NOWITECH

Norwegian Research Centre for Offshore Wind Technology

Annual Report 2015

fme
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

Offshore Wind: It is time for the next wave!

Offshore wind farms will be an important part of a future sustainable energy system. IEA expects offshore wind to supply 5 % of the global electricity demand in 2050[1]. In Europe alone investments in offshore wind farms over the next ten years are expected to sum up to NOK 1000 billion. This represents a golden opportunity for development of new knowledge-based jobs.

The technology and market is still in an early phase with great potential for development and cost reductions. Targets are set to reduce the levelized cost of energy (LCoE) from offshore wind farms by 50 % within 2030[2]. Strong research and development efforts are paramount to reach such cost reduction. Offshore wind energy is prioritized in the Norwegian research strategy Energi21 and in the European SET-plan.

> NOWITECH has proven a very effective spearhead for research, providing international visibility and impact.

Norway has an important role to play building on the research carried out in NOWITECH and in other projects, and utilizing the expertise from energy and maritime industries: Statoil is now taking the floating wind turbine concept, Hywind, to the next step with a 30 MW pilot wind farm. DNV GL is leading in consulting and certification services. Norwegian industry is competitive with supplies to the offshore wind market within marine operations, substructures, power collection and transmission. Norwegian entities are also active in European research projects. Still, there is very significant potential to increase the Norwegian engagement. According to Eksportkreditt Norge a viable goal is that a 10 % share of the supply to new offshore wind farms in Europe comes from Norwegian entities by 2020[3].

> NOWITECH has prepared 40 innovations. Now it is time for the next wave!

I very much support this goal; and I am convinced that continued strong research together with the industry is vital to achieve this goal.

NOWITECH has proven a very effective spearhead for research, providing international visibility and impact. A set of separate projects could not have achieved this, thus with NOWITECH now being close to completion, it is time for new initiatives to continue the required research for value creation, new jobs and bringing down the LCoE from new offshore wind farms. NOWITECH has prepared 40 innovations. Now it is time for the next wave!

Director NOWITECH

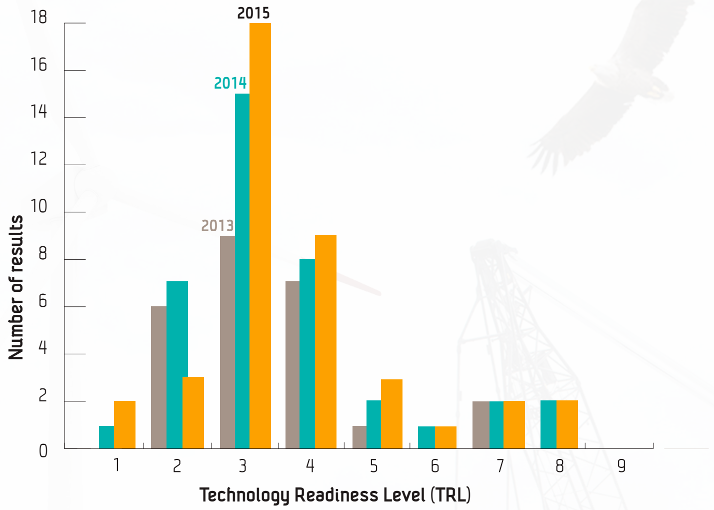
John Olav Giæver Tande

Figure 1: Statoil is now taking the floating wind turbine concept, Hywind, to the next step with a 30 MW pilot wind farm to be installed in Scotland in 2017. Ill: Statoil.

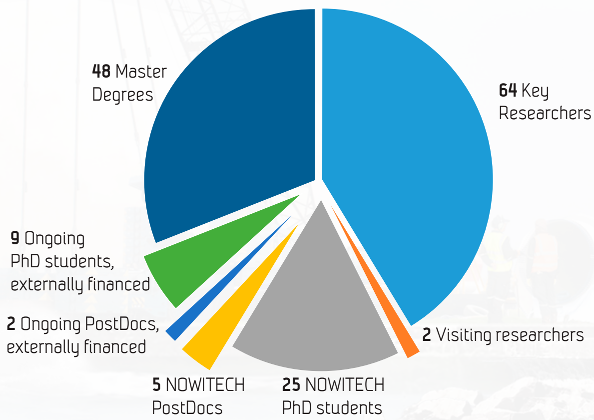
1 IEA Technology Roadmap (2013) 2DS scenario https://www.iea.org/publications/freepublications/publication/Wind_2013_Roadmap.pdf
2 European Wind Energy Technology Platform (TPwind), 2014, Strategic Research Agenda, www.ewea.org/report/tpwind-sra
3 http://syslagronn.no/2016/02/03/syslagronn/pa-tide-med-omstart-for-norsk-havvind_75421/
http://sysla.no/2016/02/17/syslagronn/markedet-fikser-ikke-havvind-av-seg-selv_77750/

2015 in numbers

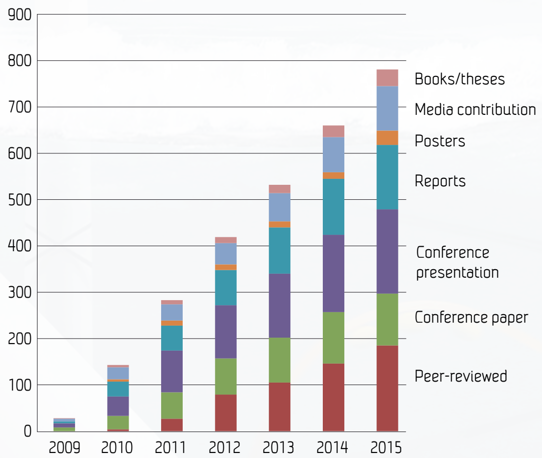
Innovations



People



Publications



NOWITECH

FME CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

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

Vision

- ✓ Contributing to large scale deployment of deep sea offshore wind turbines,
- ✓ An internationally leading research community on offshore wind technology enabling industry partners to be in the forefront.

Objective

- ✓ 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

- ✓ Innovations, knowledge building and education aiming to reduce the cost of energy from offshore wind farms.

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 three work packages (WPs): Substructures and numerical tools (WPA), Operation & Maintenance and Materials (WPB), Grid and Wind Farms (WPC).

Results

Excellent research work directed towards industry needs is carried out. A total of 40 industry relevant results and innovations are in progress. This includes new software tools, processes and technology. The results of NOWITECH are migrating to commercial use, licence agreements, and business developments.

The educational programme provides for first-rate recruitment opportunities for the industry. NOWITECH has so far financed 25 PhD students and 5 post-doctoral researchers. In addition, 10 PhD students and 2 postdocs on offshore wind energy are on-going at NTNU with finance from other sources, but carried out in alignment with NOWITECH.

The scientific work is of the highest international standard with 190 peer-reviewed paper and more than 20 invited keynotes at international conferences since start up.

Very significant spin-off activities have been achieved. Since the start, more than 60 new projects with an accumulated budget in excess of NOK 1500 million have been initiated 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 providing added value.

Value for Industry Partners

- Excellent research with significant budget and duration directed towards industry needs
- First-rate recruitment opportunities from strong master, PhD and Postdoc programme
- A high gearing of research expenditures and first access to detailed results for business development
- Access to international network and strategic position in important European forums
- Knowledge and innovations contributing to reduced cost of energy from offshore wind farms
- 40 innovations

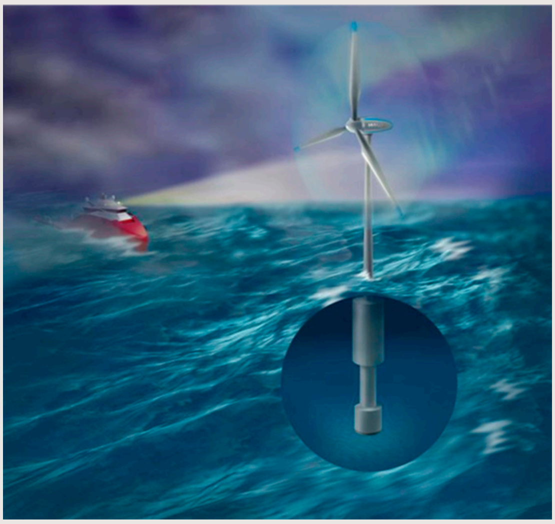


Figure 2: NOWITECH has focus on "deep sea", i.e. +30 m water depth, both bottom-fixed and floating technology. A key target is innovations reducing cost of energy from offshore wind farms. Main areas of research are numerical modelling, materials, substructures, grid connection, maintenance and control.

Table of contents

NOWITECH – Norwegian Research Centre for Offshore Wind Technology – is one of eleven Norwegian Centres for Environment-friendly Energy Research *(in Norwegian: FME – Forskningssentre for miljøvennlig energi).* The Centre is co-funded by the Research Council of Norway, the user partners and the research partners.

SINTEF Energy Research is the coordinating institution.

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Editorial: John Olav Tande, Hans Christian Bolstad, Anne Steenstrup-Duch and Astrid Benedicte Lundquist
Contributions from the following members of the Centre Management Group: Roy Stenbro, Jens Kjær Jørgensen, Harald Svendsen, Karl Merz, Thomas Welte, Ole David Økland, Per Arne Wilson, Trond Kvamsdal, Debbie W. Koreman and Randi Aukan.

Photos and illustrations: Gry Karin Stimo, NTNU, Statoil, Bjarne Stenberg, Oxygen and SINTEF

2015 HIGHLIGHTS

John Olav Giæver Tande,
Director NOWITECH

NOWITECH continues to deliver new knowledge and innovations that will reduce the cost of energy from future offshore wind farms and increase value creation in terms of new jobs, products and services. The industry participation has increased with Norsk Automatisering AS (NAAS) joining in 2015 to further develop their remote presence concept for unmanned inspection of offshore wind farms. The remote presence idea came from NAAS, and has been matured through a PhD study carried out in NOWITECH and through a portfolio of other projects, including the EU FP7 project LeanWind and a BIA project co-funded by the Research Council of Norway. They have now established a new company EMIP AS to commercialise the concept. Once being applied in the market the concept can radically reduce the need for service personnel to physically access offshore wind farms, thus reducing the cost of energy from future offshore wind farms.

In recent media coverage the potential is reported to be a billion business with multiple application areas.

Another company that has been established applying results from NOWITECH is Seram Coatings AS. They have a patented process for a thermally sprayed silicon carbide coating for which a breakthrough came as part of NOWITECH PhD study by Fahmi Mubarok. The process provides for an extremely hard, wear-resistant, low friction ceramic coating. In recent media coverage the potential is reported to be a billion business with multiple application areas.

In total NOWITECH has brought forward 40 innovations. These are all illustrated on the next two pages and further described in the section on research work and results later on this annual report. The innovations are all reported with a Technology Readiness Level (TRL) and shows excellent progress. The total number of innovations has increased, and the innovations have developed towards higher maturity, see graphic on page 3.

The educational programme provides for first-rate recruitment opportunities for the industry. A total of eight PhDs successfully defended their theses at NTNU in 2015, of which seven were fully funded by NOWITECH and one by other sources, but carried out in alignment with NOWITECH. In addition, 48 master students graduated from NTNU with theses on offshore wind energy. This is a remarkable increase from previous years that since 2009 has varied between 18 and 28, and demonstrates high and increasing interest in offshore wind energy among master students at NTNU.

The scientific work is of high international standard. In 2015 NOWITECH prepared 121 publications including 39 peer-reviewed papers, 15 conference presentations, 18 reports and 20 media contributions. The use of web, newsletters and organization of workshops and conferences enhance the communication:

- Two seminars were held in the series "Industry meets Science" in cooperation with WindCluster Norway. These facilitate improved interaction between research and industry, also for parties outside NOWITECH and as a Norwegian shadow-group towards the European strategic research agenda on offshore wind.
- A main event for communicating open results from NOWITECH is the EERA DeepWind conference held every year in Trondheim. The EERA DeepWind'2015 Deep Sea Offshore Wind R&D Conference, February 4-6, was a success with 65 oral and 50 poster presentations and fully booked with 200 delegates from all over Europe, and from USA and Japan.

Participation in relevant national and international forums is emphasised. Amongst others in 2015 NOWITECH was presented during the Energy Science Week in Tokyo, Japan coordinated by the Research Council of Norway. This has resulted in new cooperative projects with Japan on offshore wind energy.

The accumulated costs for NOWITECH in 2015 were NOK 40 million co-funded by the Research Council of Norway (RCN), the industry parties and the research parties.

NOWITECH PARTNERS

The NOWITECH Partners in 2015 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:

CD-adapco
DNV GL
DONG Energy
Fedem Technology AS
Fugro OCEANOR AS
Kongsberg Maritime AS
Norsk Automatisering AS
SmartMotor AS
Statkraft Development AS
Statnett SF
Statoil Petroleum AS

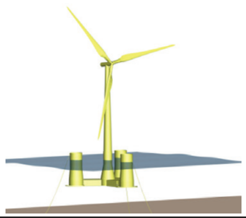
Associate research partners:

Massachusetts Institute of Technology (MIT), USA
Michigan Technological University (Michigan Tech), USA
National Renewable Energy Laboratory (NREL), USA
DTU, Denmark
Fraunhofer IWES, Germany
University of Strathclyde, UK
TU Delft, Netherlands
Nanyang Technological University (NTU), Singapore

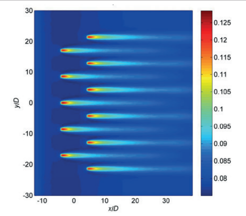
Associate industry partners:

Hexagon Devold AS
Enova
Energy Norway
Innovation Norway
Norwegian Wind Energy Association (NORWEA)
Norwegian Centres of Expertise Instrumentation (NCEI)
NVE
WindCluster Norway

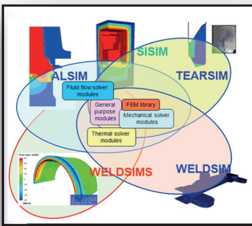
NOWITECH INNOVATIONS



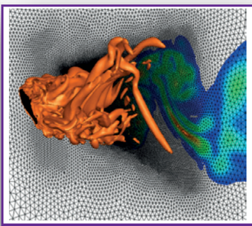
3DFloat integrated model
TRL7



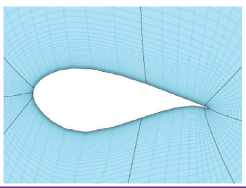
3DWind park wake model
TRL6



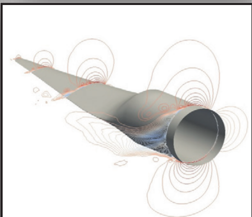
INVALS general purpose optimization
TRL8



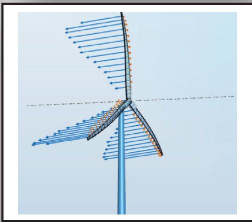
Commercial grade rotor CFD
TRL6



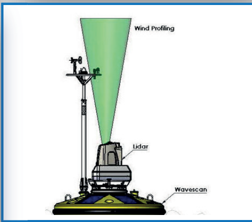
Variational Multiscale Error Estimator
TRL3



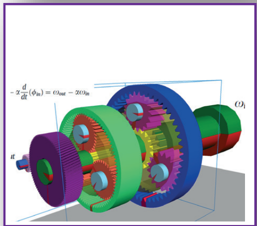
www.IFEM.no
TRL3



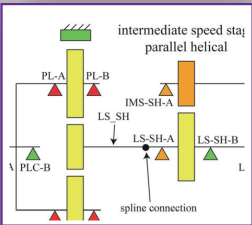
www.ASHES.no
TRL5



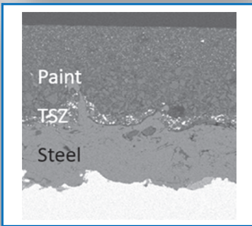
Seawatch Wind Lidar Buoy
TRL8



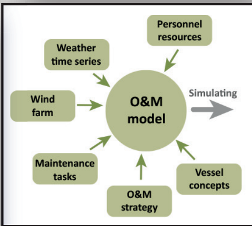
Gearbox fault detection
TRL3



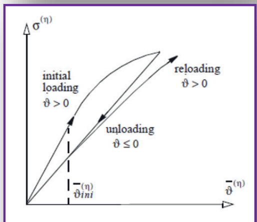
Gearbox vulnerability map
TRL4



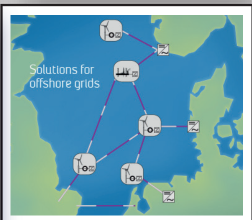
Dual layer corrosion protection coatings
TRL3



NOWIcob
TRL4

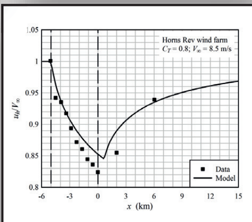


Fatigue damage simulation
TRL4

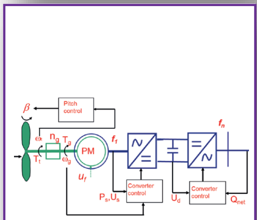


PSST Power System Simulation
TRL3

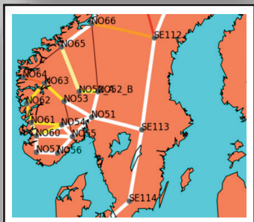
Net-Op network optimization
TRL3



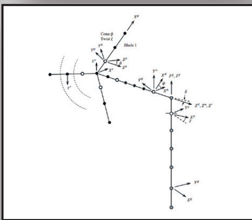
Viper Estimate Energy Output from Offshore Wind Farms TRL3



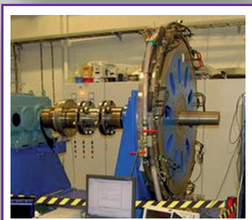
Wind turbine electrical interaction
TRL2



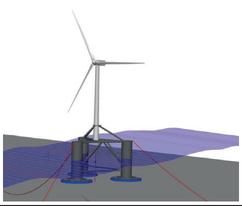
Network Reduction
TRL2



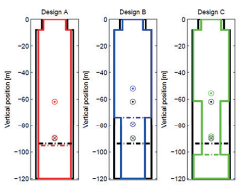
STAS linear State-Space Wind Power Plant Analysis
TRL2



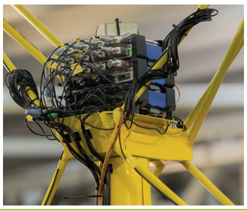
PM generator magnetic vibrations
TRL4



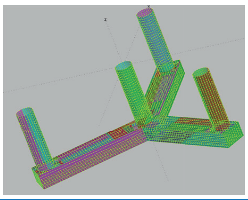
Simo-Riflex
TRL7



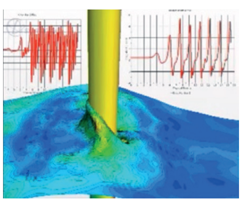
WindOpt
TRL4



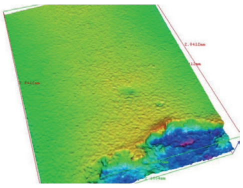
Real time hybrid model test in ocean basin
TRL3



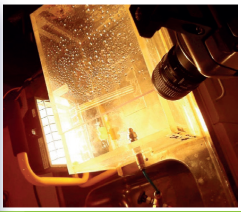
Novel floater
TRL2



CFD simulation
TRL5

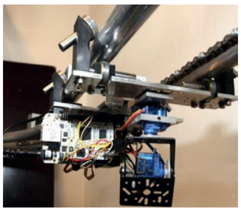


Droplet erosion resistant blade coatings
TRL3

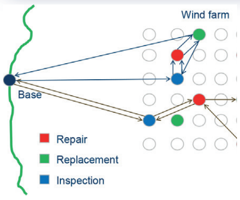


Droplet erosion testing
TRL4

Fleet optimization
TRL4

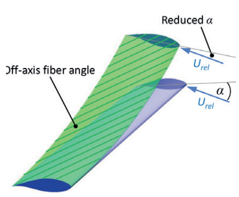


Remote Presence
TRL5

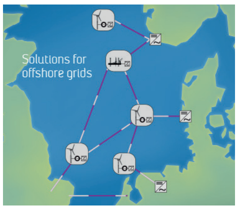


Routing and scheduling
TRL2

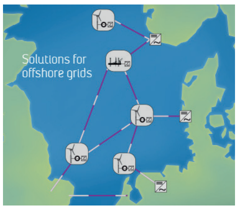
Thermally sprayed SiC coatings
TRL4



Buckling resistant blades
TRL3

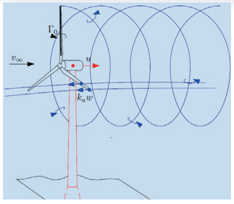


Smartgrid Lab HVDC grid
TRL4

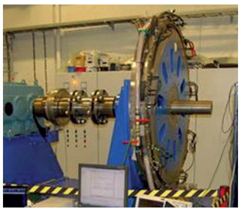


Control of multi-terminal HVDC grid
TRL4

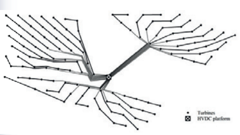
Wind Supply to Oil & Gas
TRL3



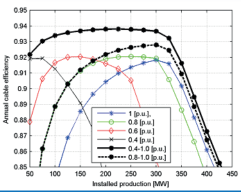
Turbine control
TRL3



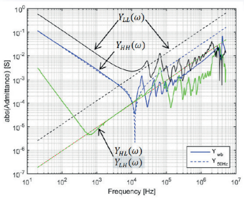
PM generator integrated design
TRL3



Wind farm collection grid optimization
TRL1



Long distance AC transmission
TRL1



Wide-band model of wind farm collection grid
TRL2

Software | Numerical model/method | Technology/Process | Research infrastructure

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 three work packages (WPs): Substructures and numerical tools (WPA), Operation & Maintenance and Materials (WPB) and Grid and Wind Farms (WPC). The organization of NOWITECH is shown in Figure 3.

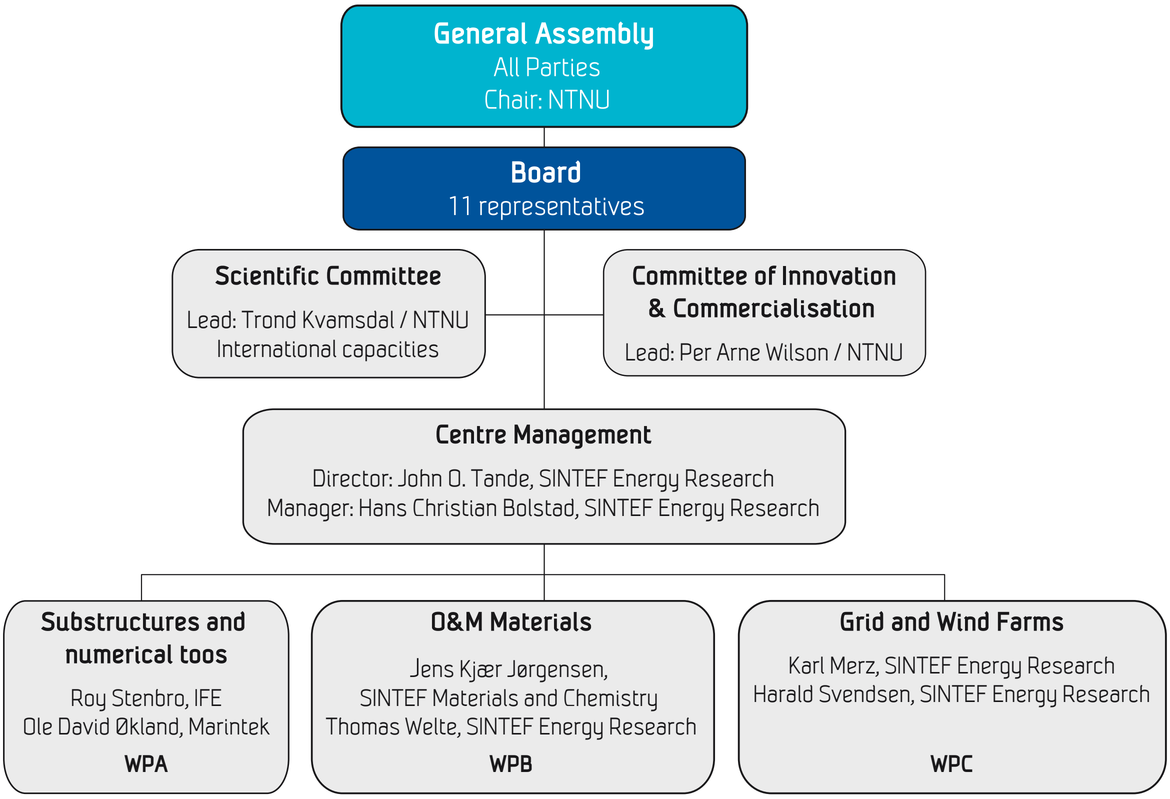


Figure 3: Outline of governance structure for NOWITECH per 2015.

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 reports to and is accountable to the General Assembly (GA). The Board monitors the implementation of the Centre and approves the annual working plans and budgets. It also oversees 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 ordinary Board meetings were held in 2015; in June in Oslo hosted by DNV-GL and in December in Trondheim at the new SINTEF Energy Lab. Both meetings were combined with a workshop the day before. The December workshop presented results from the work packages and was combined with the annual GA meeting. Both board meetings had innovations and strategy for development of NOWITECH on the agenda. The December meeting approved the proposed budget and work plans for 2016.

The Board members in 2015 were Olav Fosso (chairman), NTNU, Johan Sandberg/Marte de Piciotto, DNV GL AS, Martin Kirkengen, IFE, Knut Samdal, SINTEF Energi, Daniel Zwick, Fedem, Jørgen Krokstad, Statkraft, Gudmund Per Olsen, Statoil, and Oddbjørn Malmo, Kongsberg.

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

Figure 4: Board members, December 2015.

RESEARCH PLAN

The research methodology includes a mix of analytic work, numerical simulations and development of software 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. 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 the funding. The Technology Readiness Level (TRL) scale is applied to communicate the progress of models and technology.

The educational activity forms part of the research programme with engagement of MSc students and funding of 25 PhD and 5 Postdoc students at NTNU. PhD and Postdoc students at NTNU working on offshore wind, but funded through other sources, are carried out in alignment with NOWITECH.

The research is organized in three work packages (WPs):

- WPA: Substructures and numerical tools. The objective is development of novel substructures for offshore wind through development, validation and use of numerical tools and experimental campaigns.
- WPB: Operation & Maintenance and Materials. The objective is to contribute to the reduction of cost of energy of offshore wind power through development of new and cost-effective O&M concepts and strategies, through efficient and optimized use of material and coatings, and through development of new coatings and improved models for structures and materials.
- WPC: Grid and Wind Farms. The objective is to develop technical solutions and methods for cost effective electromagnetic and electrical designs, controls, grid connection and power system integration of offshore wind farms.

The WPs bring researchers together across traditional fields of engineering science and facilitate team building and innovations. The preparation of joint workshops and research strategies further strengthen the multi-disciplinary team efforts. Figure 4 shows main meetings, reporting events and how the annual work plans for the next year are prepared with spring and autumn industry meetings before approval by the Board in November/December.

Work is carried out in coordination with the other FME (Centres for Environmental Energy Research) on offshore wind, namely NORCOWE. The Centres are complementary to each other and constitute together a very strong research effort on offshore wind energy.

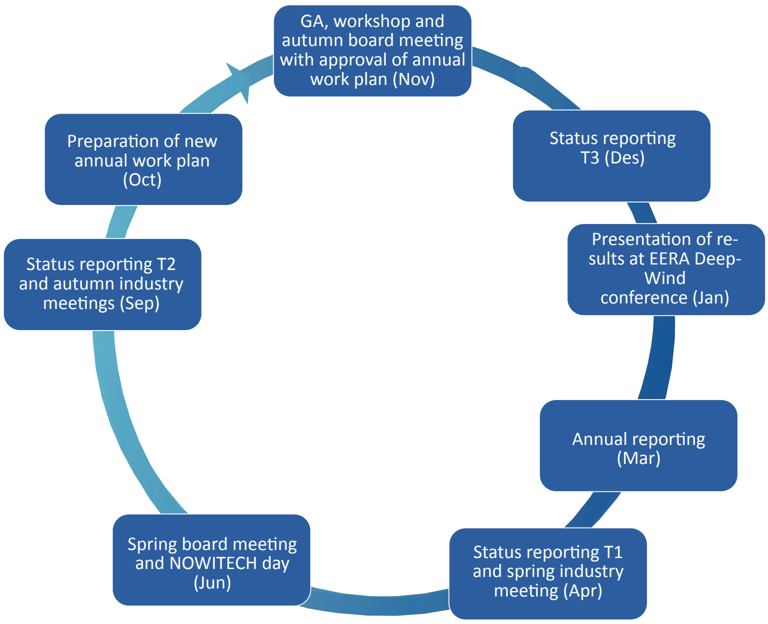


Figure 5: Annual schedule of main meetings, reports and preparation of the annual work plans.

CENTRE MANAGEMENT


John Olav Giæver Tande, Director NOWITECH


Hans Christian Bolstad, Manager NOWITECH

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

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 chair and the project secretary of NOWITECH. 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. 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 work is divided into Management and Outreach as outlined below.

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, budgeting, financial and membership legal aspects, meetings in the CMG with WP leaders and representatives from the SC and CIC, preparations for the GA and Board, and reporting to the RCN. CMG meetings have been held on a monthly basis during 2015. These are for team-building, planning, follow-up, information exchange and strategic discussions.

The Outreach activity

includes preparing general presentations of the Centre, dissemination of results, keeping contact with industry parties, overall coordination towards other projects, relevant organisations and FME's, in particular NORCOWE, and engagement in developing new offshore wind research projects and strategies. The Centre management is engaged in this also through CIC and SC. Dissemination activities by the management in 2015 included hosting delegations visiting NOWITECH, preparation of media contributions, keeping web and e-room updated, preparation of newsletters, organization of the "Industry meets Science" seminars biannually together with WindCluster Norway and organization of the annual offshore wind R&D conference in Trondheim, EERA DeepWind'2015, see also section 13. In 2015 NOWITECH also participated and presented NOWITECH in the Energy Science Week in Tokyo, Japan coordinated by the Research Council of Norway. This has initiated new cooperative projects with Japanese offshore wind research groups.

Setting the international research agenda with the industry

Engagement in developing offshore wind projects and research strategies in 2015 included both national and international activities:

- Giving input to The Standing Committee on Energy and the Environment at Stortinget on offshore wind energy (http://blog.sintefenergy.com/politikk/demopark-for-havvind-er-et-viktig-klimabidrag/).
- Giving input to the Energy White Paper (Energimeldingen) in preparation by Norwegian Ministry of Petroleum and Energy.
- Giving input to the SET-plan Steering Committee on offshore wind energy development (https://setis.ec.europa.eu/system/files/declaration_of_intent_offshore_wind.pdf).
- Heading the working group on offshore wind energy as part of the European Technology Platform on Wind Energy (TPwind). TPwind will be replaced with ETIP wind in 2016.
- Heading the sub-programme on offshore wind energy in the European Energy Research Alliance (EERA) joint programme on Wind Energy.
- Participation in the Board of WindCluster Norway

International engagement is further described in section 11.

COMMITTEE FOR INNOVATION AND COMMERCIALIZATION

Per Arne Wilson, NTNU, CIC Chair

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, and through spin-off projects and the creation of new industry. The committee is industry focused and chaired by Per Arne Wilson, NTNU. CIC cooperates with NTNU's Entrepreneurship School (NEC) and NTNU TTO in commercialisation of ideas created in NOWITECH, while Innovation Norway and Enova assist CIC in project development, also between NOWITECH partners and SMEs outside NOWITECH.

Activities by CIC in 2015 included preparation of the NOWITECH Innovation Award, support towards commercialization of selected NOWITECH results, and in cooperation with the NOWITECH management, assisting in applying the Technology Readiness Level for communicating progress in innovations, and giving support to external parties in developing new business ideas.

NOWITECH Innovation Award

The NOWITECH Innovation Award was established in 2015 with the aim to stimulate and reward knowledge-based innovation and / or entrepreneurship within the field of offshore wind energy. The criteria for the award are potential for reducing the cost of offshore wind energy, degree of novelty and commercial viability.

Following an open call for all affiliated with NOWITECH, six nominations for the NOWITECH Innovation Award 2015 were received and assessed by a committee of experts from industry and research, namely: Oddbjørn Malmo, Kongsberg Maritime, Daniel Zwick, Fedem Technology, Per Arne Wilson, NTNU/chair NOWITECH CIC, and John Olav Tande, SINTEF/director NOWITECH. All nominees satisfied the criteria for the award and were strong candidates; still the committee agreed unanimously on the winner:

The winning innovation represents, when fully developed, a step change in offshore wind turbine technology, enabling the power from large offshore wind turbines to be transported to shore without the use of any expensive offshore substation. The two award winners Sverre Gjerde and Pål Keim Olsen have carried out critical work in bringing this innovation forward as part of their PhD work at NTNU on high voltage DC generator technology for offshore wind turbines. They have demonstrated the technology in laboratory scale, and their work is well documented.

Their work has been inspired and carried out with support mainly from NTNU, SINTEF Energi, SmartMotor and the Research Council of Norway. The support to their work is greatly acknowledged.

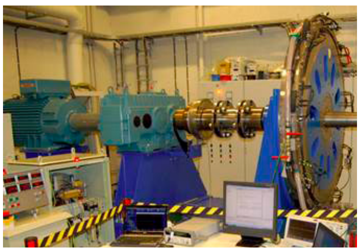


Figure 6: Laboratory set-up at NTNU/SINTEF for validating control of a modular series connected converter for a transformerless offshore wind turbine connection (left). Pål Keim Olsen and Sverre Gjerde received the award during the NOWITECH Innovation Day18 June 2015 (right).

SCIENTIFIC COMMITTEE

Trond Kvamsdal
NTNU, Chair SC

Michael Muskulus
NTNU, Vice-chair

The Scientific Committee (SC) has developed a top quality PhD and Postdoctoral programme in collaboration with CMG. This includes an active recruitment strategy, invitation of international experts for giving lectures, arrangements of scientific colloquia and seminars, and exposing scholars to industry and leading international research groups through NOWITECHs mobility programme.

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 advice on scientific focus and priorities.

The Scientific Committee consists of a core group with relevant NTNU professors and the Centre Director, and an extended group consisting of other Norwegian members and representatives of the associated international research partners.

During 2015 the Scientific Committee core group met more or less on a monthly basis. They handled day-to-day operations regarding PhD and Postdoc programme, recruitment, educational issues, etc. and applicants for the mobility programme. In 2015 the programme supported intermediate-term research visits and SC meetings.

The extended SC accomplished two full meetings in 2015; one in February back-to-back with the EERA DeepWind conference in Trondheim, and one in June in Bergen. These extended SC meetings involved an evaluation of the scientific content of NOWITECH's results and giving strategic advice on direction of research. The SC also pays attention to the publication activity in NOWITECH.

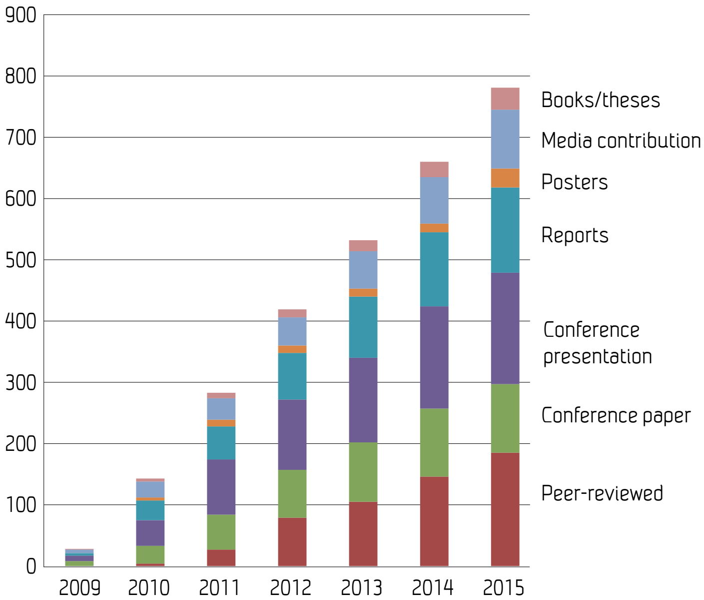


Figure 7: Accumulated number of publications in NOWITECH.

NOWITECH RESEARCH WORK AND RESULTS 2015

WPA

NUMERICAL TOOLS AND SUBSTRUCTURES

Ole David Økland
WPA co-leader

Roy Stenbro,
WPA co-leader

The objective of WPA is to enhance development of novel substructures for offshore wind through development, validation and use of numerical tools and experimental campaigns.

The work is divided into three tasks:

A.1 Development and validation of numerical models
A.2 Assessment of novel design concepts
A.3 Experiments and demonstrations

WPA

NUMERICAL TOOLS AND SUBSTRUCTURES

Summary of results 2015

WPA has good interaction between the industry and research partners. The industry partners are highly involved in work prioritizing. CD-adapco is actively cooperating in the research work, which should lead to improvements in their commercial CFD tools. Research into integrated modelling in WPA have benefited industrial offshore wind turbine (OWT) projects, such as Sheringham Shoal, Dudgeon and the world's first floating wind park – Hywind Scotland.

Research into integrated modelling in WPA have benefited industrial offshore wind turbine (OWT) projects, such as Sheringham Shoal, Dudgeon and the world's first floating wind park – Hywind Scotland.

The PhDs in WPA are progressing well with 3 candidates successfully finishing in 2015 and now employed in relevant industry, see Table 1. In total, in WPA, 6 out of 14 PhD candidates have finished so far, and 6 more are expected to finish during 2016.

WPA represents state of the art competence in the field of OWT modelling with respect to both CFD and integrated models. The researchers are active in international fora, especially in IEA OC5 for validating offshore wind aero-hydro-servo-elastic modelling tools, and let results be scrutinized through publication. More than ten peer-reviewed articles were published in 2015 as part of WPA activities.

A total of 13 innovations are in development in WPA. These include new models, methods, processes and technology at various stages of development, see Table 2. A highlight from 2015 is the application of the new hardware-in-the-loop (HIL) model test technique (#13) for experimental laboratory scale validation of a floating wind turbine (#12). The test was carried out in MARINTEK's Ocean Basin with waves creating hydrodynamic loads, whereas the aerodynamic loads were simulated in real time and applied on the model through actuators, see Figure 8. The test was a world's first of a kind, very successful and documented also in a short movie:

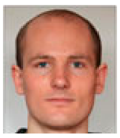
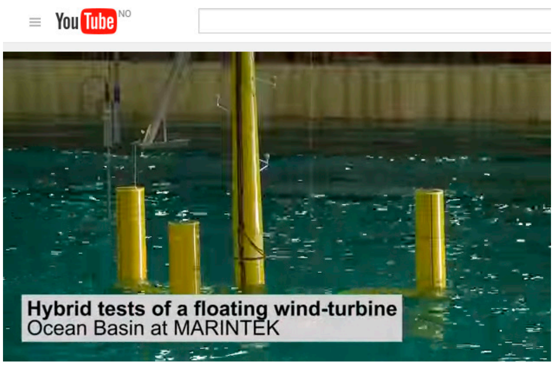
PhD candidate		Current employer	Thesis title
Nordanger, Knut		IKM Ocean Design AS	Two-dimensional simulation methods for offshore wind turbines
Wang, Kai		Aker Engineering & Technology AS	Modelling and dynamic analysis of a semi-submersible floating vertical axis wind turbine
Zwick, Daniel		Fedem Technology	Simulation and Optimization in Offshore Wind Turbine Structural Analysis

Table 1: WPA PhD candidates successfully finishing in 2015.



https://youtu.be/sIywrZFKd84.

Another highlight from 2015 is the kick-off of the European Horizon 2020 project LIFES50+ as an important spin-out from WPA activities. The project shall bring forward innovative technology for floating substructures for very large wind turbines (10 MW) at water depths greater than 50 m. The project is led by MARINTEK and carried out in a consortium consisting of twelve leading industry and research partners. Ultimately, LIFES50+ shall lead to a considerable lower LCoE for large floating offshore wind farms.

Good effort and results are also obtained within the area of advanced sea loads modelling. This is an area of high industry priority due to its importance for risks and costs. Also, in 2015 a pilot activity on marine operations related to installation and maintenance of offshore wind turbines was carried out. It forms the basis for further investigation and improved models aiming at reduced cost and risk related to marine operations.

Figure 8: Scaled HIL model test of an optimized floating wind turbine. Photo: MARINTEK.

NOWITECH INNOVATIONS 2015 WPA

Result	TRL	Impact
1 Model: IFE - 3DFloat integrate simulation tool	7	Integrated OWT models are essential to research and engineering. The model is in commercial use in the OWT industry.
2 Model: MARINTEK SIMO-RIFLEX simulation software package	7	Integrated OWT models are essential to research and engineering. The model is in commercial use in the OWT industry.
3 Model: IFE - 3DWind offshore wind turbine park wake CFD simulation tool. Development and validation finished 2011.	6	Understanding and simulation of the wake effects are essential to park layout, park energy prediction and important to turbine wind loads predictions.
4 Model: SINTEF ICT & NTNU IFEM-CFD fluid structure simulation tool	3	When further developed the model can be able to simulate how a deforming OWT interacts with sea and air, which can be important for example for advanced rotor research and engineering.
5 Method: NTNU Dept. of Mathematical Sciences - A posteriori based error estimator	3	This method could be used to increased accuracy and/or speed numerical simulations, if it for example were implemented in CFD or FEM simulations software.
6 Software: MARINTEK Floatopt/WindOpt spare buoy and semi-sub offshore wind turbine and mooring optimization soft-ware tool.	4	Can do cost optimized design of spar buoy and semi-sub type OWT substructure and mooring and minimize CAPEX in these areas.
7 Software: IFE - ALSIM / INVALSIM general and offshore wind turbine optimization software tool. Development finished in 2011.	8	When coupled with another model this software is able to cost optimize systems or components and minimize LCOE. Such tools are commonly used in many industries. It has been used for rotor, mooring and tower optimization. Services provided to the OWT industry.
8 Method: IFE, CD-adapco - use of commercial CFD software simulations for wind turbine aerodynamics.	5	State of the art CFD tools are the computer tools we have that can offer the most insight into fluid dynamics phenomena, for example rotor performance under normal or faulty operations. It's part of the standard toolbox for advanced research and engineering. CFD simulation services have been performed for to the OWT industry.
9 Method: IFE, CD-adapco – use of commercial CFD simulation tools for OWT hydrodynamics	5	Integrated engineering tools rely of simplification to be simple and fast enough for engineering needs. The cost of this is reduced realism and uncertainties. CFD can be used when more accurate results are needed, e.g. in the case of larger waves. We observe a trend of increasing use of CFD in the industry.
10 Prototype: Fugro-OCEANOR float-ing met-ocean buoy with LIDAR for measuring wind speed at different heights above sea level.	8	NOWITECH contributed to the start-up of this development. It is now offered as a commercial product by Fugro OCEANOR. It can drastically reduce the cost of collecting data on current, waves and wind at an offshore site.
11 Comparison of software codes for analysing semi-sub wind turbines pinpointing accuracy	NA	Several research partners in WPA have been involved in the OC4 study under the auspices of IEA regarding comparison of software and experiments for analysing various offshore wind turbines. The result is better software and improved knowledge of how to use such software. This is of value to both research and industry.
12 Novel design of brace-less semi-submersible platform for 5 MW wind turbine	2	A preliminary design of a semi-submersible platform for a horizontal axis 5 MW wind turbine has been developed as a milestone deliverable in WPA.
13 Experimental techniques for offshore wind turbines.	3	Scaled model testing is important for validation of methods and design-tools. Techniques where load effects from wind and waves can be combined for scaled models will lead to more accurate design tools and more optimal and cost effective designs.

Table 2: New models, methods, processes and technology in development.

WPB

OPERATION & MAINTENANCE AND MATERIALS

Thomas Welte,
WPB co-leader
Tasks B1,2

Jens Kjær Jørgensen,
WPB co-leader
Tasks B3,4,5

The objective of WPB is to contribute to the reduction of cost of energy of offshore wind power through development of new and cost-effective O&M concepts and strategies, through efficient and optimized use of material and coatings, and through development of new coatings and improved models for structures and materials.

The work is divided into five tasks:

Task B.1 Maintenance strategies
Task B.2 Surveillance and condition monitoring
Task B.3 Rotor blade structure and materials
Task B.4 New coatings for better performance
Task B.5 Testing and qualification of new coatings

WPB

OPERATION & MAINTENANCE AND MATERIALS

Summary of results 2015

The activities in WPB on operation and maintenance (O&M) concepts and strategies and the optimized use of material and coatings for offshore wind turbine applications, provide the industry with new knowledge and innovations for cost reduction.

Some of the results have already been transferred to the industry and are under further development by new spin-off companies.

A total of 12 innovations are in development in WPB. These include new models, methods, processes and technology at various stages of development, see Table 4. The results cover the whole range of research in WPB from O&M strategy model development, inspection strategies, rotor blade materials and structures, corrosion protection (coating systems) and testing of corrosion protection systems. Some of the results have already been transferred to the industry and are under further development by new spin-off companies. Examples are the software tools for O&M and logistics decision support, which have been used by NOWITECH industry partners Statoil and Statkraft for analyses in connection with developing the next generation wind farms (e.g. Dudgeon), and the remote presence concept and the silicon carbide coating technology, that have been developed by former NOWITECH WPB PhD students, and that currently are further developed in new spinoff companies, EMIP AS and Seram Coatings AS, respectively.
The PhDs in WPB are progressing well with 2 candidates successfully finishing in 2015, see Table 1, including one externally financed. In total, in WPB, 4 out of 5 PhD candidates financed by NOWITECH have completed their theses so far. The one remaining is already employed in industry, but still expected to complete his defence during 2016.

WPB produced five peer-reviewed papers during 2015, and furthermore one book chapter, eight presentations/posters on international conference, ten reports/memos and two PhD dissertations. Two key publications are:

- Dinwoodie, I.; Endrerud, O.E.; Hofmann, M.; Martin, R.; Sperstad, I.B.: Reference Cases for Verification of Operation and Maintenance Simulation Models for Offshore Wind Farms. *Wind Engineering*, vol. 39, no. 1, 1-14, 2015. This paper describes a reference case and a process for the verification and benchmarking of O&M models. The results from a comparison between four different models are presented, and the reference case has already been used by several other parties for testing their models. The article

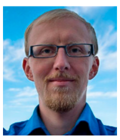
PhD candidate		Current employer	Thesis title
Nejad, Amir Rasekhi		NTNU	Dynamic Analysis and Design of Gearboxes in Offshore Wind Turbines in a Structural Reliability Perspective
Slimacek, Vaclav		NTNU	Heterogeneous Poisson processes with application to wind turbine reliability

Table 3: WPB PhD candidates successfully finishing in 2015. Vaclav Slimacek was externally financed, but his PhD work was carried out in alignment with NOWITECH.

is expected to also in the future be a useful reference for O&M model benchmarking and verification. A poster has also been prepared on this same subject, and this won Best Poster Award during DeepWind'2015.

- Bjørgum, A., interview by Monika Seynsche at the German radio station Deutschlandfunk: Nanopartikel schützen Rotorblätter vor Erosion (Nano particles protect rotor blades from erosion), Oct. 2015. This radio interview with Astrid Bjørgum, senior advisor at SINTEF Materials and Chemistry, gave insight in how nanoparticles as developed in NOWITECH WPB, can help to protect the rotor blades of wind turbine from droplet erosion.

WPB researchers are active in international cooperation: SINTEF Materials and Chemistry cooperates with DTU on determination of cohesive fracture mechanical laws for laminated composites, Figure 10, and takes part in the EERA Wind Sub Programme "Structures and Materials" where they contribute with the work related to composite materials and coatings. SINTEF Energy Research is involved in the IEA Wind Tasks 26 and 33 on, respectively, "Cost of Wind Energy" and "Reliability Data". SINTEF Energy Research and MARINTEK participate and organize the so-called "Offshore wind O&M modelling group" together with EDF R&D, University of Strathclyde, University of Stavanger and NREL. A workshop on Reliability Data and Maintenance Modelling with more than 40 international participants was co-organized by IEA Wind Task 33, Fraunhofer, NOWITECH, NORCOWE, LEANWIND and EERA in Berlin, 23 September, 2015.

Two software tools for simulation and optimization of offshore wind farm operation, maintenance and logistics have been developed in WP B (NOWIcob and vessel fleet optimization tool, Table 4, #4 and 5). The tools can, for example, be used for estimation of operational costs and availability, to find the optimal maintenance fleet size and mix (ships, vessels, helicopters, etc.) or to estimate the cost-benefit of new of improved technical solutions and innovations. The tools are used by NOWITECH industry partners and others according to license agreements.

Two software tools for simulation and optimization of offshore wind farm operation, maintenance and logistics have been developed.

During 2015 the tools have been further developed together with the industry partners and in the EU FP7 project LEANWIND. A validation and verification workshop was arranged in May 2015 with participants from DNV GL, Kongsberg, Statkraft and Statoil.

The remote presence concept consisting of a remotely controlled robot in the nacelle (Table 4, #7) has been further developed by Norsk Automatisering AS and NTNU Postdoc Øyvind Netland (former NOWITECH PhD student). Field tests of the system have been started in 2015 in a wind turbine at Ørlandet, and a new company EMIP AS has been established to commercialize the system.

The remote presence concept consisting of a remotely controlled robot in the nacelle has been further developed by Norsk Automatisering AS and NTNU.

The spinoff company Seram Coatings AS with former NOWITECH PhD-student Fahmi Mubarok and his NTNU supervisor Nuria Espallargas, has further developed the thermally sprayed silicon carbide coating technology (Table 4, #8) in direction of a commercial product. In 2015 Seram Coatings AS won Startprisen and the Academic Enterprise Awards (ACES) in Barcelona and professor Nuria Espallargas won "Best Young Innovator". In recent media coverage the potential for the innovation is reported to be a billion business with multiple application areas.

In recent media coverage the potential for the innovation is reported to be a billion business with multiple application areas.

Figure 9: Seram Coatings AS won the 2015 ACES Award for Academic Enterprise against stiff competition from three other university start-ups from France and Sweden.

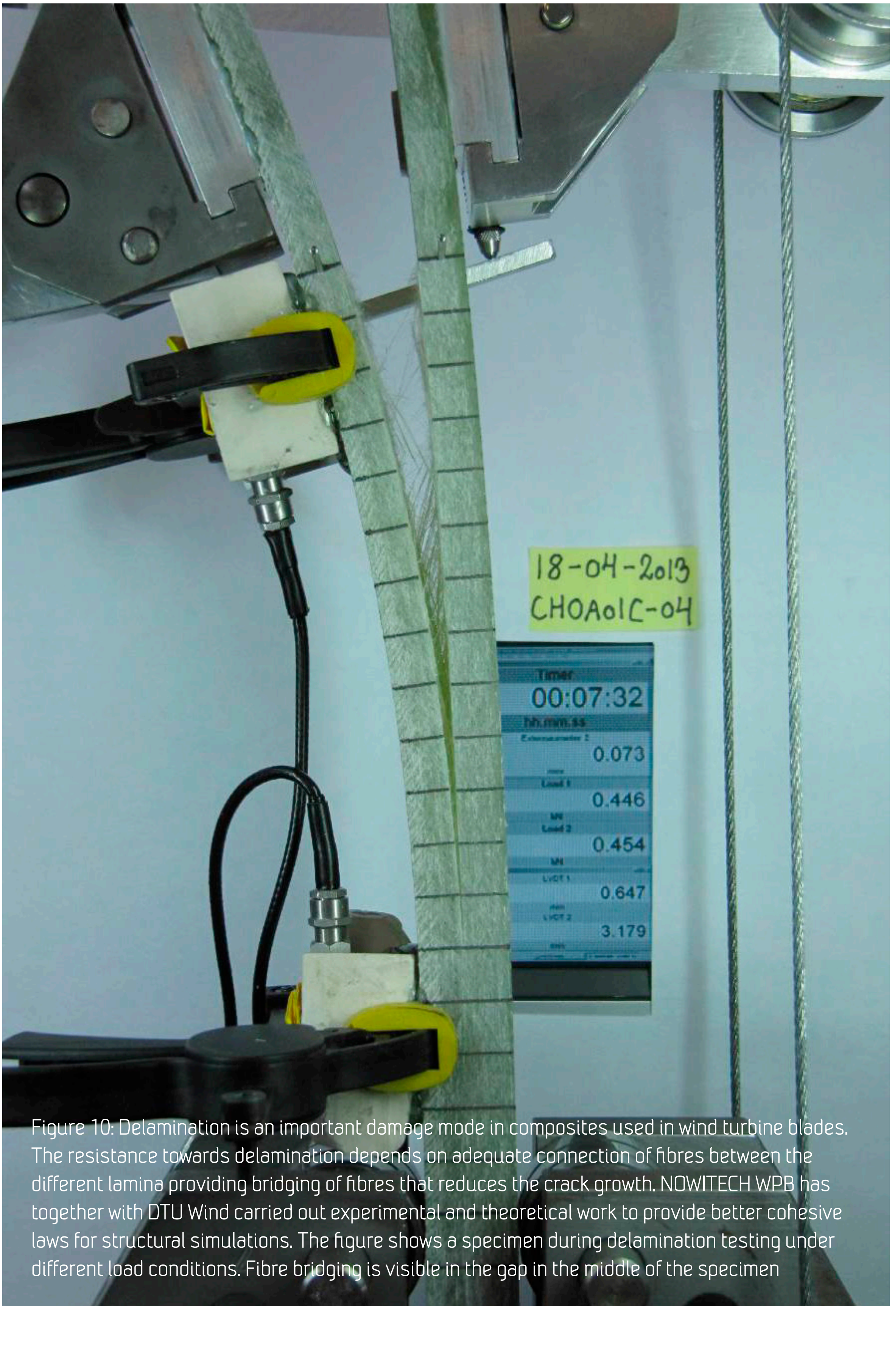


Figure 10: Delamination is an important damage mode in composites used in wind turbine blades. The resistance towards delamination depends on adequate connection of fibres between the different lamina providing bridging of fibres that reduces the crack growth. NOWITECH WPB has together with DTU Wind carried out experimental and theoretical work to provide better cohesive laws for structural simulations. The figure shows a specimen during delamination testing under different load conditions. Fibre bridging is visible in the gap in the middle of the specimen

NOWITECH INNOVATIONS 2015 WPB

Result	TRL	Impact
1 Method to increase buckling resistance in wind turbine blades through unbalanced fibre composite lay ups.	3	The potential for load alleviation and increased critical buckling load through the use of unbalanced fibre layup has been documented for a large number of design cases through simulations and laboratory experiments.
2 Progressive fatigue damage stiffness reduction simulation model for composite materials. Including test and parameter fitting procedures.	4	The model can be used to simulate the change in stiffness and remaining lifetime of composite structures subjected to fatigue loads as i.e. a wind turbine rotor blade spar.
3 Novel protective coating systems for offshore wind turbines substructures. Maintenance-free coating systems comprising thermally sprayed zinc (TSZ) paint with self-healing properties on top.	3	Longer lifetime and reduced maintenance of steel structures.
4 Software: NOWIcob – A life-cycle profit analysis tool for offshore wind farms	4	A tool to simulate the O&M cost of an offshore wind farm over the lifetime. NOWIcob can serve as a decision support tool to analyse the consequences of different decisions regarding maintenance and logistic strategy.
5 Software: Vessel fleet optimization – An optimization model and tool for making decisions about optimal vessel fleet to support the maintenance operations	4	Decision support tool for offshore wind farm operators. The model will give output results with regarding (i) location of maintenance bases (onshore/offshore) and (ii) the vessel fleet size and mix i.e. which vessels/helicopters to invest in and/or charter
6 Erosion resistant coatings for WT blades. Coatings based on nanoparticle modification of commercial coatings.	3	The maintenance of the leading edge of blades is expensive, thus a better drop erosion protective coating will increase useful life and reduce O&M costs.
7 New product: Remote inspection - A remotely controlled robot installed inside wind turbine nacelle.	5	Remote inspection using the robot is an alternative to expensive and time consuming manned inspection. The low cost of a remote inspection allows for more frequent inspections, which potentially can increase the reliability.
8 New product: Thermally sprayed silicon carbide coating. New cost effective thermally sprayed silicon carbide (SiC) coating useful for components that requires high wear resistance and low friction.	4	The properties of SiC makes the coatings highly attractive for many industrial applications as a new and cost-effective competitor to most hard coating materials on the market. The goal is to reduce wear of components and increase lifetime, and thus reduce O&M costs.
9 Software: Routing and scheduling optimization - Tool for optimization of vessel routing and maintenance scheduling	2	An optimization model for daily scheduling of maintenance operations in an offshore wind park (which maintenance task to perform when and in which order and with which ships and personnel).
10 Droplet erosion test setup: Laboratory set up for droplet erosion testing of wind turbine blade coatings.	4	Simplified and cost-effective drop erosion testing of coatings. This setup is used for testing Innovation 6, erosion resistant coatings.
11 Wind turbine drivetrain fault detection model. Prognostic model for fault detection in wind turbine drivetrains.	3	Model for early detection of wind turbine drivetrain faults based on condition monitoring data.
12 Gearbox inspection and maintenance planning method. Method for fatigue reliability-based inspection and maintenance planning of gear-box components in wind turbine drivetrains.	3	Method can lead to more effective inspections and thus reduce the downtime for fault detection and routine inspection, because inspection and maintenance can be focused on those components which hold higher probability of damage.

Table 4: New models, methods, processes and technology in development.

WPC

GRID AND WINDFARMS

Harald G Svendsen
WPC co-leader

Karl O Merz
WPC co-leader

The objective is to develop technical solutions and methods for cost effective electromagnetic and electrical designs, controls, grid connection and power system integration of offshore wind farms.

The work is divided into four tasks:

C.1 Wind turbine generator systems
C.2 Wind power plants
C.3 Offshore grids
C.4 Power system integration

WPC

GRID AND WINDFARMS

Summary of results 2015

WPC has good cooperation between industry and research partners. The annual work programme is determined through a match between industry needs for research and innovation and the scientific expertise amongst research partners. In 2015 two new activities were the result of high industry prioritisation by wind farm developers: The investigation into long distance HVAC cable transmission, and wideband modelling of a 66 kV wind farm for investigation of harmonics and resonance phenomena.

Three PhD students associated with WPC successfully defended their theses, Dr RA Barrera Cardenas, Dr. Z Zhang, and Dr M Valavi. All three have wind energy related employment. The three remaining Nowitech funded PhD candidates (M Pedersen, PC See, A Soloot) are expected to defend their theses in 2016. Two associated candidates (VC Tai and PK Olsen) are also expected to finish in 2016, while one (AG Endegnanew) will continue into 2017.

WPC has produced seven peer-reviewed scientific articles in 2015, five reports, and ten conference presentations and posters. Two key publications are

- M Valavi, A Nysveen, R Nilssen, *Effects of Loading on Radial Magnetic Forces and Vibration in Low-Speed Permanent Magnet Machine with Concentrated Windings,* IEEE Transactions on Magnetics **51** (2015), doi:1109/TMAG.2014.2377014. This study investigates vibrations in wind turbine direct-drive generators, and shows that the spatial harmonic responsible for some of the vibration is affected by d-axis currents. The result is important because it gives an improved knowledge basis for designing better wind turbine generators with lower vibrations.

- A Soloot, HK Høidalen, B Gustavsen, *Influence of the winding design of wind turbine transformers for resonant overvoltage vulnerability,* IEEE Transactions on Dielectrics and Electrical Insulation **22** (2015), doi:10.1109/TDEI.2015.7076828. This study investigates potential resontant overvoltages in wind turbine transformers due to switching transients, and their dependence on winding

Methods to supply wind energy to offshore oil and gas platforms has been a big activity in NOWITECH.

PhD candidate		Current employer	Thesis title
Cárdenas, René Alexander Barrera		JSPS fellowship Univ Tsukuba	Meta-parametrised meta-modelling approach for optimal design of power electronics conversion systems: Application to offshore wind energy
Valavi, Mostafa		PostDoc NTNU	Magnetic Forces and Vibration in Wind Power Generators: Analysis of Fractional-Slot Low-Speed PM Machines with Concentrated Windings
Zhang, Zhaoqiang		Greenway Energy AS	Ironless Permanent Magnet Generators for Direct-Driven Offshore Wind Turbines

Table 5: WPC PhD candidates successfully finishing in 2015.

type, using detailed modelling techniques. The study is important since such phenomena are not easily captured by simplified models and can potentially lead to very costly repairs.

WPC research activities are part of international collaborations through coordination with related work in European research projects, such as IRPWIND, EERA-DTOC, and BestPaths. Moreover, NOWITECH scientists are strongly involved in EERA JP Wind sub-programmes for offshore wind and grid integration, as well as having a leading role in the new IEA Wind Task 37.

Methods to supply wind energy to offshore oil and gas platforms has been a big activity in NOWITECH in previous years and these results are now being brought forward in a new IPN project with Statoil. Another 2015 spin-off related to WPC is a new KPN project considering reliability and ruggedness of high power high voltage power electronics (RELIPE).

In order to understand the dynamics of a wind farm as a complete system with interactions between aerodynamic, hydrodynamic, mechanical, electrical, and control domains it is necessary to have an integrated description formulated in a way that allows analytical tools to be applied. This is achieved with the linearised state space model (STAS) that is being developed in NOWITECH. Using STAS, frequency domain analyses for the entire system is possible, something that is very useful for example for developing wind farm control strategies, see also *Table 6: New models, methods, processes and technology in development.* #12.

In large offshore wind farms, there are clear benefits of increasing the voltage level from 33 to 66 kV, which is reflected in an industry move in this direction. However, the change in voltage affects the electrical properties of the wind farm grid, shifting resonance frequencies. In order to be able to predict and avoid harmful harmonics and other electrical interactions, wideband models for 66 kV wind farm grid components are developed and applied, see also *Table 6: New models, methods, processes and technology in development.* #14 and Figure 11.

Another topic that has been in focus in 2015 is the possibility for extending the range for HVAC transmission. With the uncertainties and high costs of HVDC transmission, the well-known and trusted AC option is attractive to many wind farm developers also for long distances. Research in NOWITECH has applied detailed power cable models to investigate how the transmission distance can be extended by smarter choice of transmission voltage, see also *Table 6: New models, methods, processes and technology in development.* #13.

Another topic that has been in focus in 2015 is the possibility for extending the range for HVAC transmission.

The 2015 NOWITECH Innovation Award was given to Sverre Gjerde and Pål Keim Olsen for the development of a modular, high-voltage, transformerless generator/converter for a wind turbine. This research was conducted in WPC.

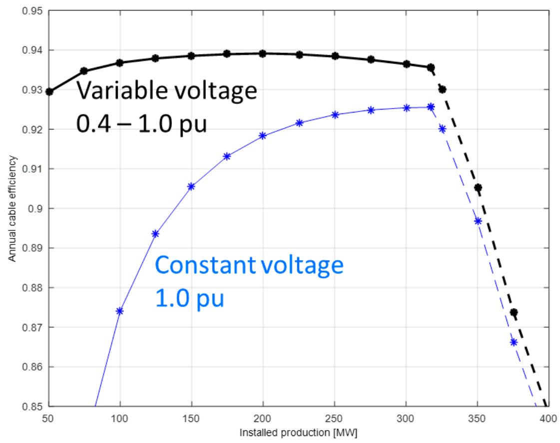


Figure 11 Operation of long distance HVAC transmission cable at variable voltage can give significant efficiency improvements. The figure is for a 200 km, 220 kV, 1000 mm² cable.

NOWITECH INNOVATIONS 2015 WPC

Result		TRL	Impact
1	Numerical model of the influence of slot harmonics on magnetic vibrational forces in PM generators	4	Identify generator designs with low vibrational forces which will allow reduction in total generator mass
2	Power System Simulation Tool (PSST), software simulation tool	3	The tool can be used to assess future scenarios for wind power integration, concerning cost of energy, nodal prices, grid bottlenecks, benefit of grid reinforcements etc.
3	Net-Op, software simulation tool	3	Tool for optimising offshore grid layout, taking into account variability in wind power, demand and prices. It can be used to identify economic offshore wind farm clustering and grid structures
4	Viper, software engineering tool	3	Engineering tool for estimating energy production for an offshore wind farm. It can be used together with electrical models in order to optimise offshore wind farm layout.
5	Electrical laboratory with multiple converters, cable emulators and wind farm emulator	4	The laboratory can be used to demonstrate technical solutions and validate numerical models for grid connection and control of offshore wind farms, including multi-terminal HVDC set-ups
6	Operational strategies for integration of wind power with oil and gas platforms	3	This knowledge can improve profitability and reduce risks for off-shore oil and gas platforms powered partially by wind energy.
7	Control of floating offshore wind turbines, advanced strategies and algorithms	3	Smart control systems for load mitigation and structural stabilization are important for optimal production of power and cost reduction.
8	Design strategy and tools for systematic investigation of different ironless PM generator concepts	3	This knowledge and tools can be used to achieve integrated generator design with minimal weight per MW
9	Library of wind turbine models for electrical studies	2	Ready to use models for analyses of grid integration, control and stability
10	Controls for grid connection of offshore wind via multi-terminal HVDC grid, algorithms and models	4	Cost-effective deployment of offshore wind in the North Sea, benefits from efficient and reliable sharing of offshore transmission infrastructure
11	Grid model reduction, algorithm and software tool	2	Create simplified, equivalent power flow models that obscures sensitive information and reduces complexity, for simulation of large grids with hundreds/thousands of buses
12	STAS, integrated linear state space model for wind farm, software model	2	Fast engineering model to assess wind farm level control strategies
13	Long distance AC cable parameter optimisation tool	1	Optimise parameters and operational strategy for long distance HVAC cables – stretching the limits of HVAC transmission
14	Wide-band model of wind farm collection grids	2	Apply in wideband frequency analysis to understand resonance phenomena, harmonics etc in 33 kV and 66 kV grids
15	Software/Method: SINTEF ER - Internal wind farm grid assessment tool	1	Optimise/compare internal wind farm grid design

Table 6: New models, methods, processes and technology in development.


Research infrastructures
Spin-off projects
International cooperation
Recruitment
Communication and Dissemination

RESEARCH INFRASTRUCTURE

The research partners have access to strong research infrastructures. This includes in-house labs, e.g. the wind tunnel at NTNU (11x3x2 m), ocean basin lab at MARINTEK (80x50x10 m), SmartGrid lab at NTNU/SINTEF and the new SINTEF Energy Lab, and field facilities like the test station for wind turbines at Valsneset, four met-masts at Frøya, EFOWI (lidars and met-ocean buoys) together with NORCOWE, and the DIPLAB mobile short-circuit facility operated by SINTEF Energy Research. The research infrastructures generally are developed with separate contracts external to NOWITECH, but prepared in alignment with NOWITECH.

The SmartGrid lab is currently going through a very significant upgrade with new equipment for hardware in the loop testing, grid emulation and flexible set-up of AC and DC systems. The lab has a broad use, but highly relevant also for research in grid connection of offshore wind farms. The funding from the RCN to realize this upgrade is highly appreciated. The same goes for the RCN support for establishing the EFOWI and DIPLAB facilities.

The new SINTEF Energy Lab opened in 2015. SINTEF has built the lab using own funds to continue to be in the forefront of international research and contribute to competiveness of the industry. *"World leading laboratories are a necessity for developing the energy solutions for the future. The task we face is no less than to carry out an energy revolution with energy systems handling 100 percent renewable sources" said Unni Steinsmo, CEO SINTEF (2004-2015).* The laboratory building has a net floor area of 5400 square metres, and houses seven distinct laboratories: High-voltage lab, Ageing test lab (for ageing tests of cables and other electrical power system components), Subsea lab, Short circuit lab, Combustion lab, High current lab, and Power system electronics lab.

The research partners have access to strong research infrastructures.

The research partners also have access to research infrastructure through international cooperation, especially through EU projects, e.g. HYDRALAB IV, MARINET and EERA IRPwind, and are also taking part in developing joint European research infrastructure through WindScanner.eu (2013-2015). This is a European Strategy Forum on Research Infrastructures (ESFRI) preparatory phase (PP) project coordinated by DTU (DK). The objective is to provide catalytic and leveraging support towards the construction of the facility. The operational European WindScanner facility is expected to become a distributed and mobile research infrastructure for lidar based 3-D wind speed measurements. SINTEF Energy Research participates in this as a Norwegian node coordinating work between the Norwegian stakeholders, including NOWITECH and NORCOWE research parties, to establish such lidar based facilities in Norway.

Figure 12: The new SINTEF Energy Lab opened 2 September 2015 with the presence of the Their Royal Highnesses Crown Prince Haakon and Crown Princess Mette-Marit.

SPIN-OFF PROJECTS

The NOWITECH research partners are attractive: A total of five new projects were started in 2015 with participation of one or more of the research partners in NOWITECH. Since start-up, the count is 64 new projects with an accumulated budget of over NOK 1500 million. The projects are with EU or Nordic funding (24), national competence building projects or infrastructure (27) or industry driven with RCN co-funding (13). These projects are with separate contracts external to NOWITECH, but carried out in alignment with NOWITECH providing added value. A selection of projects is listed in Table 4. A number of bilateral projects directly for industry come in addition.

Since start-up, the count is 64 new projects with an accumulated budget of over NOK 1500 million.

Project title	Type	Partners	Start	End
1 Lifes50+ (Qualifying innovative floating substructures for 10MW wind turbines.)	EU H2020	MARINTEK, etc. (12 partners in total)	2015	2019
2 ReliPE (Reliability and ruggedness of high power high voltage power electronics)	RCN KPN	SINTEF Energi AS, Statkraft, GE Power Conversion, Mitsubishi Europe, EDF	2015	2019
3 Redwin (Reducing cost of offshore wind by integrated structural and geotechnical design)	RCN KPN	NGI, IFE, NTNU, Statkraft, Statoil	2015	2018
4 AWSOME (11 PhDs within O&M methodologies)	EU H2020 MCA	DTU, Strathclyde, NTNU, etc.	2015	2018
5 MOVE: Marine Operation Centre	RCN SFI	NTNU Ålesund, MARINTEK, Statoil, etc.	2015	2023
6 Support on offshore wind maintenance and logistics studies	Bilateral	Statkraft, MARINTEK, SINTEF Energi	2015	2015
7 EERA IRPWIND	EU FP7	DTU, NTNU, SINTEF Energy Research, Marintek, etc.	2014	2018
8 SmartGrids lab	RCN infrastructure	NTNU, SINTEF Energy Research	2014	2018
9 Best Path	EU FP7	Red Electrica, Iberdrola, SINTEF Energy Research, etc,	2014	2018
10 Kon-Wake	RCN IPN	Kongsberg, SINTEF MC	2014	2016
11 WiWind	RCN IPN	Kongsberg, SINTEF ICT	2014	2016
12 Wind farm Energy storage	Industrial	SINTEF Energy Research, Iberdrola, Gamesa	2014	2015
13 DIMSELO	RCN KPN	IFE, DTU, STATOIL, STATKRAFT, NTNU	2013	2016
14 Eurosunmed	EU FP7	CNRS, SINTEF ER	2013	2017
15 Leanwind	EU FP7	Univ Cork, MARINTEK, Kongsberg, SINTEF ER, NAAS ++	2013	2017
16 EWEM: European Wind Energy Master	EU	TU Delft, DTU, NTNU, Universität Oldenburg	2013	-
17 Offshore Energy Storage system	RCN IPN	Sub Hydro, SINTEF Energy Research, etc.	2013	2015
18 Offshore DC: DC grids for integration of large scale wind power	Nordic	Risø DTU, AAU, Chalmers, SINTEF Energy Research, VTT, Dong, Vestas, ABB, Energinet.dk, NTNU,	2013	2015
19 North Sea Offshore Network and Storage	RCN	SINTEF ER	2013	2016
20 Beppo - Blue Energy Production in Ports	EU Interreg	Port of Oostende, SINTEF Energy Research, Marintek, etc.	2013	2015

21	WINDSENSE: Add-on instrumentation system for wind turbines	RCN IPN	Kongsberg Maritime, Statoil, NTE, SINTEF Energy Research, Marintek, NTNU, etc	2013	2014
22	ProOfGrids: Protection and Fault Handling in Offshore HVDC Grids	RCN KPN	SINTEF Energy Research, NTNU, RWTH Aachen University, Statnett, Statoil, NationalGrid, EDF, GE Power Conversion, NVE, Siemens, Statkraft	2012	2017
23	Fluid Structure Interactions for Wind Turbines	RCN KPN	SINTEF IKT, Statoil, TrønderEnergi, Kjeller Vindteknikk, FFI, NTNU, SINTEF	2012	2017
24	InnWind: Innovative wind conversion systems (10-20MW) for offshore applications	EU FP7	Risø DTU, SINTEF Energy Research, etc.	2012	2016
25	MARE-WINT: new Materials and Reliability in offshore WINd Turbines technology	EU FP7	Polish Academy of Sciences, NTNU, Marintek, etc.	2012	2016
26	WindScanner.eu	EU ESFRI	DTU, Fh IWES, ECN, ForWind, CENER, SINTEF Energy Research, LNEG, University of Porto and CRES	2012	2015
27	RenWind	RCN IPN	Reichhold, SINTEF MK, DTU Wind	2012	2015
28	EERA-DTOC: EERA Design Tools for Offshore Wind Farm	EU FP7	DTU Risø, SINTEF Energy Research, etc.	2012	2015
29	FAROFF: Far offshore operation and maintenance vessel concept development and optimization	RCN IPN	Statkraft, MARINTEK, Fred Olsen, Odfell, SINTEF Energy Research	2012	2014
30	Offwind: Prediction tools for offshore wind electricity generation	Nordic	IRIS, SINTEF, FFI, WindSim, Storm Geo etc.	2012	2014
31	Nordic wind power O&M network	Nordic Energy Research	Energi Norge, SINTEF Energy Research, VTT, Vindforsk, Chalmers, Risø DTU	2011	2015
32	MARINET: Marine Research Infrastructures Network for Energy Technologies	EU FP7	HMRC University College Cork, Risø DTU, NTNU, University of Strathclyde, Fraunhofer IWES, SINTEF Energy Research, etc	2011	2015
33	DIPLAB (ETEST, 8 MVA short-circuit emulator)	RCN infrastructure	SINTEF Energy Research	2011	2014
34	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.	2011	2013
35	PowerUP: Effektive verdikjeder for offshore vindmøller	RCN Mid-Norway	SINTEF, NTNU, Høgskolen i Molde, Møreforskning	2011	2013
36	HiPRwind: High Power, high Reliability off-shore wind technology	EU FP7	Fraunhofer IWES, SINTEF Energy Research, NTNU etc.	2010	2015
37	DeepWind: Future Deep Sea Wind Turbine Technologies	EU FP7	DTU, Statoil, SINTEF Energy Research, etc.	2010	2014
38	MARINA Platform: Marine Renewable Integrated Application Platform	EU FP7	Acciona, NTNU etc.	2009	2013

Table 7: Selection of projects with participation of one or more NOWITECH research partners.

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. The programme is enhanced with the EU FP7 IRPWIND project started in March 2014 with coordination by DTU and objectives closely aligned with EERA JPwind.

- European Technology Platform for wind energy (TPwind), www.windplatform.eu; the platform is replaced by end 2015 with the new European Technology and Innovation Platform (ETIP) on wind energy. John Tande (SINTEF Energy Research) was Chair of the offshore working group within TPwind, and a member of the TPwind Steering Committee. He will continue in the Steering Committee of ETIP wind.

- European Academy of Wind Energy (EAWE), www.eawe.eu; SINTEF, NTNU and IFE participate. EAWE members meet at least once a year at the annually PhD seminar.

In 2015 the research parties in NOWITECH participated in more than 15 projects with EU or Nordic funding providing for very substantial international collaboration.

- European Wind Energy Master (EWEM), www.windenergymaster.eu, is a joint (NTNU, TU Delft, DTU and University of Oldenburg) Erasmus Mundus MSc programme on wind energy providing for a 2 year specialization within Wind Physics, Rotor Design, Electric Power Systems and Offshore Engineering. NTNU is engaged in EWEM offering specialization in Electric Power Systems and Offshore Engineering.

- IEA Wind, www.ieawind.org; The research partners of NOWITECH are active in all relevant tasks of IEA Wind, including Task 25 (Design and operation of power systems with large amounts of wind power), Task 26 (Cost of wind energy), Task 29 (Mexnext: Analysis of wind tunnel measurements), Task 30 (Comparison of Dynamic Computer Codes and Models for Offshore Wind Energy (OC4, OC5)) and Task 37 (Wind Energy Systems Engineering). The latter was started in 2015 with SINTEF Energy Research, NREL and DTU sharing the management and coordination of the task

- IEC TC88, www.iec.ch. The research partners of NOWITECH are active in all working groups with relevance for offshore wind turbines. SINTEF Energy Research is heading the Norwegian sister-organization NK88 and represents Norway in TC88.

International cooperation is also through research mobility programmes, transnational laboratory access programmes, participation in EU projects, meetings and collaboration with the international associated research parties of NOWITECH through SC and other means, guest lectures, the involvement of international industry parties, hiring of internships etc. In 2015 the research parties in NOWITECH participated in more than 15 projects with EU or Nordic funding providing for very substantial international collaboration.

NOWITECH participated in the Japan - Norway Energy Science Week in 2015, sparking a number of possible cooperative activities with Japanese research groups within offshore wind.

Figure 13: The Japan-Norway Energy Science Week in 2015 was concluded with a visit at AIST FREA (Fukushima Renewable Energy Institute) to discuss R&D into renewable energy. Photo: RCN.

RECRUITMENT

Since the start of NOWITECH, 25 PhD scholars and 5 Postdocs at NTNU have been funded by the Centre. In addition, another 10 PhD and 2 Postdoc students were associated to the Centre in 2015. These do 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 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 total of eight PhDs successfully defended their doctoral work in 2015 at NTNU on offshore wind energy. Of these seven had funding from NOWITECH and one had funding from other sources. A list of all PhD students and Postdocs financed through NOWITECH or by other sources on offshore wind energy at NTNU can be found in Appendix.

The remaining PhD and Postdocs financed by NOWITECH are due to finish in 2016-2017, see Figure 11, with the exception of one that started in 2015 and will finish in 2018 after the completion of NOWITECH.

The MSc education on wind energy has been enhanced at NTNU through NOWITECH.

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 theses. 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.

During 2015, professors and scientific staff at NTNU, with relations to NOWITECH, were supervisors for 48 MSc students with theses specializing in offshore wind energy (see Appendix). This is a remarkable increase from previous years, Figure 15, and demonstrates high and increasing interest in offshore wind energy among master students at NTNU. 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.

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.

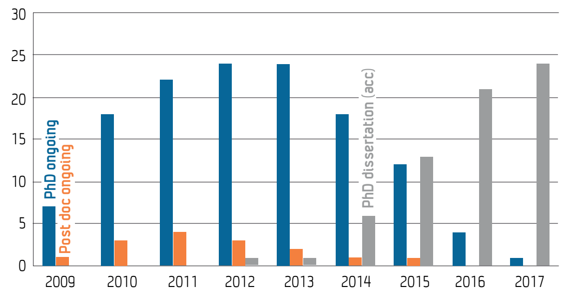


Figure 14: Timeline of PhD and Postdoc programme funded by NOWITECH. Data for 2016-2017 are estimates.

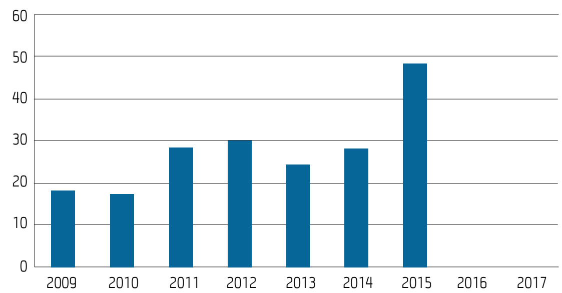


Figure 15: Annual number of MSc theses in offshore wind energy at NTNU since start of NOWITECH.

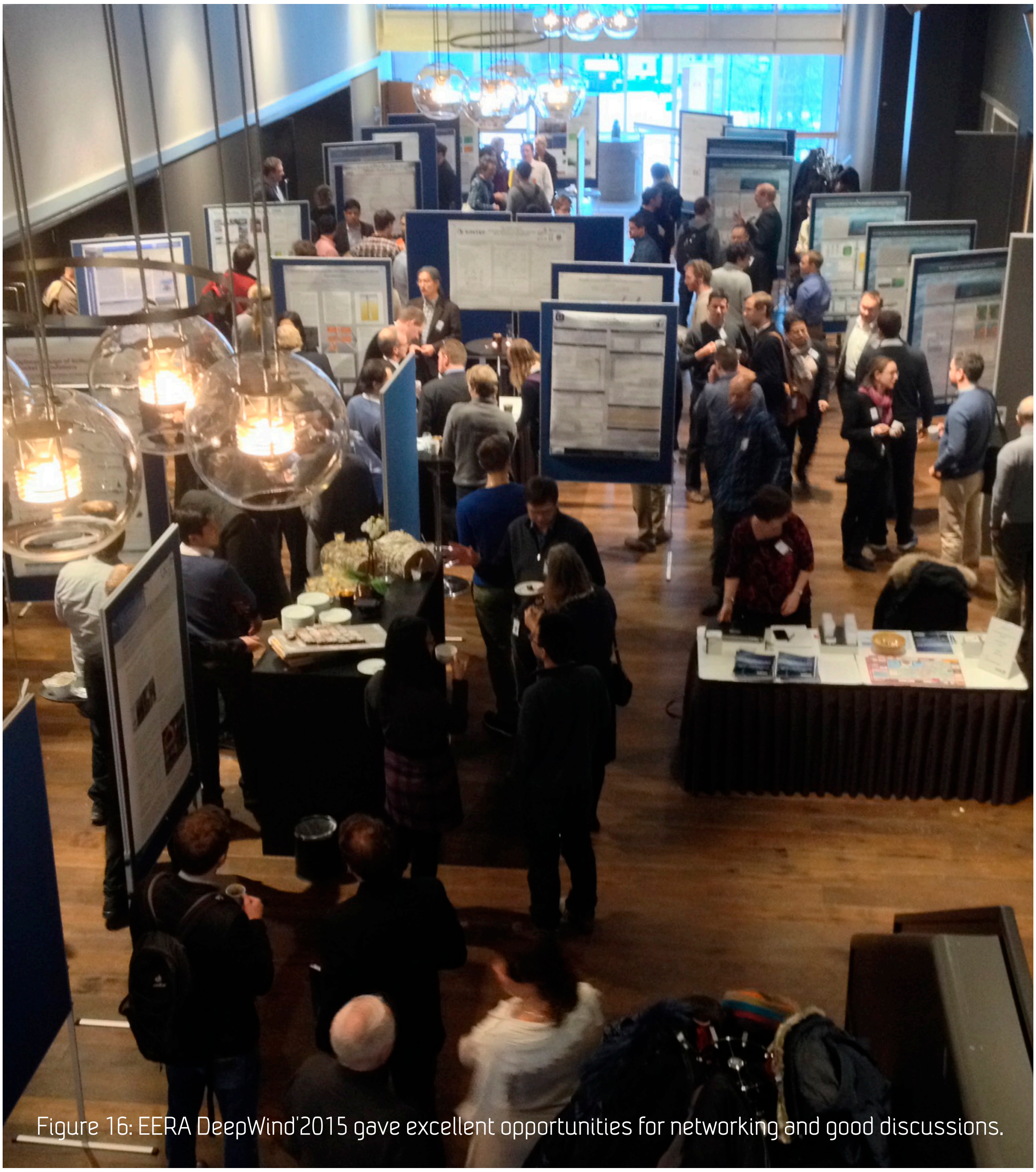


Figure 16: EERA DeepWind'2015 gave excellent opportunities for networking and good discussions.

COMMUNICATION AND DISSEMINATION

The scientific results of the Centre are disseminated efficiently and are achieving international recognition.

Publications

since start-up include 190 peer-reviewed papers, 139 reports, 96 media contributions and 181 conference presentations of which more than 20 were invited keynotes, see Figure 16. In 2015 NOWITECH prepared 121 publications, including 39 peer-reviewed papers, 18 reports, 11 books/ theses, 20 media contributions, 17 posters and 15 conference presentations. Details of these are given in the appendix. All NOWITECH partners have access to a project e-room, where all internal information, publications and project results are presented.

The scientific results of the Centre are disseminated efficiently and are achieving international recognition.

EERA DeepWind conference

A main event for communicating open results from NOWITECH is the EERA DeepWind conference held every year in Trondheim. The EERA Deep-Wind'2015 Deep Sea Offshore Wind R&D Conference, February 4-6, was a success with a mix of plenary presentations with broad appeal and presentations in parallel sessions and posters on specific science and technology themes. The conference is established as an important venue on deep sea offshore wind R&D organized in association with the European Energy Research Alliance (EERA) joint programme on wind energy. The aim is to present the latest and best on-going R&D on deep sea offshore wind farms. In total 65 oral and 50 poster presentations were held addressing new turbine and generator technology, grid connection and power system integration, met-ocean conditions, operation & maintenance, installation and sub-structures, wind farm optimization, and experimental testing and validation. The conference was fully booked with 200 delegates from all over Europe, and also from USA and Japan. In addition to the exciting main event there were side events including a workshop on EERA IRPwind access to open data and an IEA Offshore Wind Code Comparison (OC5) meeting. The presentation from the conference is available at the conference website EERA Deep-Wind'2015 whereas selected papers after a careful peer-review process are published in the open access journal Energy Procedia (Elsevier).

The conference was fully booked with 200 delegates from all over Europe, and also from USA and Japan.

Other communication activity

Other main channels for open communication of NOWITECH activities and results 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. The web page is continuously updated.
- The NOWITECH newsletters give short teasers of results and information on activities in NOWITECH. The newsletters are distributed through e-mail and public web. They are open and shall be understandable also for the educated non-expert, but with links for further reading to the NOWITECH e-room for partners only. Two newsletters were produced in 2015.
- The seminar series "Industry meets Science" is continued in cooperation with Wind Cluster Norway. The aim of the seminar series is to facilitate an improved interaction between the research in NOWITECH and relevant industry, also those that are not partners in NOWITECH. Two seminars were held in 2015.
- NOWITECH was present with presentations and/or stands at more than ten international conferences during 2015 including the EWEA Offshore conference being recognised as the main international exhibition and conference with more than 8000 participants.
- In November, John Olav Tande, spoke to the Standing Committee on Energy and the Environment about offshore wind. He explained how a Norwegian demo park could be an important climate contribution globally and create new green industry in Norway. This is what he said: http://blog.sintefenergy.com/politikk/demo-park-for-havvind-er-et-viktig-klimabidrag/ (in Norwegian)

Figure 17: Susanna Galloni from the European Commission opened DeepWind'2015 with the talk "Progress of offshore wind through R&D in FP7 and H2020".

Figure 18: EERA DeepWind'2015 poster award winners Lisa Ziegler, NTNU / Siemens Nederland N.V.(left) and Rebecca Martin, EDF Energy R&D UK Centre Ltd, (right). Lisa won the best poster award for Scientific Content for her work entitled "Sensitivity of Wave Fatigue Loads on Offshore Wind Turbines under varying Site Conditions" and Rebecca won best poster award for Communication for her work entitled "Reference cases for benchmarking operation and maintenance models for offshore wind farm".

FORSIDEN / MENINGER / KRONIKK / SEKS GRUNNER TIL AT VINDKRAFT ER EN GOD IDÉ

AV: JOHN OLAV TANDE, SENIORFORSKER SINTEF ENERGI OG LEDER NOWITECH OG NILS A. RØKKE, KLIMADIREKTØR SINTEF

PUBLISERT: 17 JUNI 2015 05:00 SIST OPPDATERT: 18 JUNI 2015 11:09

Kronikk onsdag 17. juni 2015

Seks grunner til at vindkraft er en god idé

Norge har ikke noe mål om å redusere antall brukte kilowattimer. Vindkraft og vannkraft er billigere enn atom-, kull- og gasskraft.

Hvis huset ditt brenner, kan ikke brannfolk krangle om de skal slukke med vann, pulver, vanntåke eller halon. Alle slukkemidler trengs. Det samme gjelder for klimaet.

Skal verden lykkes med overgangen til fremtidens bærekraftige energisystem, trenger vi alle virkemidlene og teknologiene. Også vindkraft.

I sin lørdagskommentar 06.06. er Stein Arne Sæther mest opptatt av hva vi ikke må gjøre. Gode grunner for vindkraft, både landbasert og offshore, er imidlertid ingen mangelvare. Her skal vi nøye oss med seks av dem:

1. Vindkraft er ingen klimabløff
Bløffen som Sæther sikter til, går utelukkende på EUs kvotesystem. Den har ingenting med vindkraft eller andre nye fornybare kilder å gjøre.

Et kvotesystem for utslipp vil gi varige

FOTO: DAN ÅGREN, ADRESSEAVISEN

John Olav Tande from NOWITECH and Nils Røkke, Climate Director in SINTEF, wrote an op-ed in Adressa 17 June, explaining why wind power is a good idea.

GEMINI.no
FORSKNINGSNYTT FRA NTNU OG SINTEF

Teknologi | Energi og miljø | Naturvitenskap | Fisk og havbruk | Nyskaping | Helse | Samfunn

Dette er en modell av en vindturbin. Her testes den med fysiske bølger og vind - innendørs. Et slikt forsøk er aldri gjort før, ifølge forskerne som sto bak eksperimentet. Foto: Ingvil Snøfugl.

Ny testmetode for vindturbiner

Nylig ble det gjennomført en modelltest av en flytende vindturbin på en måte ingen andre har gjort tidligere. Forskerne tilførte modellen fysiske bølger og simulerte vinden – alt i sanntid.

Av Ingvil Snøfugl
Published 20.11.15

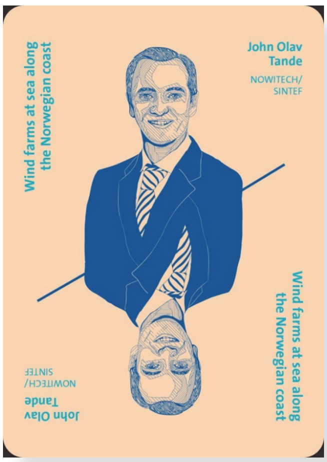
Del artikkel:

MODELLFORSØK: Modellen i havlaboratoriet ble påført kraftige, fysiske bølger og vind oppimot 25 meter i sekundet fra sanntids simulatorer.

– De fleste havbassengene er bygget for å teste olje- og gassinstallasjoner. De simulerer bølger veldig bra, men måler ikke vind av samme kvalitet som en vindtunnel. MARINTEK har ingen vindtunnel, og vi fant derfor ut at vi heller kan simulere vind. Det gir svært nøyaktige resultater,

Fakta:
Formål: Prøve ut ny testmetode
Hvor: Havlaboratoriet ved MARINTEK i Trondheim
Turbin: Modell i 1:30 skala, dvs 4 meter testmodell tilsvarer 120 meter høy vindturbin i reelle omgivelser.

20. November, GEMINI.no, presented a new method for testing wind turbines, developed at NTNU and MARINTEK in the NOWITECH project.



Preparing for the United Nations Climate Negotiations in Paris, the Research Council of Norway hosted an event during Arendalsuka. The Minister of Climate and Environment, and leading the Norwegian delegation in Paris, Tine Sundtoft, received a "Climate Card" from NOWITECH, on why we need wind farms at sea.

3. September, John Olav Tande, held an open lecture at NTNU, where he spoke about all the innovations from NOWITECH and why the world needs offshore wind

Figure 19: A selection of communication activities in 2015.

APPENDIX

Personnel

Publications

Financial statement

PERSONNEL

Key researchers in NOWITECH in 2015

	Name	Affiliation	Role
1	Tande, John Olav Giæver	SINTEF Energy Research	Centre Director
2	Bolstad, Hans Christian	SINTEF Energy Research	Centre Manager
3	Steenstrup-Duch, Anne	SINTEF Energy Research	Commications Manager
4	Kvamsdal, Trond	NTNU / SINTEF Information and Communication Technology	SC, WPA
5	Nysveen, Arne	NTNU	SC, WPC
6	De Vaal, Jacobus	IFE	WPA
7	Nygaard Tor Anders	IFE	WPA
8	Oggiano, Luca	IFE	WPA
9	Fabio Pierella	IFE	WPA
10	Berthelsen, Petter Andreas	Marintek	WPA
11	Foques, Sebastien	Marintek	WPA
12	Fylling, Ivar	Marintek	WPA
13	Karimirad, Madjid	Marintek	WPA
14	Ormberg, Harald	Marintek	WPA
15	Sauder, Thomas	Marintek	WPA
16	Stansberg, Carl Trygve	Marintek	WPA
17	Vatne, Sigrid	Marintek	WPA
18	Grøva, Morten	Marintek	WPA
19	Bachynski, Erin	Marintek	WPA
20	Luxey, Neil	Marintek	WPA
21	Sandvik, Peter	Marintek	WPA
22	Thys, Maxim	Marintek	WPA
23	Fossen, Thor Inge	NTNU	WPA
24	Gao, Zhen	NTNU	WPA
25	Krogstad, Per Åge	NTNU	WPA
26	Skjetne, Roger	NTNU	WPA
27	Steen, Sverre	NTNU	WPA
28	Rasheed, Adil	SINTEF Information and Communication Technology	WPA
29	Johnsen, Heidi	SINTEF Materials and Chemistry	WPA, WPB
30	Stenbro, Roy	IFE	WPA, Management
31	Økland, Ole D.	Marintek	WPA, Management
32	Moan, Torgeir	NTNU	WPA, WPB, Management, SC
33	Muskulus, Michael	NTNU	WPA, Management, SC
34	Halvorsen-Weare, Elin E.	Marintek	WPB
35	Nonås, Lars Magne	Marintek	WPB
36	Valland, Anders	Marintek	WPB
37	Stålhane, Magnus	NTNU	WPB
38	Vatn, Jørn	NTNU	WPB
39	Lindqvist, Bo	NTNU	WPB
40	Sperstad, Iver	SINTEF Energy Research	WPB

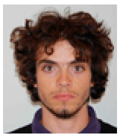
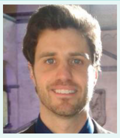
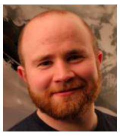
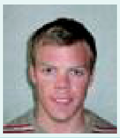
41	Armada, Sergio	SINTEF Materials and Chemistry	WPB
42	Bjørgum, Astrid	SINTEF Materials and Chemistry	WPB
43	Gaarder, Rune Harald	SINTEF Materials and Chemistry	WPB
44	Giovanni Perillo	SINTEF Materials and Chemistry	WPB
45	Juan Yang	SINTEF Materials and Chemistry	WPB
46	Grytten, Frode	SINTEF Materials and Chemistry	WPB
47	Andrew Gibson	MARINTEK	WPB
48	Jørgensen, Jens Kiær	SINTEF Materials and Chemistry	WPB, Management
49	Welte, Thomas	SINTEF Energy Research	WPB, Management
50	Høidalen, Hans Kristian	NTNU	WPC
51	Uhlen, Kjetil	NTNU	WPC
52	D'Arco, Salvatore	SINTEF Energy Research	WPC
53	Endegnanew, Atsede	SINTEF Energy Research	WPC
54	Farahmand, Hossein	SINTEF Energy Research	WPC
55	Kirkeby, Henrik	SINTEF Energy Research	WPC
56	Niklas Magnusson	SINTEF Energy Research	WPC
57	Mo, Olve	SINTEF Energy Research	WPC
58	Gustavsen, Bjørn	SINTEF Energy Research	WPC
59	Holdyk, Andrzej	SINTEF Energy Research	WPC
60	Vrana, Til Kristian	SINTEF Energy Research	WPC
61	Anaya-Lara, Olimpo	SINTEF Energy Research	WPC
62	Reigstad, Tor Inge	SINTEF Energy Research	WPC
63	Fosso, Olav	NTNU	WPC, Chairman of the Board
64	Merz, Karl	SINTEF Energy Research	WPC, Management
65	Svendsen, Harald	SINTEF Energy Research	WPC, Management

Visiting Researchers

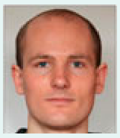
	Name	Affiliation	Nationality	Gender	Duration	Topic
1	Prof. Hans-Gerd Busmann	Fraunhofer IWES	GER	M	1-2015 to 4-2015	Operation and maintenance of wind farms
2	Prof. Olimpo Anya-Lara	University of Strathclyde	UK	M	1-2015	Grid connection of wind farms

NOWITECH PhD Students

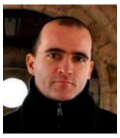
The following PhD students have received financial support from NOWITECH and have completed or are working towards a PhD. Those that have completed their PhD are marked with blue , and those that completed in 2015 are also marked with a star (*).

	PhD candidate		Period	Current Work Place	WP	Topic of PhD thesis
1	Bardal, Lars Morten		2012-2015	NTNU	A	Design wind and sea loads for offshore wind turbines
2	Bracchi, Tania		2009-2013	NTNU (HiST)	A	Downwind Rotor: Studies on yaw Stability and Design of a Suitable Thin Airfoil
3*	Cárdenas, René Alexander Barrera		2011–2014	JSPS fellowship Univ Tsukuba	C	Meta-parametrised meta-modelling approach for optimal design of power electronics conversion systems: Application to offshore wind energy
4	Chabaud, Valentin		2011–2016	NTNU	A	Experimental investigation of coupled hydrodynamic and aerodynamic performance of floating wind turbines
5	Chella, Alegan Mayilvahanan		2010-2014	NTNU	A	Wave forces on wind turbine structures
6	Cox , Kevin		2010-2013	Christian Michelsen Research	B	Lift control of wind turbine blades by using smart composite materials manipulating aerodynamics rotor properties
7	Dombre, Emmanuel		2011-2015	EDF	A	Hydrodynamic modeling and analysis of floating wind turbines
8	Eriksen, Pål Egil		2010-2014	NTNU	A	Rotor wake turbulence
9	Frøyd, Lars		2009-2012	4Subsea	A	Wind Turbine Design: Evaluation of Dynamic Loads on Large Offshore Wind Turbines
10	Hameed, Zafar		2009-2012	Rolls Royce	B	Maintenance optimization of wind farms from design to operation (models, methods, framework)

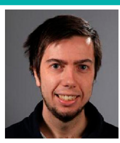
11	Kvittem, Marit Irene		2009-2013	DNV GL	A	Modelling and response analysis for fatigue design of a semi-submersible wind turbine
12	Luan, Chenyu		2011-2015	NTNU	A	Efficient stochastic dynamic response analysis for design of offshore wind turbines
13	Mubarok, Fahmi		2010-2014	PostDoc IPM NTNU+ Seram Coatings AS	B	Thermally Sprayed Silicon Carbide Coating
14*	Nejad, Amir Rasekhi		2012-2015	PostDoc CeSOS, NTNU	B	Dynamic Analysis and Design of Gearboxes in Offshore Wind Turbines in a Structural Reliability Perspective
15	Netland, Øyvind		2010-2013	PostDoc IPM NTNU	B	Remote Inspection of Offshore Wind Turbines – A Study of the Benefits, Usability and Feasability
16*	Nordanger, Knut		2010-2014	IKM Ocean Design AS	A	Two-dimensional simulation methods for offshore wind turbines
17	Pedersen, Morten Dinhoff		2010-2013	NTNU	C	Design of control systems for load mitigation and stabilization of floating wind turbines
18	See, Phen Chiak (Bryan)		2012-2015	NTNU	C	Development of market models incorporating offshore wind farms and offshore grids
19	Siddiqui, M.Salman		2015-2018	NTNU	A	Stochastic Processes in Dynamic Stall Behavior in Turbulent Wind
20	Soloot, Amir Hayati		2009-2013	ABB	C	Analysis of switching transients in wind parks with focus on prevention of destructive effects
21*	Valavi, Mostafa		2010-2014	PostDoc	C	Magnetic Forces and Vibration in Wind Power Generators: Analysis of Fractional-Slot Low-Speed PM Machines with Concentrated Windings
22	Van Buren, Eric		2009-2012	Kværner	A	Bottom-fixed support structure for wind turbine in 30-70 m water depth

23*	Wang, Kai		2010-2014	Aker Engineering & Technology AS	A	Modelling and dynamic analysis of a semi-submersible floating vertical axis wind turbine
24*	Zhang, Zhaoqiang		2010-2013	Greenway Energy AS	C	Ironless Permanent Magnet Generators for Direct-Driven Offshore Wind Turbines
25*	Zwick, Daniel		2009-2013	Fedem Technology	A	Simulation and Optimization in Offshore Wind Turbine Structural Analysis

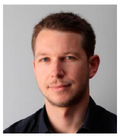
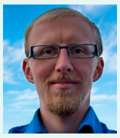
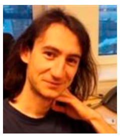
NOWITECH Postdoctoral Researchers

	Postdoc		Period	Current Work Place	WP	Topic
1	Anthonippillai Antonarulrajah		2009-2011	Not known	B	Influence of material and process parameters on fatigue of wind turbine blades in a marine environment
2	Madjid Karimirad		2010-2012	MARINTEK	A	Alternative floating wind turbines for moderate water depths
3	Steve Völler		2010-2012	SINTEF Energi	C	Balance management with large scale offshore wind integration
4	Mukesh, Kumar		2011-2013	College of Charleston, USA	A	Adaptive methods for accurate CFD-simulations of aerodynamic loads on offshore wind turbines
5	Ali Nematbakhsh		2013-2015	University of Notre Dame, USA	A	Alternative floating wind turbines for moderate water depths

Ongoing Postdoctoral Researchers aligned with NOWITECH, externally financed

	Postdoctoral Researcher		Period	WP	Topic
1	Magnus Stålhane		2013-2015	B	Optimization of maritime logistics
2	Lene Eliassen		2013-2015	A	Effects of large rotors

Ongoing PhD students aligned with NOWITECH, externally financed

	PhD student		Period	WP	Topic
1	Bartl, Jan		2014-2017	A	Wind turbine wake interactions
2	Endegnanew, Atsede		2014-2017	C	Offshore grids
3	Hansen, Thomas Henrik Hertzfelder		2014-2016	A	Design and analysis of wind turbine rotor blades for offshore applications
4	Hanssen-Bauer, Øyvind Waage		2014-2017	A	Investigation of the structure of turbulent wakes formed behind wind turbines
5	Olsen, Pål Keim		2011-2014	C	Electrical Degradation phenomena in insulation materials exposed to combined DC and AC voltage
6	Schafhirt, Sebastian		2013-2017	A	Modelling of support structure dynamics for offshore wind turbines
7*	Slimacek, Vaclav		2011-2015	B	Heterogeneous Poisson processes with application to wind turbine reliability
8	Suja-Thauvin, Loup		2013-2016	A	Nonlinear sea loads on large mono piles (industry PhD candidate with Statkraft)
9	Tu, Ying		2014-2018	A	Inverse modelling of wave slamming forces for offshore wind turbine jacket substructures
10	Tai, Vin Cent		2012-2015	C	Offshore grids

Master Degrees during 2015 in offshore wind at NTNU

	Name	Gender	Topic
1	Visser, N.	M	Experimental set-up of the Double Slip Joint.
2	Nous, R.J.M.	M	A Dynamic Approach to Evaluating the Effect of Slamming on a Jacket Foundation Template Lowered Through the Wave Zone.
3	Centen, I.H.	F	Predicting scour around offshore wind turbines using soft computing techniques.
4	Smilden, E.	M	Preventing Tower resonance Induced by Thrust Variations on a Large 10 MW Wind Turbine.
5	Golieva, A.	F	Low Short-Circuit Ratio Connection of Wind Power Plants.
6	Voortman, R.L.B.	M	State-of-the-art design methods for wind turbine towers.
7	Khentalov, V.A.	M	New end fitting based on bolted joints with composite structures.
8	Kolparambath, S.K.	M	DC/DV Converters for Multi-terminal HVDC system for Integrating Offshore Wind Farms.
9	Paust, H.S.	M	Finite Element Modeling and Structural State Estimation of a Bottom Fixed Offshore Wind Turbine.
10	Vittori, F.E.	M	Design and Analysis of Semi-submersible Floating Wind Turbines with focus on Structural Response Reduction.
11	Dondero, D.	M	Time-domain Global Response Analysis of a Novel 5 MW Semi-submersible Wind Turbine Considering the Effect of second-order Wave Loads
12	Hartviksen, H.	M	Application of Scaling Laws for Direct Drive Permanent Magnet Generators in Wind Turbines.
13	Dharmawardena, H.I.	M	Modelling Wind Farm with Frequency response for Power System Dynamic Studies
14	Høivik, Ø.	M	Flexible distribution network.
15	Lu, Shining	F	DC Cable Short Circuit Fault protection in VSC-MTDC.
16	Llado, M.G.	M	Structural Reliability Analysis and Robust Design of Offshore Wind Turbine Support Structures.
17	Trygsland, E.	M	Numerical Study of Seabed Boundary Layer Flow around Monopile and Gravity-based Wind Turbine Foundations.
18	Eliassen, J.C.	M	Winding and Testing of Superconducting Coils.
19	Borenius, R.	M	Kombinert vind- og bølgekraft.
20	Nesje, B.	F	The need for Inertia in the Nordic Power System.
21	Melaaen, C.S.	M	The impact of outages on the profitability of HVDC –cables between the Nordic area and the continent using the EMPS model.
22	Valaker, E.A.	M	Droplet Erosion Protection Coatings for Offshore Wind Turbine Blades.
23	Raknes, N.T., Ødeskaug, K.	F	Optimal Scheduling of Maintenance Tasks and Routing of a Joint Vessel Fleet for Multiple Offshore Wind Farms.
24	Smelvær, I.S.	F	Analysis of the Norwegian-Swedish Market for Green Certificates Using the EMPS Model.
25	Venås, C.	M	Life cycle assessment of electric power generation by wind turbines containing rare earth magnets.
26	Frimann-Dahl, J.F.	M	Experimental Validation and Design Review of Wave Loads on Large-Diameter Monopiles.
27	Ødegård, J.N.	M	Laboratory Demonstration of Frequency Support Provision from VSC-HVDC-connected Full Converter Wind Turbines.
28	Xu, Kun	M	Design and Analysis of Mooring System for Semi-submersible Floating Wind Turbines in Shallow Water.
29	Bjørnsen, G.S.	M	A Comparison of methods for Estimation of Fatigue and extreme Mooring response for a Floating Spar Wind Turbine.
30	Løken, T.K.	M	Energy Systems on Autonomous Offshore Measurement Stations.
31	Grøtting, H.	M	Small Water Plane Area Solutions for Access of Offshore Wind Turbines.
32	Krathe, V.L.	F	Aero-Hydro Dynamic Analysis of Offshore Wind Turbine.

33	Sande, E.S.	M.	Fatigue Assessment of Offshore Wind Turbine Support Structures with the Frequency Domain Method.
34	Ommedal, H.K.H.	F	Cost of flexibility in the future European power system.
35	Overgård, I.E.	F	Reliability-based Design of a Monopile Foundation for Offshore Wind Turbines based on CPT Data.
36	Grønningsæter, E.K.	M	Tidal Boundary Layer Flow in Coastal Zones.
37	Johannesen, S.	F	Portfolio Optimization of Wind Power Projects.
38	Ghidey, Hiruy	M	Reliability-based design optimization with Cross-Entropy method.
39	Saccoman, M.Y.J.	F	Coupled Analysis of a Spar Floating Wind Turbine considering both Ice and Aerodynamic Loads.
40	Ziegler, L.S.	F	Probabilistic estimation of fatigue loads on monopole-based offshore wind turbines.
41	Fechner, S.	M	Preprosessering av meteorologiske data for atmosfæriske teoretiske/numeriske modeller.
42	Bakkom, O.E.	M	Computer-aided optimization of an offshore jacket for a wind turbine with a simplified load model.
43	Hetland, J.	M	Numerical Modelling of a Pile Model test with Focus on Small-strain Stiffness.
44	Bidne, A.	M	Formal Safety Assessment of Dynamically Positioned Vessels.
45	Wiklak, P.A.	M	Parameter study of power production in wind farms – experimental investigation of interaction of two wind turbines in tandem array.
46	Aanonli, A.K.	F	Floating Wind Turbines in Oil and Gas Activity.
47	Ceccotti, C.	F	Parameter study of electric power production in wind farms.
48	Spiga, A.	M	Parameter study of electric power production in wind farms.

The NTNU master students listed above are as recorded at www.daim.idi.ntnu.no with “offshore wind” as topic for their master thesis.

PUBLICATIONS 2015

Journal and Peer Review Papers

1. Sethuraman, L.; Xing, Y.; Venugopal, V.; Gao, Z.; Mueller, M.; Moan, T.; "A 5 MW direct-drive generator for floating spar-buoy wind turbine: Drive-train dynamics", Journal of Mechanical Engineering Science
2. Nematbakhsh, A.; Bachynski, E.; Gao, Z.; Moan, T.; "Comparison of Wave induced Response of a TLP Wind Turbine Obtained by CFD Method and Potential Theory"; ISOPE 2014; Proceedings of the Twenty-fourth (2014) International Ocean and Polar Engineering Conference; Busan; Korea; June 15-20, 2014
3. Nematbakhsh, A.; Gao, Z.; Michailides, C.; Moan, T.; "Comparison of experimental data of a moored multibody wave energy device with a hybrid CFD and biem numerical analysis framework"; Proceedings of the ASME 2015
4. Nematbakhsh, A.; Bachynski, E.; Gao, Z.; Moan, T.; "Comparison of wave load effects on a TLP wind turbine using computational fluid dynamics and potential flow theory approaches", Applied Ocean Research, Vol 53
5. Bachynski, E.; Chabaud, V.; Sauder, T.; " Real-time hybrid model testing of floating wind turbines: sesitivity to limited actuation", Energy Procedia, Vol 80
6. Bachynski, E.; Ormberg, H.; "Comparison of Engineering Models for the Aerodynamic Load Distribution along a Wind Turbine Blade", ISOPE 2015, Document ID ISOPE-I-15-235
7. Endegnanew, A. et al; " Integrated modelling platform for dynamic performance assessment of floating wind turbines"; Energy Procedia, Vol 80
8. Spro, O.C. et al; " Influence of technical limitations and operation on sizing of an offshore energy storage connected to an offshore wind farm"; Energy Procedia, Vol 80
9. Nejad A. R.; Guo Y.; Gao Z.; Moan T.; "Development of a 5 MW reference gearbox for offshore wind turbines", Wind Energy, ISSN 1099-1824
10. Nejad, A.; Bachynski, E.; Kvittem, M.I.; Luan, C.; Gao, Z.; Moan, T.; "Stochastic dynamic load effect and fatigue damage analysis of drivetrains in land-based and TLP, spar and semi-submersible floating wind turbines", Marine Structures, Vol 42
11. Nejad, A.; Bachynski, E.; Gao, Z.; Moan, T.; " Fatigue Damage Comparison of Mechanical Components in a Land-Based and a Spar Floating Wind Turbine", Procedia Engineering, Vol 101
12. Gjerde, S.S.; Olsen, P.K.; Ljøkelsøy, K.; Undeland, T.; "Control and fault handling in a modular series-connected converter for a transformerless 100 kV low-weight offshore wind turbine"; IEEE Transactions on Industry Applications; Vol 50 (2014)
13. Ormberg, H.; Bachynski, E.; "Sensitivity of estimated tower fatigue to wind modeling for a spar floating wind turbine", ISOPE - International Offshore and Polar Engineering Conference. Proceedings / 2015, ISBN 978-1-880653-89-0
14. Kvittem, M.; Moan, T.; "Time domain analysis procedures for fatigue assessment of a semi-submersible wind turbine", Marine Structures, Vol 40
15. Svendsen, H.; "Grid model reduction for large scale renewable energy integration analyses", Energy Procedia, Vol 80
16. Brantsæter, H; Kocewiak, L; Årdal, AR; Tedeschi, E.; "Passive filter design and o shore wind turbine modelling for system", Energy Procedia, Vol 80
17. Magnusson, N; Eliassen, JC; Abrahamsen, AB; Nysveen, A; Bjerkli, A; Runde, M; King, P; "Design aspects on winding of an MgB2 superconducting generator coil"; Energy Procedia, Vol 80
18. Soloot, A.; Høidalen, H.K.; Gustavsen, B.; "Influence of the winding design of wind turbine transformers for resonant overvoltage vulnerability"; IEEE Transactions on Dielectrics and Electrical Insulaton, Vol 22, Issue 2
19. Nordanger, K.; Holdahl, R.; Kvarving, A.M.; Rasheed, A.; Kvamsdal, T.; "Implementation and comparison of three isogeometric Navier–Stokes solvers applied to simulation of flow past a fixed 2D NACA0012 airfoil at high Reynolds number", Computer Methods in Applied Mechanics and Engineering; Vol 284
20. Dai, L., Stålhane, M., Utne, I.; "Routing and Scheduling of Maintenance Fleet for Offshore Wind Farms"; Wind Engineering, Vol 39, Issue 1

21. Gundegjerde, C.; Halvorsen, I.B.; Halvorsen-Weare, E.E.; Hvattum, L.M.; Nonås, L.M.; "A stochastic fleet size and mix model for maintenance operations at offshore wind farms", Transportation research Part C: Emerging Technologies, Vol 52
22. Valavi, M.; Nysveen, A.; Nilssen, R.; "Effects of Loading on Radial Magnetic Forces and Vibration in Low-Speed Permanent Magnet Machine with Concentrated Windings"; IEEE Transactions on Magnetics, Vol 51
23. Dinwoodie, I.; Endrerud, O.E.; Hofmann, M.; Martin, R.; Sperstad, I.B.; "Reference Cases for Verification of Operation and Maintenance Simulation Models for Offshore Wind Farms", Wind Engineering, Vol 39, Issue 1
24. Netland, Ø.; Jenssen, G.; Skavhaug, A.; "The capabilities and Effectiveness of Remote Inspection of Wind Turbines"; Energy Procedia, Vol 80
25. Chella, A.M.; Bihs, h.; Myrhaug, D.; Muskulus, M.; "Hydrodynamic characteristics and geometric properties of plunging and spilling breakers over impermeable slopes"; Ocean Modelling; doi:10.1016/j.ocemod.2015.11.011
26. Chella, M.A.; Bihs, H.; Myrhaug, D.; Muskulus, M.; "Breaking characteristics and geometric properties of spilling breakers over slopes"; Coastal Engineering; 2015, Vol 95
27. Chella, M.A.; Bihs, H.; Myrhaug, D.; "Characteristics and profile asymmetry properties of waves breaking over an impermeable submerged reef"; Coastal Engineering, Vol 100
28. Van Opstal, T.; Fonn, E.; Holdahl, R.; Kvamsdal, Tl; Kvarving, A.M.; et al; "Isogeometric Methods for CFD and FSI-Simulation of Flow around Turbine Blades"; Energy Procedia, Vol 80
29. Brantsæter, H.; Kocewiak, L.; Årdal, A.; Tedeschi, E.; "Passive Filter Design and Offshore Wind Turbine Modelling for System Level Harmonic Studies"; Energy Procedia, Vol 80
30. Siddiqui, M.S.; Rasheed, A.; Kvamsdal, T.; Tabib, M.; "Effect of Turbulence Intensity on the Performance of an Offshore Vertical Axis Wind Turbine"; Energy Procedia, Vol 80
31. Valaker, E.A.; Armada, S.; Wilson, S.; "Droplet Erosion Protection Coatings for Offshore Wind Turbine Blades"; Energy Procedia, Vol 80
32. Goldschmidt, M.; Muskulus, M.; "Coupled Mooring Systems for Floating Wind Farms "; Energy Procedia, Vol 80
33. Rousis, A.O.; Anaya-Lara, O.; "DC Voltage Control for Fault Management in HVDC System"; Energy Procedia, Vol 80
34. Stieng, L.E.; Helland, R.; Schafhirt, S.; Muskulus, M.; "Relative Assessment of Fatigue Loads for Offshore Wind Turbine Support Structures"; Energy Procedia, Vol 80
35. Chew, Kok-Hon; Tai, K.; NG, E.Y.K.; Muskulus, M.; "Optimization of Offshore Wind Turbine Support Structures Using an Analytical Gradient-based Method"; Energy Procedia, Vol 80
36. Stålhane, M.; Hvattum, L.M.; Skaar, V.; "Optimization of Routing and Scheduling of Vessels to Perform Maintenance at Offshore Wind Farms"; Energy Procedia, Vol 80
37. Bardal, L.M.; Sætran, L.R.; Wangsness, E.; "Performance Test of a 3MW Wind Turbine – Effects of Shear and Turbulence"; Energy Procedia, Vol 80
38. Karimirad, M.; Michailides, C.; "Dynamic Analysis of a Braceless Semisubmersible Offshore Wind Turbine in Operational Conditions"; Energy Procedia, Vol 80
39. Netland, Ø.; Jenssen, G.; Skavhaug, A.; "The Capabilities and Effectiveness of Remote Inspection of Wind Turbines"; Energy Procedia; Vol 80

Published Conference papers

1. Vrana, T.K; Svendsen, H.G.; Endegnanew, A.G.; "Wind Power Grid Codes - Historic Development, Present State and Future Outlook", Wind Integration Workshop; Brussel, 2015-10-22

Books / Chapter in books / Theses

1. Simonsen, T.; Tønset, C.; “Droplet Erosion Resistant Coatings for Offshore Wind Turbine Blades: Testing in Harsh Conditions” - Bachelor Thesis
2. Valaker, E.A.; “Droplet Erosion Protection Coatings for Offshore Wind Turbine Blades” - Master Thesis
3. Slimacek, V.; “Heterogeneous Poisson processes with application to wind turbine reliability”; PhD Thesis
4. Nordanger, K.;”Two-dimensional simulation methods for offshore wind turbines” - Doctoral Thesis
5. Zwick, D.; “Simulation and Optimization in Offshore Wind Turbine Structural Analysis” - Doctoral Thesis
6. Wang, K.; “Modelling and dynamic analysis of a semi-submersible floating vertical axis wind turbine” - Doctoral Thesis
7. Valavi, M.; “Magnetic Forces and Vibration in Wind Power Generators” - Doctoral Thesis
8. Barrera-Cardenas, R.A.; “Meta-parametrised meta-modelling approach for optimal design of power electronics conversion systems: application to offshore wind energy” - Doctoral Thesis
9. Zhang, Z.; “Ironless Permanent Magnet Generators for Direct-Driven Offshore Wind Turbines” – Doctoral Thesis
10. Nejad, A.; “Dynamic Analysis and Design of Gearboxes in Offshore Wind Turbines in a Structural Reliability Perspective” – Doctoral Thesis
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3. Svendsen, H.; " Grid model reduction for large scale wind integration analyses", EERA DeepWind'2015 Conference, Trondheim, 4-6 February 2015
4. Tande, J.O.; "Innovations in offshore wind energy"; EERA DeepWind'2015 Conference, Trondheim, 4-6 February 2015
5. Svendsen, H.G.; "Status and potential for wind power", International workshop on Renewable Energy and Hydrogen Export
6. Tande, J.O.; "Innovations in Offshore Wind Energy"; SINTEF Seminar on offshore wind; Trondheim, 7 May 2015
7. Nonås, L.M.; " Offshore Wind - A planning and logistics perspective", INTPOW konferansen, March 2015
8. Bjørgum, A.; " New coatings for corrosion protection of offshore wind structures", Corrosion Protection for Offshore Wind; Bremen; 28 – 30 april 2015
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11. Korpås, M.; " Balancing options and costs for offshore wind in the North Sea", EERA DeepWind'2015 Conference, Trondheim, 4-6 February 2015
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13. Tande, J.O.; "Wind Power – Status and Perspectives"; IFEA Årsmøte; Oslo; 15. April 2015
14. Merz, K.; " Linear Models for the Dynamic Analysis of Wind Turbines and Wind Power Plants", EERA DeepWind'2015 Conference, Trondheim, 4-6 February 2015
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FINANCIAL STATEMENT 2015

(All figures in NOK 1000)

FUNDING

Name	Amount	Amount
Norges forskningsråd		20 000
SINTEF Energi AS		2 271
NTNU		7 346
IFE		711
MARINTEK		1 629
SINTEF		739
Kongsberg Maritime	503	
Det Norske Veritas	500	
CD-adapco	657	
Fedem Technology AS	666	
Fugro Oceanor AS	525	
Dong Energy Power	500	
Norsk Automatisering AS	503	
Statkraft Development AS	1 500	
Statnett SF	500	
Statoil Petroleum AS	1 150	
Subtotal Industry Partners		7 004
Other contributors		300
Public Partners		0
Total		**40 000**

COSTS

Name		Amount	Amount
SINTEF Energi AS	(Host Institution)		9 083
NTNU	(Research Partner)		15 452
IFE	(Research Partner)		2 844
MARINTEK	(Research Partner)		6 514
SINTEF	(Research Partner)		2 953
Kongsberg Maritime		503	
CD-adapco		657	
Fedem Technology AS		666	
Fugro Oceanor AS		525	
Norsk Automatisering AS		503	
Subtotal Industry Partners			2 854
Other costs			300
Public Partners			0
Total			**40 000**

NOWITECH
Norwegian Research Centre
for Offshore Wind Technology

Host institution
SINTEF Energi AS (SINTEF Energy Research)

Chairman of the Board
Olav B Fosso
olav.fosso@ntnu.no
Phone: + 47 995 89 248

Centre Director
John Olav Giæver Tande
John.O.Tande@sintef.no
Phone: +47 913 68 188

Centre Manager
Hans Christian Bolstad
Hans.Christian.Bolstad@sintef.no
Phone: + 47 994 60 751

www.NOWITECH.no

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