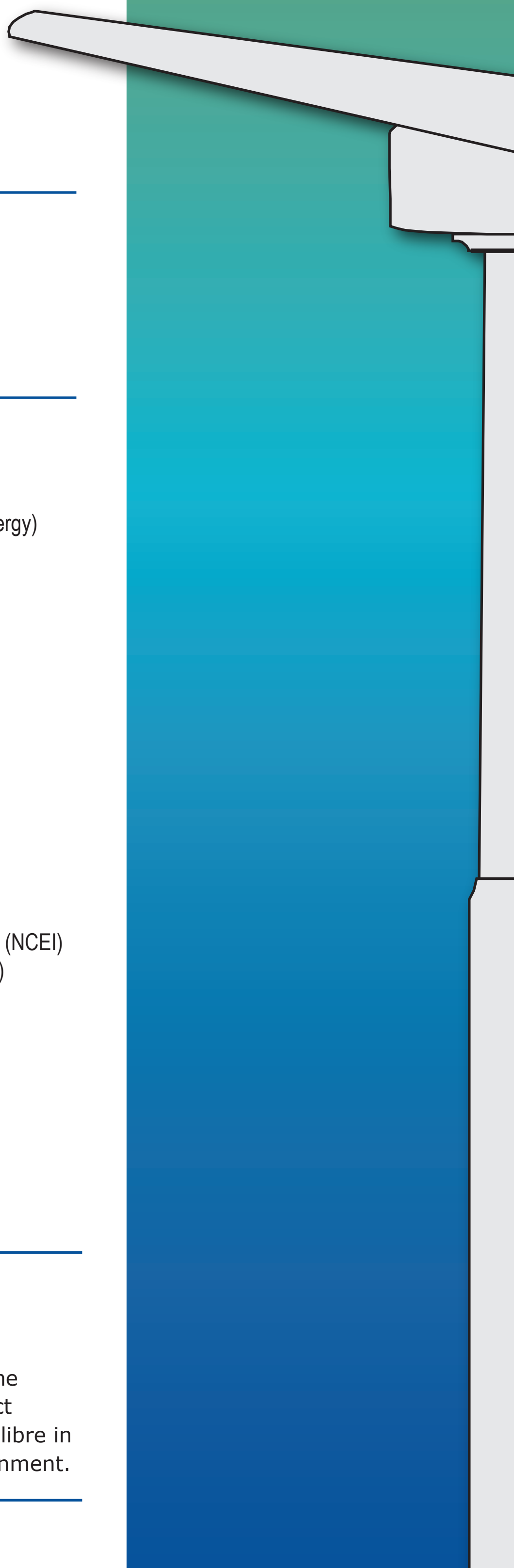
A.3.4 Reports

1. Tande, J.O.; Editor: DeepWind2012 - 9th Deep Sea Offshore Wind Seminar, 19 - 20 January 2012, Royal Garden Hotel; Trondheim; Norway; SINTEF Energi AS
2. Holdahl, R.; Flow around a 2D NACA0015 wing pro les at high Reynolds numbers; SINTEF ICT, Applied Mathematics
3. Vogl, A.; Østbø, N.P.; Bjerkan L.; Kjær Jørgensen, J ; Sensors for condition monitoring of different components of (offshore-) wind power plants. Possibilities for further evaluation in NOWITECH and beyond; SINTEF IKT 2012
4. Mubarok, F.; Lubrication systems in the offshore wind turbine: State of the art study; NTNU / SINTEF Materials & Chemistry
5. Bein, T.; Huhn, H.; Leeuw, M.; Jantunen, E.; Heggset, J.; Skavhaug, A.; Operation & Maintenance of Offshore Wind Parks - Strategic Research Agenda; Fraunhofer LBF; Fraunhofer IWES; TNO; VTT; SINTEF Energi AS
6. Nonås, L.M.; Weare, E.H.; Hoffman, M.; Vessel fleet size and mix analysis for maintaining an offshore wind farm; MARINTEK; May 2012
7. Bjørgum, A.; Hofmann, M.; Welte, T.; Life cycle cost analysis for corrosion protective coatings; SINTEF Materialer og Kjemi; May 2012
8. Strasunskas, D.; NTNU; Valuation of Remote Presence Robotics in Offshore Wind Turbines, Report on a valuation framework and internal workshop; February 2012
9. Hofmann, M.; Sperstad, I.B.; User manual and documentation NOWIcob model (D5.1-12); SINTEF Energi AS; 2012
10. Hofmann, M.; Framework for evaluation of access technology and logistics support; SINTEF Energi AS; 2012
11. Hofmann, M.; Sperstad, I.B.; User manual and documentation NOWIcob model (D5.1-32); SINTEF Energi; 2012
12. Tande, J.O.; NOWITECH Day 2012; SINTEF Energi AS; 2012
13. Tande, J.O.; Grid connection of offshore wind farms; SINTEF Energi AS; 2012
14. Heggset, J; Hofmann, M.; Operation and maintenance of offshore wind farms - trends and outlookUser manual and technical documentation NOWIcob model; SINTEF Energi AS; 2012
15. Marvik, J.I.; Voltage phase angle impact on wind turbine generator response to voltage dips; SINTEF Energi AS; 2012
16. Marvik, J.I; Endegnanew, A.G.; Svendsen, H.G.; Offshore wind – power transmission system (memo); SINTEF Energi AS; 2012
17. Cheynet, E.; Schmid, B.; Wear properties of coatings for wind turbine blades; ENSCI; SINTEF M&C; 2012
18. Tyrhaug, Magnus H.; Coatings and modeling leading edge erosion of wind turbine blades (Prosjektoppgave); NTNU, 2012

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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