ANNUAL REPORT 2021

NORTH WIND

CONTENTS

NORTHWIND IN A NUTSHELL

NorthWind - Norwegian Research Centre on Wind Energy – is a strategic precompetitive research cooperation co-financed by the Research Council of Norway, industry, and research partners. The centre is hosted and headed by SINTEF in close collaboration with NTNU, NGI, NINA and UiO as research partners.

The primary objective of NorthWind is to bring forward outstanding research and innovation to reduce the cost of wind power and facilitate its sustainable development. This will grow exports and create new jobs.

NorthWind is part of the FME-scheme: Norwegian Centres for Environment-friendly Energy Research (in Norwegian: Forskningssenter for miljøvennlig energi). These are time-limited research centres which conduct concentrated, focused and long-term research of high international quality to solve specific challenges in the field of renewable energy and the environment.

NorthWind started in June 2021 and is scheduled to continue for 8 years with a total budget of about 350 MNOK, of which 120 MNOK is from the Research Council of Norway. This report summarises the achievements of NorthWind for its first half year of operation.

VISION AND GOALS

FME NorthWind (Norwegian Research Centre on Wind Energy) brings forward outstanding research and innovation to reduce the cost of wind energy, facilitate its sustainable development, create jobs, and grow exports.

The Centre will provide outstanding research and prospects for at least 20 innovations that can be developed into new products and services for the international market. It will create new methodologies, numerical models, and software to design and operate the wind power plants of the future, generating profit and respecting nature.

Case studies will be carried out in close cooperation with industry partners pinpointing tangible design and operational solutions.

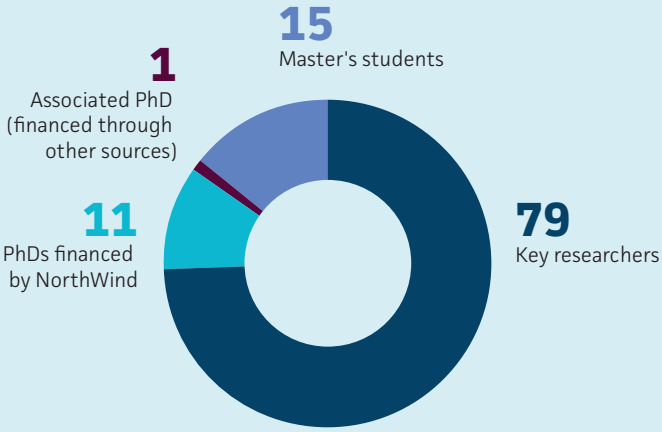
NORTHWIND BY NUMBERS

52 partners

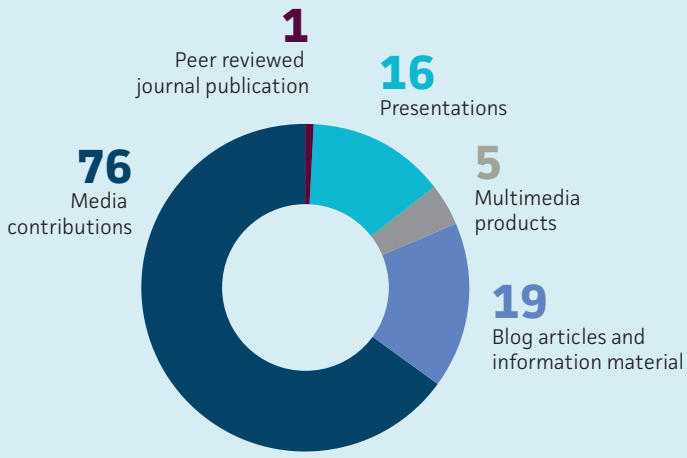
8 years

350 MNOK

People*



Communication and dissemination*



* Data shown in graphs is from NorthWind's first half-year of activity, June-December 2021.

MESSAGE FROM THE CENTRE DIRECTOR

John Olav Giæver Tande is the director of the North-Wind research centre, and a pioneer in floating offshore wind energy. He is Chief Scientist and Research Manager at SINTEF Energy Research (Norway). From 2009 to 2017, he was the Director of NOWITECH (Norwegian Research Centre for Offshore Wind Technology). Both NorthWind and NOWITECH have been funded by the Research Council of Norway (RCN) and national/international industry. In 2019, John Olav Giæver Tande received the Mission Innovation Champion Award at the fourth Mission Innovation ministerial meeting in Vancouver, Canada.

Photo: Hans Christian Bolstad

Wind energy is vital to reach climate targets, to secure an affordable energy supply and to enhance a competitive industry. To meet climate targets, there is a need for more renewable CO_2-free generation, energy efficiency measures and CCS. We need it all, and we need it fast. We are in the middle of an energy revolution. Offshore wind will be a big part of this. It is an energy source that is abundantly available and can be installed and operated while respecting nature. At NorthWind, we carry out R&I to make this a reality.

It is exciting to work at NorthWind. It was started less than a year ago in June 2021, but we have already achieved a good momentum and are starting to deliver:

- The first 12 PhD students are already hired.
- NorthWind web getting attention with about 3000 monthly views.
- A first spin-off project is established: This is the new Green Platform Ocean Grids project (2022-2024) that will be carried out in alignment with NorthWind and excellently strengthen the research on offshore grids for connecting offshore wind farms.
- A series of webinars has been arranged with strong line-up of speakers and excellent participation of industry and research.
- There is dialogue with start-up companies to explore further development of innovations.
- Industry is active and engaged in the work programme and in user case studies.

It has been challenging to start the work during the pandemic, but Covid has not affected progress. We have arranged meetings and events online. This has functioned very well, and NorthWind's five Work Packages (WP) have already produced tangible results, which you can read about in detail in this report.

The work is carried out with engagement from both the research and industry partners of NorthWind. We will do our outmost to deliver results with high positive impact. We aim for research and innovation to reduce the cost of wind energy, to create jobs and grow exports, and we will support sustainable development with respect for nature and people. Our mission is to accelerate the green transition.

Above: NorthWind director John Olav Tande receives FME plaque from Research Council of Norway special advisor Tone Ibenholt.

MESSAGE FROM THE CHAIR

Elling Rishoff holds an M.Sc. in Naval Architecture and Ocean Engineering from NTNU (1987). He has over 30 years' experience with technology leadership in the marine and technical software fields with a strong know-how in digital transformations. His previous experience includes CEO of DNV Software and DNV Group CIO. He has engaged with the Offshore wind software industry since 2008. He currently holds the position of Senior Vice President Incubation Offshore Wind at DNV in Norway.

In the time since FME Northwind was initiated, we experienced a series of challenges to the stability and prosperity of our society and environment. This includes both production and supply of energy and the effect that using energy has on our environment and ourselves.

More than ever, we need to lessen our reliance on fossil fuels and replace them with renewable sources of clean energy. The message from the recent UN Report on Global Climate is that these challenges must be addressed now. This makes wind power more important than ever, and greatly raises the expectations and potential for NorthWind to make a difference.

The Norwegian energy supply is already well founded on established hydro power, but all forecasts predict significantly increased need for additional power in the decades ahead. In Norway, this is needed both for internal (industrial and domestic) use, and as a safe and reliable supply of additional power to our neighbours and European partners.

Our wide expertise, long experience and deep knowledge in design, development and operation of offshore structures and installations give us a unique position to take a pole position in the transformation of the North Sea into a powerhouse for clean energy that contributes to Europe's energy balance. If successfully exploited, this will generate both effective supply chain for developing and producing clean energy, a profitable Norwegian export industry and new jobs.

As electricity process soar, renewable energy sources continue to become more competitive, but the combined challenge of raising trust and decreasing cost remains. Therefore, focus must be on creating a scalable industry – with focus on industrialisation, and enabled by standardisation. This requires digital processes with focus on minimal risk and maximal reliability – including infrastructure security against hostile actions.

Both design, engineering, manufacturing and installation must be enhanced by simulation and hybrid testing, and operation must be connected with active sensors and digital twins to create **a learning engine**.

To ensure that Norway has sufficient expertise and capability to develop its renewable future, we need to educate the next generation of engineers and managers to master the green shift. This includes active research and experimentation, and focus on education through Master programs, PhD studies and Postdoc opportunities. It is equally important that we push forward with the legislation and permission to develop our wind resource sites, installations and infrastructure through on-site experimentation (Metcenter) and the first (of many, many) commercial sites (Hywind Tampen).

If we are to master and manage a *greener future*, it will require a holistic approach – and decisive action that will shorten the time to clean energy. The central question we must address at Northwind is how we build the knowledge to exploit the possibilities and master the challenges that lie ahead of us as we build a renewable future.

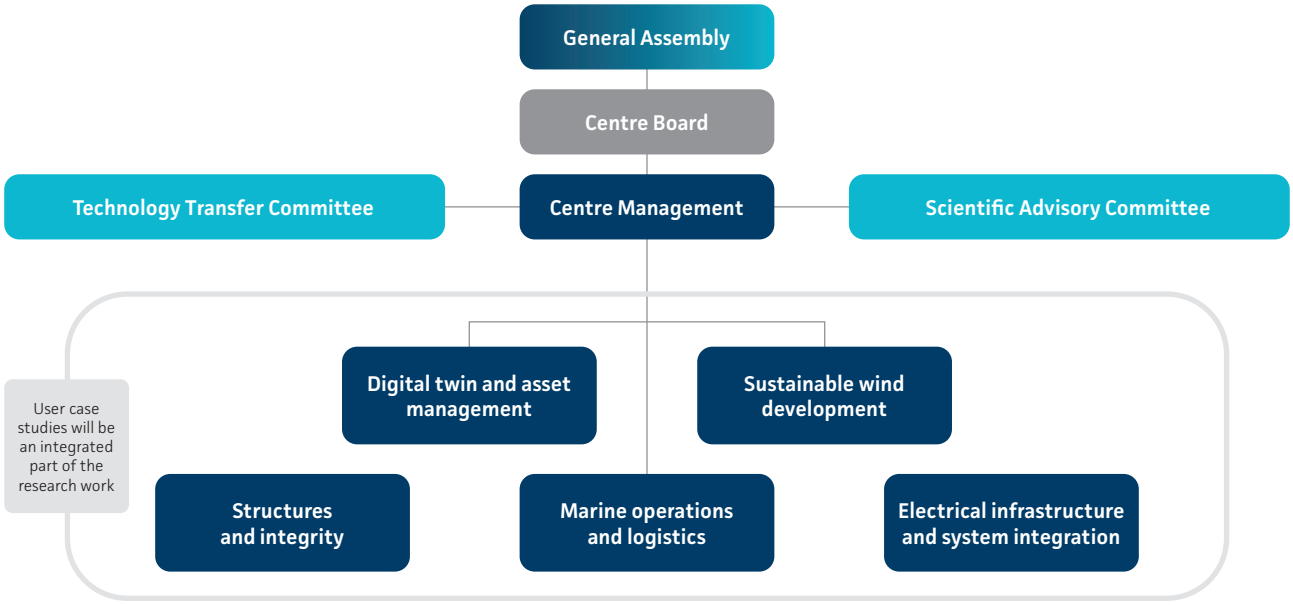
ORGANISATION

NorthWind is composed of a strong team of research and industry partners with complementary expertise and roles. The Centre is organised with a General Assembly of all partners, a Board with industry in majority and a Centre Management Group (CMG) for daily operation.

The CMG consists of a centre director, communication manager, and the heads of the WPs, SAC and TTC. The Scientific Advisory Committee (SAC) is leading the PhD programme and liaison with associated research partners, and gives advice on the scientific content and progress of the Centre. The Technology Transfer Committee (TTC) has a specific responsibility to bring results towards commercial use, including linking with SINTEF TTO, NTNU TTO, industry partners' business development and corporate venture units (Equinor Technology Invest, ABB Technology Ventures, DNV GL Ventures, etc.), industry clusters (Offshore Wind Cluster, RENERGY etc.), Innovation Norway and Enova.

Board

- Elling Rishoff (Chairperson), DNV
- Geir Olav Berg, Aker Offshore wind
- Jan-Kristian Haukeland, DOF
- Ole J. Nordahl, Equinor
- Håkon Hallem, Force Technology
- Torunn Lund Clasen, Nexans
- Björn Mo Östgren, Statkraft
- Anne Brisset, Total Norge
- Norunn Myklebust, NINA
- Johan Einar Hustad, NTNU
- Petter Støa, SINTEF



Scientific Advisory Committee

The Scientific Advisory Committee leads the PhD programme, liaises with the associated research partners, and gives advice on the scientific content and progress of the Centre.

It is led by NTNU (Prof. Trond Kvamsdal) and is composed of members from the research partner organisations (NTNU, SINTEF, UiO, NINA and NGI) and associated partner organisations (DTU, EUI, Fraunhofer, NCEPU, NREL, TNO and University of Strathclyde Glasgow). The Committee will have a full meeting with the international partners in the spring of 2022.

Technology Transfer Committee

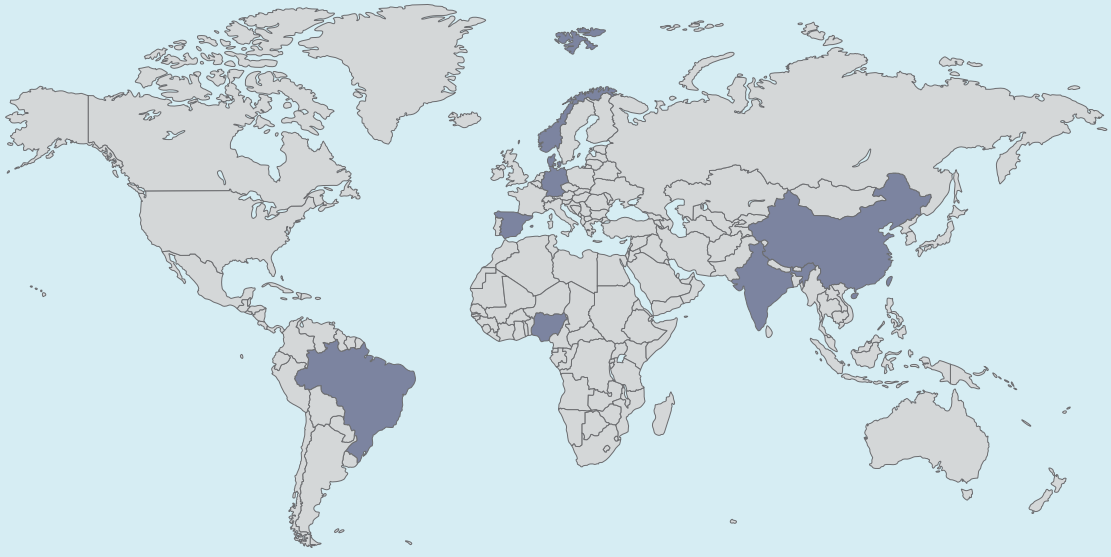
The Technology Transfer Committee (TTC) has a specific responsibility to bring results towards commercial use, including linking with SINTEF TTO, NTNU TTO, industry partners' business development and corporate venture units (to be appointed by industry members), industry clusters (Offshore Wind Cluster, Wind Cluster Norway, NORWEA, NORWEP, RENERGY), Innovation Norway and Enova. The committee held one meeting in 2021 and plans to reconvene four times in 2022.

Collaboration with start-ups

NorthWind was approached by two start-ups. The centre gave advice and facilitated meetings between NorthWind partners and start-ups.

1. A new cost-effective technology for replacement of wind turbine blades for floating offshore wind. New design for floating offshore foundation.
2. Development of a new wind turbine foundation and an installation tool for floating wind farms.

Scientific Advisory Committee members
International Associated Partners



NorthWind is facilitating the process for further development of the technologies together with new funding. Both technologies can create new projects – IPNs, JIPs, etc.

Webinar series

The Technology Tranfer Committee launched a successful webinar series in September, in collaboration with Windcluster Norway and Norwegian Offshore Wind Cluster. One workshop was also held in collaboration with FME NTRANS. The various events attracted a total of 364 registered participants.

- Control and operation of wind farms, 17.09.2021, with presentations from TrønderEnergi and SINTEF Energy
- Environmental design and operations, 29.10.2021, with presentations from NINA, NTNU, SINTEF Ocean and SINTEF Energy
- Regulation and framework in development and operation of offshore wind, 17.11.2021, with presentations from UiO, NORWEA and Aker Offshore Wind
- EU wind R&I strategy and calls, 29.11.2021, with presentations from ETIPwind, EERA JP Wind, the Research Council of Norway and SINTEF
- Workshop: The Norwegian wind power controversy, 07.12.2021, with presentations and discussions between research scientists, industry experts, members of the community and other stakeholders.

High level partnerships

The research partners (SINTEF, NTNU, UiO, NGI and NINA) are at the international forefront of wind energy research, with complementary expertise and a strong track record as partners/hosts of FMEs and other major research activities. Together, the participating companies cover the full supply chain from planning to deployment.

FME Northwind brings together about **50 partners from research and industry** all around the world. The participation of outstanding international universities and institutes (DTU, TNO, Fraunhofer, University of Strathclyde, NREL and NCEPU) as associate research partners strengthens the centre. They will advise on research and collaborate to ensure the quality of research is at the highest international level.

Research partners

SINTEF
Centre lead

NTNU

NGI

UNIVERSITY OF OSLO

NINA
Norwegian Institute for Nature Research

Industry partners

ABB

AKER OFFSHORE WIND

AMON WIND

aibel

Baker Hughes

COGNITE

DNV

DR. TECHN. OLAV OLSEN ARTELIA GROUP

DCF

EDR MEDESO

EIDEL
EIDSVOLL ELECTRONICS AS

NOR

Norsk olje&gass

Energi Norge

ENERGY INNOVATION

equinor

ESVAGT

Finnmark Kraft

FORCE TECHNOLOGY

Fred. Olsen Seawind

FUGRO

GFMS

Hafslund Eco

HAV design

Huisman

Associates


DTU


EUI
FLORENCE
SCHOOL OF
REGULATION


Fraunhofer


NREL


TNO


University of
Strathclyde
Glasgow


impello


KONGSBERG


Lloyd's
Register

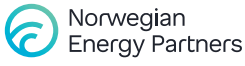

4subsea


TotalEnergies


exans


NKT


NOV


Norwegian
Energy Partners


Norconsult


NorSea


OFFSHOREWIND
Norwegian Offshore Wind Cluster


Odfjell
Oceanwind


RENERGY
Renewable Energy Cluster


Linja


Statkraft


STORE
NORSKE


SUSTAINABLE
ENERGY
NORWEGIAN
CATAPULT
CENTRE


Sval


TrønderEnergi


VARD
a Fincantieri company

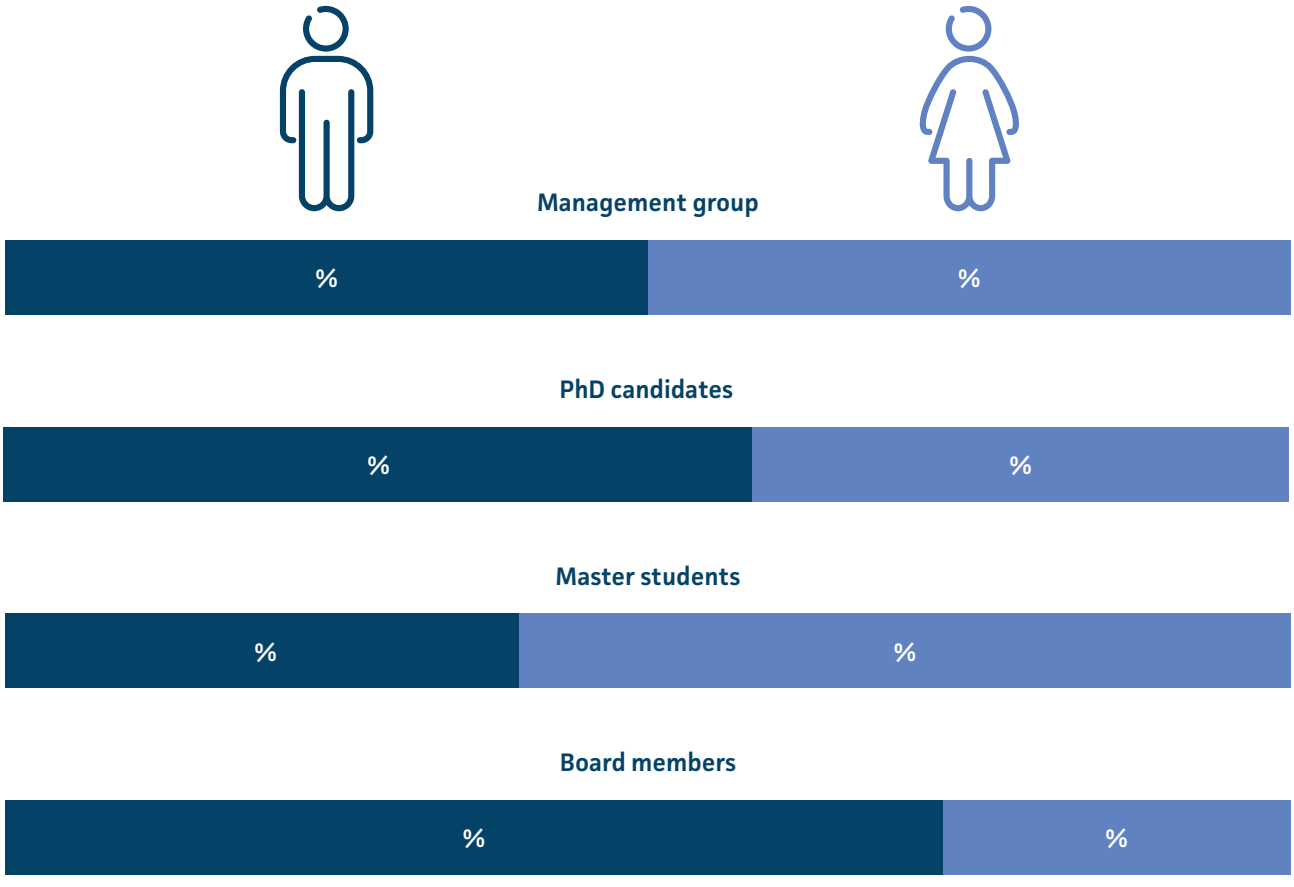

windcluster
NORWAY


Huisman

GENDER EQUALITY

NorthWind's management group has good gender balance (50/50). Women were encouraged to apply to our PhD programme, and 5 out of 12 of the selected PhD candidates are women. The centre will continue trying to improve gender balance in the PhD programme in the future. The master's programme has a higher proportion of women. It currently has 15 students, of which 9 are women.

The gender balance on the board is skewed: 3 members out of 11 are women. This will be discussed by the Board, with a view to improve the balance.



OUR CONTRIBUTION TO A MORE SUSTAINABLE WORLD

NorthWind's research in cheaper, more sustainable wind energy contributes to reaching many of the UN's Sustainable Development Goals. Here are three of them that we consider as the most relevant and where we hope to achieve significant impact through our research.

Working to enable the massive deployment and integration of wind energy into the energy system at a competitive cost addresses goal 7: *Ensure access to affordable, reliable, sustainable and modern energy for all.*

The anticipated increase in the market share of cost-competitive on- and offshore wind energy by 2030 is one of the most important drivers for reaching emissions reduction targets, and targets goal 13: *Take urgent action to combat climate change and its impacts.*

Work on sustainable solutions for offshore wind energy development targets goal 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development.*

COVID-19

NorthWind started its activities in the midst of the pandemic. The announcement by Minister of Petroleum and Energy, Tina Bru, that the centre was awarded funding, was done via videoconference in December 2020, to a small outdoors audience assembled in Trondheim.

No large physical events have been organised since the centre started its activities. The kick-off in June was held online, as well as NorthWind's Annual Innovation Forum, in December. Both the 2021 and the 2022 editions of the EERA DeepWind conference were held online.

Most meetings of the Centre Management Group and of the work package leaders were also held online, but we were luckily able to organise a few physical ones. These were particularly appreciated since getting to know each other is important in the start-up phase.

Online meetings and webinars have been well-attended, and helped us reduce associated costs and well as greenhouse gas emissions.

Otherwise, the pandemic has had no significant effects on Centre activities. All work packages are progressing according to plan.

Since 2004, EERA DeepWind has gathered annually the foremost experts on offshore wind from around the world. NorthWind took an active role in organising the conference this year. The event normally takes place in Trondheim but has been held online these past two years, because of the Covid-19 pandemic.

SINTEF NTNU EERA European Energy Research Alliance

These are exciting times for offshore wind, and this was reflected in the number and quality of the presentations we saw at the 2022 edition of the EERA DeepWind conference.* The conference was held 19-21 January, co-hosted by SINTEF, NTNU and the European Energy Research Alliance's (EERA) joint programme on wind energy.

The development of offshore wind farms is vital to reach climate goals and can be done with respect for nature and other users of the sea. It will provide clean energy, green jobs and prosperity. But research and innovation are a key to success, and we are excited to have established the NorthWind research centre to address key challenges.

In her opening speech at the DeepWind conference, Norway's Minister of Petroleum and Energy, Marte Mjøs Persen stated that "offshore wind is high on the Government's agenda". She stressed the importance of research and innovation in solving technical challenges, reducing costs and minimising environmental impacts.

Peter Eecen, coordinator of EERA Joint Programme Wind Energy, called in his keynote address for the creation of two large EU lighthouse projects: 1- Large scale offshore wind integration, and 2- Floating wind. The objective of these projects would be to address grand scientific and technical challenges crucial for the advancement of offshore wind, in line with the EU's stated target of 300 GW of installed offshore wind capacity by 2050.

The programme included presentations by top specialists in the field, addressing the following topics:

- New turbine and generator technology
- Grid connection and system integration
- Met-ocean conditions
- Operation & maintenance
- Installation and sub-structures
- Wind farm control
- Wind farm optimisation
- Experimental testing and validation
- Sustainable development

In total, around 150 presentations were given at the conference. **These are all available online for registered conference participants throughout 2022** with recorded video and presentations in pdf format.

The papers submitted for the conference are now in peer-review for publication in the Journal of Physics: Conference series. These are expected to be online with open access by the fall of 2022.

The EERA DeepWind conference concluded with the poster award ceremony:

* Most of the work for the planning and arrangement of the conference took place in 2021. We have therefore included it in the report for 2021, although the conference itself took place in January 2022.

The conference also presented a top roster of keynote speakers:

Marte Mjøs Persen
Minister of Petroleum and Energy, Norway

Adrian Timbus
Vice President Portfolio and Strategic Marketing at ABB

Lena Kitzing
Associate Professor and Head of Section of Society, Markets and Policy at DTU Wind Energy

Peter Eecen
Coordinator, EERA JP Wind and R&D manager at TNO

Geir Olav Berg
CTO and SVP engineering at Aker Offshore Wind

Amy Robertson
Offshore Wind Group manager at the NREL

Young-Ho LEE
Professor at the Korea Maritime & Ocean University

Jon Dugstad
Director Wind and Solar, Norwegian Energy Partners

Hanne Wigum
Manager of Offshore Wind Technology at Equinor

Matthijs Soede
Dr. ir. Senior Policy Officer at the European Commission

Yongqian LIU
Professor, Renewable Energy School, North China Electric Power University

Arvid Nesse
Head of the Marine Energy Test Centre (Metcentre)

Trond Kvamsdal
Professor at the Department of Mathematical Sciences, NTNU

John Olav Tande
Chief Scientist at SINTEF and director of the NorthWind research centre

MARK YOUR CALENDARS:
The next EERA DeepWind conference will take place in Trondheim, 18-20 January 2023.

VALUE FOR INDUSTRY PARTNERS

- Excellent research with significant budget and duration, directed towards industry needs
- First-rate recruitment opportunities from strong master's, PhD, and post-doctoral programmes
- First access to detailed results for business development
- Access to an international network and strategic positioning in important European forums
- Knowledge and innovations reducing the cost of energy from offshore wind farms, and reducing the environmental and societal impacts
- Collaboration through user case studies proposed by the industry

User case studies

The purpose of the user case studies is for experts from across NorthWind's work packages to address specific challenges in collaboration with industry partners. We expect at least 20 such studies to be carried out as part of NorthWind. So far, nine user case studies have been proposed by the industry and work has started on two of them:

- Proof of concept for wind power in Longyearbyen and other off-grid settlements in arctic climate environments. Contributing to a zero-emission energy system in Longyearbyen. Relevant for off-grid locations.
- The user case “Offshore wind and Society” is a collaborative effort of FME NorthWind and FME NTRANS. It explores aspects such as acceptance, regional development, politics/policies, innovation and controversies associated with offshore wind. The user case aims to facilitate dialogue between different actors in the two centres and to build insights that both research and user partners can use in their work on offshore wind.

INTERNATIONAL COOPERATION

NorthWind's Scientific Advisory Committee has representatives from DTU (Denmark), TNO (Netherlands), Fraunhofer (Germany), Florence School of Regulation (Italy), NREL (United States) and NCEPU (China). These collaborators contribute at their own expense with advice and input to the Centre, particularly the PhD programme and other activities linked to the sharing of open results. We invited these partners to join the Scientific Advisory Committee because they are leaders in their field and because the Centre's research partners already have an extensive and productive collaboration with them. This includes cooperation associated with EU projects and network organisations, cooperation in the Norway-China programme and cooperation through the IEA in the wind power area.

Current EU projects where FME NorthWind research partners are involved include:

- MaRINET2: Leading access to marine research facilities (2018-2021)
- WATEREYE: O&M tools integrating structural health in offshore wind energy (2019-2022)
- FARMCONNERS: Paving the way for industrialisation of Wind Farm Control (2019-2022)
- TotalControl: Develop the next generation of wind power plant control tools (2018-2022)
- UPWARDS: Develop an integrated simulation framework for wind turbine and wind parks (2018-2022)
- DACOMAT: Damage Controlled composite materials (2018-2022)

Network activities through EERA JP Wind and ETIPWind reinforce European cooperation. FME NorthWind partners are active in these organisations. Particularly, SINTEF has a strategic position as leader of EERA's offshore wind program and as a member of ETIPWind's executive committee.

All of Norway's nine cooperation countries outside of the EU/EEA are relevant with regards to collaboration in the field of wind power. These countries are: Brazil, Canada, India, Japan, China, Russia*, South Africa, the Unites States and South Korea.

The Norway-China collaboration currently has one active project: CONWIND (2020-2022). There is a potential to start similar projects with the other countries in the list. Japan, the United States and South Korea have all announced big plans in floating offshore wind and stand out as relevant partner countries, both in terms of research and opportunities for industrial projects and exports.

Several of NorthWind's research partners are active participants in the IEA Wind Technology Collaboration Programme. This strengthens networking possibilities and helps ensure that NorthWind partners are up to date with the latest developments on the international research front.

* As of March 2022, all research cooperation with Russian authorities is suspended.

COLLABORATION WITH OTHER FMES

NorthWind collaborated with other FMEs in providing recommendations about the use of the North Sea as a springboard for the green transition (see also page 38-39). These recommendations were presented at Arendalsuka on 16 August, together with a report prepared by research centres LowEmission, FME NCCS, FME NTRANS and FME NorthWind.

The report highlights ways in which the North Sea can become a hub for new climate technologies and green jobs – in areas like CO_2 storage, the electrification of the oil and gas industry, the North Sea network, offshore wind, energy islands and hydrogen.

The report was then adapted for an international audience and presented at the COP26 UN Climate Change Conference on 9 November in Glasgow. Such collaboration with other research centres is useful, as it helps providing the big picture and achieving a greater impact.

NorthWind also co-organised an online workshop with FME NTRANS about the Norwegian windpower controversy (7 December). The two centres collaborate on the topic of wind energy, especially in matters concerning sustainable development of wind energy.

RESEARCH PLAN

The primary objective of FME NorthWind is to bring forward outstanding research and innovation to reduce the cost of wind power and facilitate its sustainable development, which will grow exports and create jobs.

The secondary objectives are to:

- De-risk critical aspects for concept selection and enable cost-effective design and fabrication of support structures through reduced uncertainty and application of novel methods (WP1).
- Develop methods and tools for efficient and safe marine operations and logistic planning for installation and maintenance of offshore wind farms (WP2).
- Develop reliable and cost-effective electric power components and system solutions to enable profitable large-scale deployment of offshore wind energy in the North Sea (WP3).
- Develop methodologies to elevate the capability level of digital twins from 0-2 to 3-5 (WP4).
- Develop tools and insights for sustainable development of wind energy to create a successful export industry, reduce cost and uncertainty, and resolve environmental and societal conflicts (WP5).

NORTHWIND RESEARCH RESULTS

WORK PACKAGE 1
STRUCTURES AND INTEGRITY

WP LEADERS
Vigdis Olden, SINTEF
vigdis.olden@sintef.no
+47 982 30 434

Ana Page, NGI
ana.page@ngi.no
+47 406 98 328

Objective

De-risk critical aspects for concept selection and enable cost-effective design and fabrication of support structures through reduced uncertainty and application of novel methods.

Main results from 2021

Establishing a sand database

- The foundation concept selection for wind turbines often relies on analyses based on limited soil condition information and some generic correlations. Enabling access to data about typical soil properties and improved correlations can facilitate the development of offshore wind projects and de-risk foundation concepts that are sensitive to soil conditions.

Laser welding of thick-walled steel plates

- For the accelerated deployment of large-scale offshore wind, we need cost-effective, sustainable, and mass-produced substructures. The ability to efficiently perform welding of thick steel plates resulting in a good quality weld with respect to full penetration and material properties is central. A full-penetration, defect-free weld has been achieved.

Identification and description of user cases

In close cooperation with the industry partners, three industrial user cases have been identified.

INNOVATION

Hybrid laser-arc welding (HLAW)

One of the most powerful laser welding stations in the Nordic Countries is part of the National research infrastructure for manufacturing, MANULAB, jointly owned by SINTEF and NTNU. In this station we have investigated the influence of several welding parameters in HLAW welding of a thick carbon steel plate, and a first successful weld has been achieved. It is worth mentioning that the Minister of Higher Education, Ola Borten Moe, visited MANULAB and the laser station on November 15.

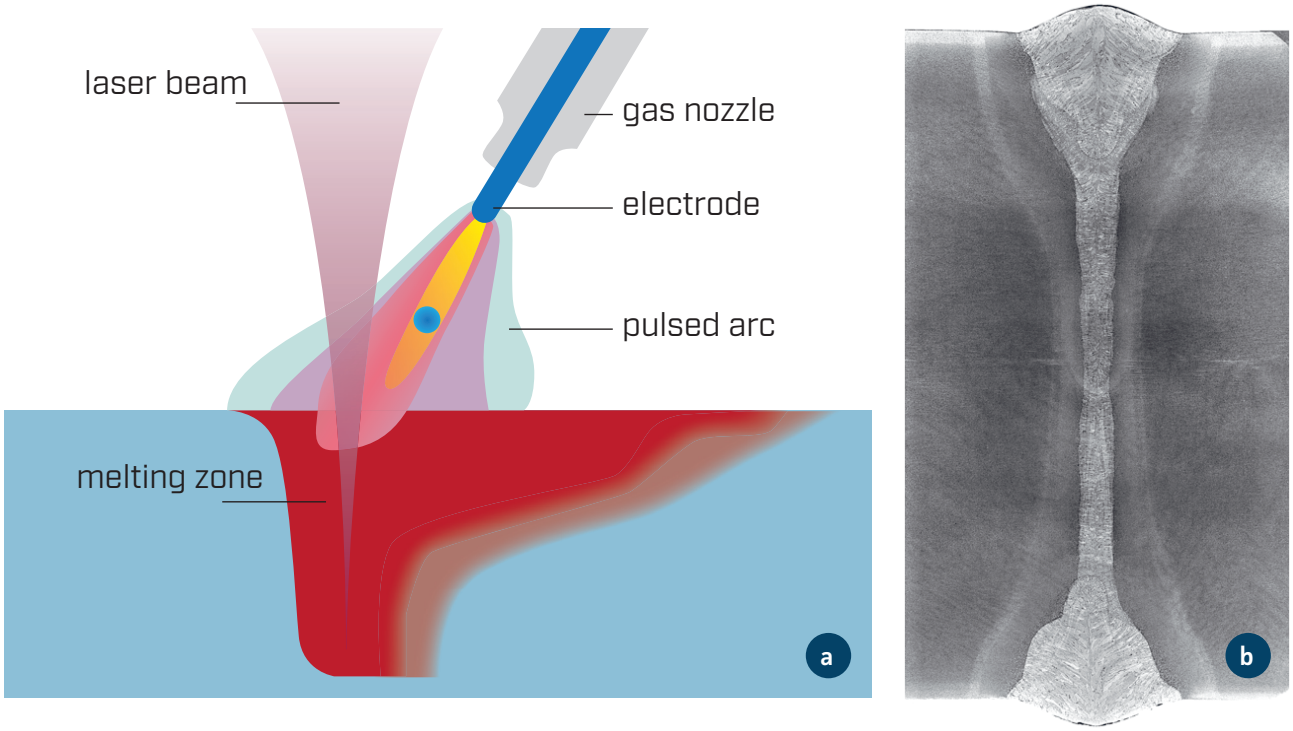
The principle of HLAW welding is a combination of laser beam and arc welding, as illustrated in the figure (a). The main advantages of the method are high productivity and cost-efficiency, suitable for serial production. More specifically, this includes a deep and narrow weld penetration, low heat input, minimal weldment distortion, a high welding speed, good gap-bridging ability with a potential of a high-quality weld. However, there are challenges including cracking and porosity, lack of fusion and process stability.

During this process, the effects of several weld parameters were investigated including welding speed, air gap, position of the arc, preheating and

type of filler wire. A full-penetration, defect-free weld has been achieved, see figure (b).

We have proven that the method may be applicable for the fabrication of substructures on a relevant material.

However, the research is still in an initial phase and hence at a low TRL (2-3[1]). Our aim is to develop the technology for higher technology readiness levels and finally to an industrial pilot.



Hybrid Laser Arc Welding a) The principle of the weld method b) A successful full penetration weld in a thick steel plate.

[1] TRL 3: Effective research and development initiated. Examples include studies and laboratory measurements to validate analytical predictions.

WORK PACKAGE 2
MARINE OPERATIONS AND LOGISTICS

WP LEADERS

Petter Andreas Berthelsen, SINTEF
petterandreas.berthelsen@sintef.no
+47 952 22 139

Henning Braaten, SINTEF
henning.braaten@sintef.no
+47 915 74 682

Zhen Gao, NTNU
zhen.gao@ntnu.no
+47 917 51 114

Objectives

Develop methods and tools for efficient and safe marine operations and logistic planning for installation and maintenance of offshore wind farms.

Main results from 2021

Installation and replacement operations

- PhD candidate working on "An approach for safe and cost-effective installation of offshore wind power cables"
- Ongoing review work on "Installation and replacement of offshore wind turbine blades". Report to be issued in 2022.

Service Operation Vessel (SOV) for offshore wind turbines

- Implemented a numerical model accounting for finite water depth in MULDIF.

Optimisation models for planning marine logistics operations

- Developed initial version of COSMO – A decision support tool for planning the maritime logistics of the installation of large offshore wind farms.

INNOVATION

COSMO – Computer tool for Optimisation and Simulation of Marine Operations

COSMO is a computer tool designed for analysis of marine operations in the installation phase of an offshore wind farm. It offers a digital representation of the logistical operations of an offshore wind farm, and is designed for early phase planning of offshore wind farm installation, built with a view to:

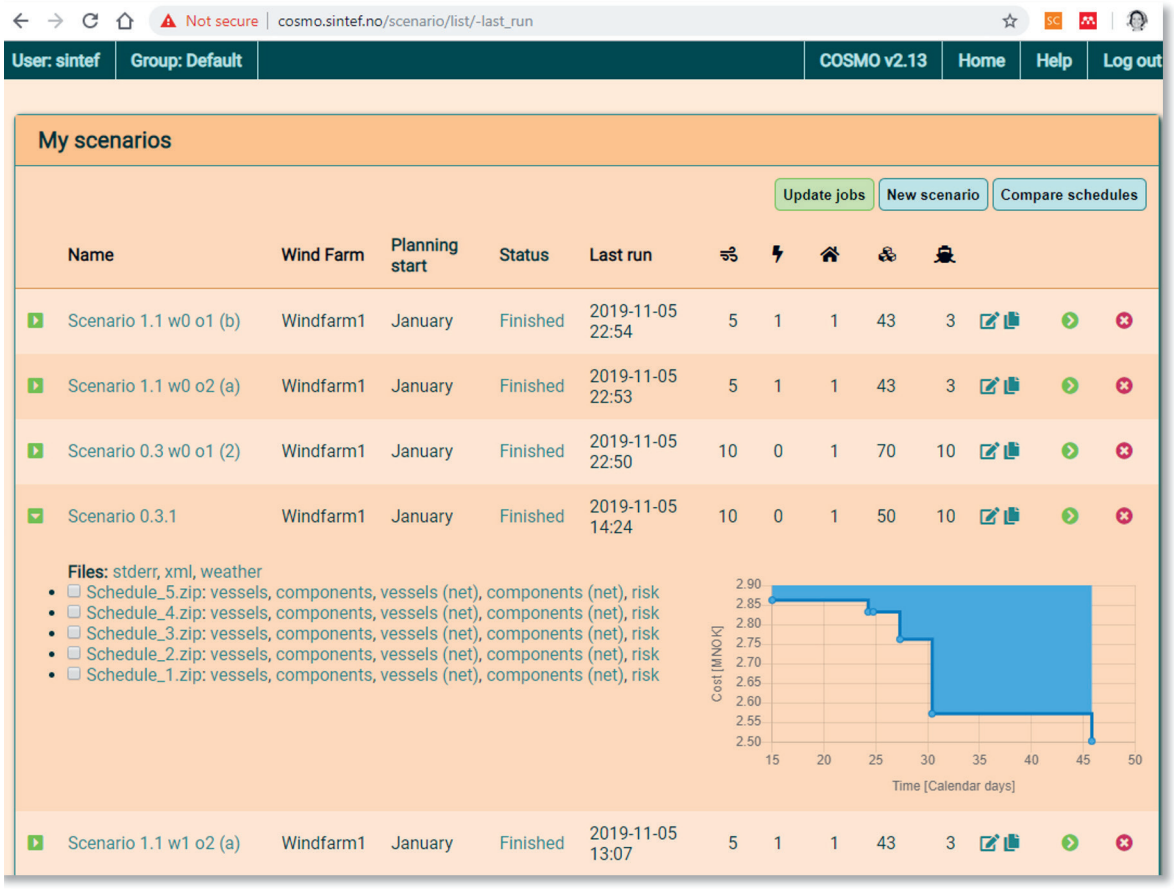
- Minimise the total time for the installation of an offshore wind farm
- Minimise the risk of delays, e.g. related to weather
- Minimise total cost of the installation of an offshore wind farm
- Evaluate and compare different concepts, both related to installation vessel concepts and concepts for installation, e.g. installation strategies

In addition to planning the operations, the tool can also be used by vessel and installation concept developers to evaluate the effects of new concepts at an early stage.

COSMO has an underlying optimisation algorithm that is a version of a Genetic Algorithm[2] where solutions found are evaluated by an agent-based

simulation model that takes into account the effects of weather and coordination between vessels, as well as installation tasks that are to be executed.

COSMO has been developed in earlier projects, its predecessor is a tool from the EU Leanwind project (2013-2017)[3], and COSMO itself has been developed in close cooperation with Equinor (2016-2019). It is currently at TRL4[4] , and the plan for further development within NorthWind is to establish a model at TRL5[5] . To reach this level, there is a need for some improved model development and testing from project participants. Aker Offshore Wind is one of the partners that will test the tool in 2022.



COSMO scenario overview with Pareto front showing the schedules found with lowest installation time and lowest installation cost.

[2] Mirjalili S. (2019) Genetic Algorithm. In: Evolutionary Algorithms and Neural Networks. Studies in Computational Intelligence, vol 780. Springer, Cham. https://doi.org/10.1007/978-3-319-93025-1_4

[3] http://www.leanwind.eu/

[4] TRL stands for technology readiness level. In NorthWind we use the same scale as EU, where TRL 1 is the lowest level and TRL 9 is the highest where the technology is fully developed. TRL 4 is a maturity level where the technology has been validated in lab.

[5] TRL 5 is a maturity level where the technology has been validated in a relevant environment.

WORK PACKAGE 3
ELECTRICAL INFRASTRUCTURE & SYSTEM INTEGRATION

WP LEADERS
Eirill Bachmann Mehammer, SINTEF
eirill.mehammer@sintef.no
+47 405 51 236

Magnus Korpås, NTNU
Magnus.korpas@ntnu.no
+47 970 42 009

Objectives

Develop reliable and cost-effective electric power components and system solutions to enable profitable large-scale deployment of offshore wind energy in the North Sea.

Main results from 2021

Electrical Infrastructure

- PhD candidate working on "Power electronics architecture and control methods for a HVDC generator for offshore wind".
- Abstract submitted on electro-thermal cable models, full paper to be submitted in 2022.
- Memo on models for degradation and lifetime assessment, paper to be submitted in 2022.
- PhD candidate working on "Novel Modular HVDC Generator for Offshore Wind" (associated with NorthWind but financed through other sources).

System integration

- PhD candidate working on "Energy storage for grid services in HVDC connected offshore wind farms".
- Memo on models to identify economically robust offshore grid configurations, paper to be submitted in 2022.
- Report on “Design and Operation of Energy Systems with Large Amounts of Variable Generation” (IEA Task 25).
- Newspaper chronicle on “Three prerequisites for Norwegian offshore wind success” (Dagens Næringsliv).

INNOVATION

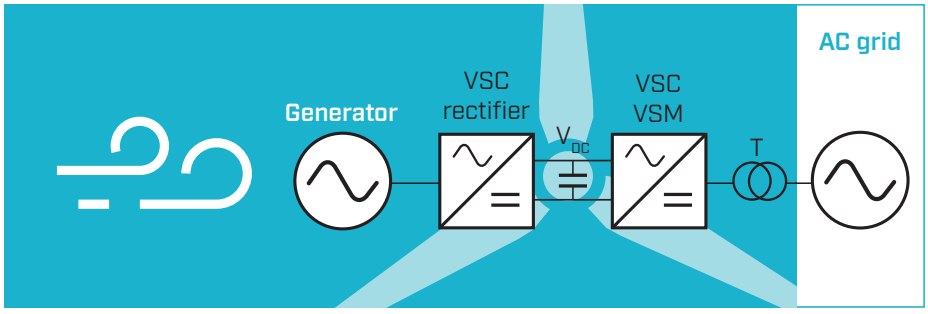
Advanced ancillary services from wind farms

Ancillary services are supporting services required by the power system operators to maintain correct functionality of the power system. Future power systems with higher share of renewables will be characterised by lower inertia and potentially weaker frequency regulation. Provision of ancillary services from large wind farms will therefore be even more crucial.

A virtual synchronous machine (VSM) is a common implementation scheme to provide grid forming capabilities and synthetic inertia. A VSM can be applicable in wind farms controlling the power according to the maximum power point tracking (MPPT) during normal conditions. However, as a reaction to disturbances, it can add virtual inertia by extracting energy from the wind turbine rotating inertia.

The power reference tracking in a VSM-based control is in general poorer compared to a classical grid following scheme. The VSM has a slow reaction speed to power production variations since power from the VSM is linked to the virtual rotor position and the virtual inertia acts like a low-pass filter.

Improving the power reference tracking is critical for a wind turbine to avoid needing to oversize the DC bus capacitor. A power feed-forward (PFF) strategy scheme for improving the tracking without affecting grid forming and inertia support has been developed in earlier projects[6]. It is currently at TRL 3[7], and the plan for further development within NorthWind is to increase the TRL to 4. To reach this level, the control scheme will be validated in the National Smartgrid Laboratory. The control scheme will also be modified to allow a more precise and faster correction.



[6] S. D'Arco and J. A. Suul, "Improving the Power Reference Tracking of Virtual Synchronous Machines by Feed-Forward Control,"*2021 IEEE 19th International Power Electronics and Motion Control Conference (PEMC)*, 2021, pp. 102-107, doi: 10.1109/PEMC48073.2021.9432548.

[7] TRL 3 is a maturity level where the concept has been proved experimentally.

WORK PACKAGE 4
DIGITAL TWIN AND ASSET MANAGEMENT

WP LEADERS
Adil Rasheed, NTNU
adil.rasheed@ntnu.no
+47 902 91 771

Kjetil Andre Johannessen, SINTEF
kjetil.johannessen@sintef.no
+47 913 45 314

Objectives

Develop methodologies to elevate the capability level of digital twin from 0-2 to 3-5.

Main results from 2021

Digital Twin adapted for wind energy

Conceptualising Digital Twins for Wind Energy:

- A technology watch on the topic of digital twins was conducted to establish the state-of-the-art in the technology. 15 industry partners provided detailed feedback which has been processed and sent back to them for their approval for circulation and publication.
- Work on a perspective article titled "A digital twin framework for wind energy" is ongoing.

Novel modelling paradigm:

- A conference paper titled "Machine-learning based non-intrusive parametric reduced-order model for flows around aerofoils and wind turbine blade" was submitted to DeepWind.
- Ongoing work on a conference paper titled "Hybrid analysis and modelling as a digital twin enabler for wind energy".

Farm flow modelling

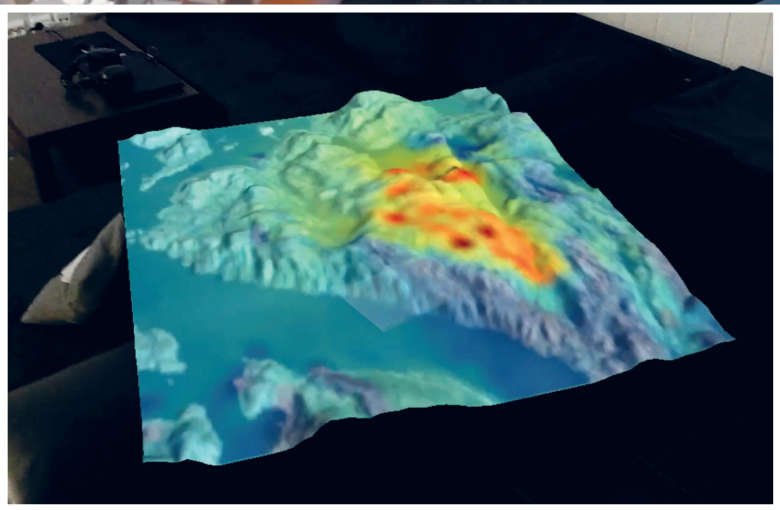
Multiscale wind modelling

- A multiscale wind prediction model has been set up for the Bessaker Wind Farm.
- Work on a paper titled "Reinforcement learning for stabilising IEA 15MW offshore wind turbine under varying wind conditions" is underway.
- Nord2000 noise models applied to Bessaker use case for idealised wind conditions
- Reduced Order Modelling of wakes using a hybrid approach.
- A journal article titled "A hybrid POD approach for the solution of transient turbulent flow problems" is ready for submission.

Asset Management

A novel Corrective Source Term Approach (CoSTA) was developed as a HAM tool for structural health monitoring

- First draft of a journal article titled "Physics Guided Neural Network-assisted Corrective Source Term Approach to Hybrid Analysis and Modelling" is ready for submission.
- Predictive maintenance and decision support for wind energy applications.
- A conference paper titled "A review of fault prognostic models for predictive maintenance of offshore wind turbines" was submitted to Deep Wind.



Holo Lens application for augmented reality inspection of wind farms

Holo Lens application for visualisation of noise pollution generated by wind farms

Informed public engagement

Development of tools for visualising datasets

- A first version of the Augmented Reality tool was demonstrated.

INNOVATION

Holo Lens digital twin application

Within NorthWind, we defined digital twin as a virtual representation of a physical asset and its applications, including real-time prediction, optimisation, monitoring, control, and improved decision making. Furthermore, we adapted the capability level scales presented in the DNV GL report to serve as a common understanding within the NorthWind consortium. The capability level will now be reported on a scale of 0-5 (0-standalone, 1-descriptive, 2-diagnostic, 3-predictive, 4-prescriptive, and 5-autonomous). As a starting point, a standalone and descriptive digital twin of the Bessaker Wind farm was developed in Augmented Reality using the Holo lens. A multiscale wind and noise prediction model along with the wind production and measurement data from the wind farm are fed into the digital twin. A user can then interact with the dataset using hand gestures. The visualisation sandbox is currently at TRL 3 and will be improved to TRL 4 to allow for interactions with online datasets and to improve intersystem interoperability. Moreover, we will improve on the visualisation control to allow for better user input interactions.

WORK PACKAGE 5
SUSTAINABLE WIND DEVELOPMENT

WP LEAD
Marianne Ryghaug (NTNU)
marianne.ryghaug@ntnu.no
+47 735 91 388

Sara Heidenreich (NTNU)
sara.heidenreich@ntnu.no
+47 735 91 779

Roel May (NINA)
roel.may@nina.no
+47 957 85 995

Objectives

Develop tools and insights for sustainable development of wind energy to create a successful export industry, reduce costs and uncertainty, and resolve environmental and societal conflicts.

Main results from 2021

The role of (Norwegian) wind in the sustainable energy transition

- PhD candidate working on "Circular business development of offshore wind energy".
- PhD candidate working on "Harnessing Norwegian maritime industrial capabilities in the emerging US offshore wind industry".

Environmental impacts and options for environmental design

- *Above-water impacts:* In 2021, work has been done on the design and preparations for applying for a permit from the Norwegian Food Safety Authority for year-round tracking of gulls (GPS precision, harness-mounted equipment).
- *Below-water impacts:* A literature search process for a review of reef effects for Scandinavia has commenced. NINA has established collaboration with IMR for taking eDNA samples at the Hywind Tampen area before construction starts; this will be followed up on in the coming years.
- *Onshore impacts:* The proposed AviSite LCA-mapping application has been presented at the Innovation Forum in 2021. The actual development will be done in 2022.
- *Integrated siting tool:* In 2021, the initial planning of the app design and system environment was done. A new cloud repository was established in NINA's Google Enterprise. The mapping of relevant map layers and configuration of workflows will be done in 2022.

Public engagement, participation and controversy

- PhD candidate working on "The framing of Norwegian wind energy futures – the cases of Svalbard and Sørlige Nordsjø II".
- Workshop with FME NTRANS on the Norwegian wind power controversy.

Publications

- Journal paper: Afewerke, S. & Karlsen, A. (2021). Policy mixes for just sustainable development in regions specialised in carbon-intensive industries: the case of two Norwegian petro-maritime regions. European Planning Studies 2021.
- Book chapter: Banet, C.: Energy planning legal requirements and offshore wind in Norway.

User cases

Sustainability Readiness levels (SRL): Literature regarding this approach and similar approaches and concepts has been collected for the development of a working framework. The aim of the framework is to identify which aspects of the other three WP5 tasks need to be included. We also take in consideration how other user cases could be relevant for the Northwind industry partners when incorporating SRL.

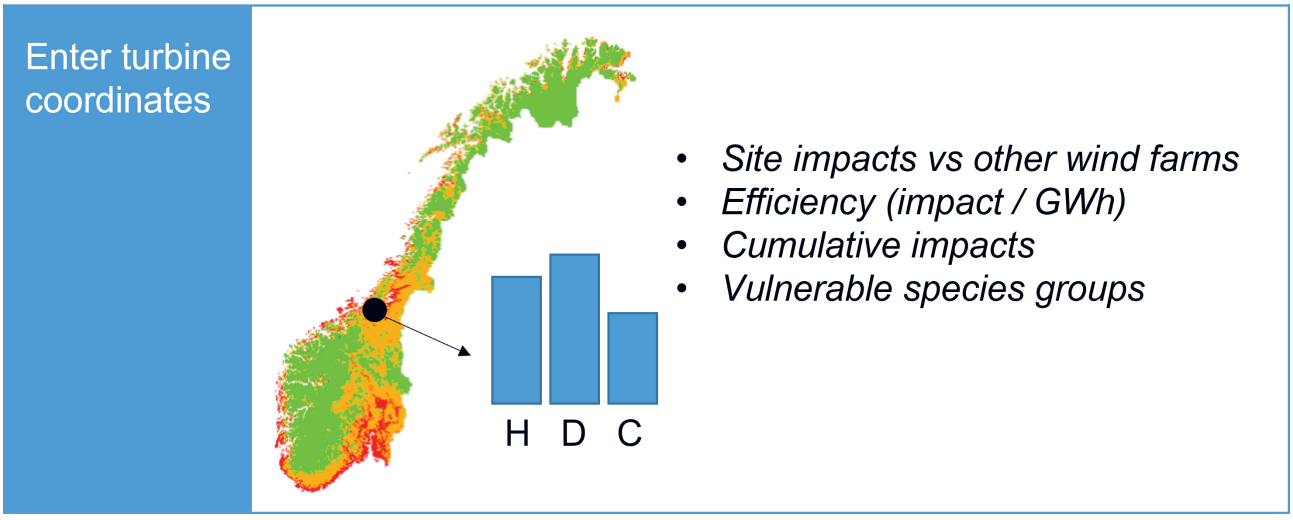
INNOVATION

AviSite – Online application for assessing life cycle impacts on avian diversity for siting of onshore wind farms

AviSite will be developed as an online application that allows users to perform life cycle impact assessment (LCIA) screening of bird impacts during the early planning phase. It will spatially visualise where impacts of avian diversity are expected to be highest and allow for locating sites with lowest conflict level per LCOE. The LCIA methodology has been developed, but the online application still needs to be constructed and validated. This is planned for 2022.

ConSite Wind – Consensus-based siting of onshore wind energy development

ConSite Wind is a Spatial Multi-Criteria Decision Analysis toolbox (S-MCDA) that is useful to build consensus, optimise spatial planning and improve transparent decision-making processes during the planning and licensing phase of wind energy projects. ConSite is designed to perform a combination of modern multi-criteria evaluation and decision analysis techniques for optimal siting of wind-power plants based on ecological, societal and technological criteria. The toolbox has been developed through several earlier and ongoing research projects, but will be made more accessible during 2022-24 as an online application in Google Earth Engine.



Example of online interface of the AviSite application.

Compilation of the interface of ConSite Wind.

SPIN-OFF PROJECT

Ocean Grid (2022-2024)

The Ocean Grid project (in Norwegian: Havnett) was awarded financial support of 82.7 million NOK through the Green Platform scheme. The project was established in part as a result of a collaboration with NorthWind, and is complementary to the research at NorthWind.

Ocean Grid will develop new technology, knowledge and solutions to enable a profitable development of offshore wind on the Norwegian continental shelf. It will look particularly at the way offshore wind will be connected to the grid. The work will touch on both bottom-fixed and floating wind farms, and will in the long term enable the creation of green jobs and increased export revenues.

The project partners will also bring their own financial contributions to the table, raising the total to 130.3 million NOK for the development of the offshore grid. Both the supply industry and energy companies will participate actively in the project, together with the research institutions. The project will span over three years.

– Our objective is to realise offshore wind on a large scale. We have to build wind farms in a cost-effective way, and we of course need to get the power all the way to the customers. It's crucial to our success that the energy companies, research institutions and suppliers collaborate towards this goal, says Florian Schuchert, VP of offshore wind solutions at Equinor (who leads the project).

The Ocean Grid project will also address the issue of market design and the regulatory framework linked to the development and operation of an offshore grid to connect large offshore wind farms. It will develop Norwegian technology and a supply industry to provide new cable designs, subsea technology and floating converter stations. Ocean Grid also has a research component, led by SINTEF, that will solve specific research challenges.

– This project will develop technology and solutions that are essential to succeed with offshore wind. It will lay the foundation for a profitable offshore wind development in Norway, and technology that can provide increased exports and new green jobs, says Chief Scientist at SINTEF and director of FME NorthWind, John Olav Tande.

Europe has a plan of installing 300 GW of offshore wind capacity by 2050. The Norwegian industry is world leading when it comes to sea and subsea technology, developed over five decades of oil and gas extraction. Norway is therefore in a unique position to build upon this expertise and take a significant portion of this new market.

– This project is important and on point to develop the right solutions and new technologies that will enable profitable offshore wind in Norway. This will lay the groundwork for new concepts, new jobs and a new supplier industry that can compete internationally, says the responsible for offshore wind at Fred. Olsen Seawind, Lars Bender, who will also act as chairman of the project's board.

Ocean Grid is composed of the following partners:

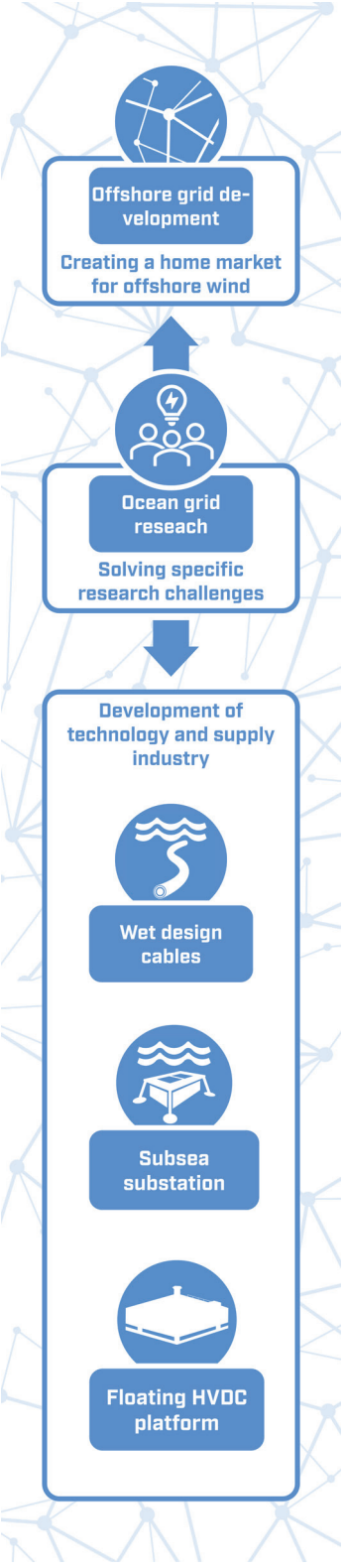
Energy companies and developers
- Equinor
- Fred Olsen Seawind
- Statnett
- Agder Energi
- Hafslund Eco
- Aker Offshore Wind
- Deep Wind Offshore
- DNV

Suppliers and manufacturers
- Aibel
- Nexans
- Hitachi Energy
- AkerSolutions
- ABB
- Benestad

Research and innovation
- SINTEF
- NTNU
- UiO

About the Green Platform scheme

The government wishes through Green Platform to enable rapid investments in green and sustainable solutions and products. Green Platform was launched as part of the government's third stimulus package in response to Covid-19 pandemic, in May 2020.



THE NORTH SEA AS A SPRINGBOARD FOR THE GREEN TRANSITION

COP26

NorthWind centre director and SINTEF Chief Scientist John Olav Tande was in Glasgow for the UN Climate Summit COP26. He spoke at the event The North Sea as a springboard for the green transition, which gathered leading scientists from four major environmental research centres, as well as representatives from the industry and politicians.

Tande spoke about the potential for offshore wind to become a major contributor to the EU's energy needs. He added that research is needed to reduce the costs of offshore wind farms, and to find ways to develop an offshore transmission grid to transport the electricity to the consumers.

Solutions are also needed to ensure a reliable and safe supply to the consumers even when the wind is not blowing. For this, the combination with hydrogen offers an excellent opportunity.

– The combination with other renewable generation on land and offshore, energy efficiency measures, load flexibility and alternative energy storage technologies, make this not only a vision, but a system that can realistically be developed to reach the goal of a net-zero power system (for Europe) by 2050, says Tande.

Tande also spoke of the important research being carried out to reduce the impacts of offshore wind on marine life. He pointed out the natural advantage of floating offshore wind in that respect:

– Floating turbines can also be installed at deep sea locations – which is what most of the sea is – which makes it easier to place them away from sensitive sea species or migrating birds.

Lighthouse initiatives

In his speech, John Olav Tande also presented a concrete suggestion to EU authorities about the future of offshore wind research. The idea was elaborated through the EU SETWind project together with European colleagues at EERA JP Wind and ETIPWind. It calls for the creation of two lighthouse initiatives. These would be two major European projects covering the R&I that needs to be addressed to make floating wind cost-competitive and to make offshore wind the backbone of the energy system.

What is a lighthouse initiative?

The term "lighthouse initiative" refers to a visionary, science-driven large-scale initiative with significant budget (tens of millions of Euros) and duration that will address grand scientific and technical challenges that are crucial for the further advancement of offshore wind energy, providing new knowledge and basis for innovation. It can be realised as a collection of research projects that are set up according to a roadmap to achieve a certain goal, or it can be a large programme-like project.

– To reach this vision, a strong increase in research and innovation is paramount, says Tande. The challenge is so big that we need international collaboration. We basically need all people on deck. We cannot afford any shortcuts. We must develop solutions that not only reach climate goals, but also respect nature. I would remind you all that this is not only a challenge that we must win; it is a great opportunity to create new green jobs, and put shortly, a better world for all of us.

Photo: SINTEF

NorthWind and its partner organisations were well-represented at COP26. Left to right: Nils Røkke, EVP Sustainability at SINTEF; Asgeir Tomasgard, Director of FME NTRANS and Professor at NTNU; John Olav Tande, Director of FME NorthWind and Chief scientist at SINTEF; Arno van Wingerde, Chief Scientist at the Fraunhofer Institute for Wind Energy Systems; Olimpo Anaya-Lara, Professor at the University of Strathclyde; and Edel Sheridan, Senior Business Developer at SINTEF.

Arendalsuka

The North Sea should play a central role in the green transition, according to a report to which FME NorthWind contributed. The document was presented at Arendalsuka, an important stage for societal debate in Norway.

The report was prepared by SINTEF and NTNU and highlights the potential of the North Sea for the decarbonisation of the economy. It underlines the importance of large-scale carbon capture and storage to reach emission reduction targets, and advocates a stronger focus on these technologies. The report also outlines how the North Sea can be home to offshore wind, zero-carbon fuels production and distribution and an international network of subsea cables – which can together pave the way for a zero-carbon economy in Norway and Europe.

– Renewable energy from offshore wind in the North Sea is a key element of Europe's decarbonisation strategy, says the leader of the NorthWind research centre, John Olav Tande.

Report authors explain that Norway has a knowledge lead which can be preserved through additional research and development. They also point out that any project in the North Sea should be carried out in an environmentally sustainable way.

Immediately following the presentation at Arendalsuka, a debate was held about the following topics:

- Ensuring sustainable development of the North Sea area
- Facilitating CO_2 storage equivalent to hundreds of Longship projects by 2050
- Maintaining the knowledge lead

The report was made by four research centres led by SINTEF and NTNU: NorthWind (SINTEF – wind energy technology), NCCS (SINTEF – carbon capture and storage), LowEmission (SINTEF – emissions reduction in the oil and gas industry) and NTRANS (NTNU – energy transition strategies).

EDUCATION AND RECRUITMENT

Research scientist training constitutes a significant part of NorthWind's activities. The centre's educational programme will fund 27 PhD grants, including 10 in-kind grants by NTNU and UiO. So far, 12 PhDs have already started.

In addition, there is an effort to have more bachelor and master students at NTNU and UiO specialising in wind energy (the target is for 200 MSc/BSc). This represents a unique recruitment base for our industry partners. Research scientist training will be provided by NTNU and UiO, in collaboration with the associate research partners.

The educational programme linked with the Centre will bring forward 27 PhDs or Post Docs, and 200 MSc and BSc candidates with wind energy as topic for their thesis.

Collaboration

An individual research plan will be developed for each PhD candidate based on the Centre's research needs. Collaboration groups between PhD students, supervisors, SINTEF researchers and relevant industry partners will maximise synergy and integration at task level. Research will address scientific and technical knowledge gaps to achieve the Centre's goals. PhD students and their supervisors will present their research at leading international conferences and annual NorthWind meetings and seminars.

International Academic Networks

The Centre will facilitate and fund PhDs to stay abroad with collaborating universities. Industry partners will provide short-term internship positions for innovation case studies. International exchange of research personnel with academic networks and internship arrangements with the Centre's industry partners will contribute to knowledge exchange between the academic communities and the industry.

Our PhD candidates

Julian Lahuerta

Affiliation: NTNU
Nationality: Norwegian
Supervisor: Prof. Asbjørn Karlsen (NTNU)
Period: 2021-2024
Thesis: Harnessing Norwegian maritime industrial capabilities in the emerging US offshore wind industry

My research project examines how Norwegian offshore wind firms adapt to the particularities of the U.S. federalist institutional system, whether Norwegian firm strategies and stakeholder engagement differs depending on the locality in question, and what the implications are for Norwegian regional development. This project will focus on two Norwegian led projects in the U.S., the Empire Wind project led by Equinor in New York State, which utilises fixed-bottom technology, and the more distant project led by Aker Solutions off the coast of California, which utilises floating technology. Both cases will employ a mixed-method qualitative framework that draws on primary data compiled from semi-structured interviews, policy documents and newspaper articles, in addition to secondary data compiled from document analysis and databases. Theoretically, this project contributes to recent discussions within economic geography and transition studies that highlight the variegated nature of national institutions and the importance of exogenous factors in regional industrial development.

Vibeke Hvidegaard Petersen

Affiliation: NTNU
Nationality: Danish
Supervisor: Prof. Magnus Stålhane (NTNU)
Period: 2022-2025
Thesis: Predictive maintenance of offshore wind turbines

This PhD candidate will start their work in 2022.

Florian Stadtmann

Affiliation: NTNU
Nationality: German
Supervisor: Prof. Adil Rasheed (NTNU), Prof. Trond Kvamsdal (NTNU), Prof. Omer San (OSU), Kjetil André Johannessen (SINTEF)
Period: 2021-2024
Thesis: Enabling Technologies for Digital Twins

A digital twin can be explained as a virtual representation of a physical asset, which describes the current – and in some cases the future – state and behaviour of the physical asset. During my project, I will review the current progress of digital twins in research and industry with focus on technologies required to enable digital twins in the context of wind power. Based on the outcome, I will continue my work in data compression, simulation, visualisation and/or autonomous control, combining domain knowledge and machine learning techniques in a hybrid analysis and modelling approach for increased speed, accuracy, reliability, and explainability of digital twins.

Veronica Liverud Krathe

Affiliation: NTNU
Nationality: Norwegian
Supervisor: Prof. Erin Bachynski-Polić (NTNU), Prof. Amir R. Nejad (NTNU), Jason Jonkman, PhD (NREL)
Period: 2021-2024
Thesis: Multiscale/-fidelity wind turbine dynamics models for structural design and control

In my thesis, I will investigate multiscale dynamic analysis of offshore wind turbines, with the overall objective of reducing downtime and cost, increasing the competitiveness of offshore wind. This means combining effects on farm level and single turbines and investigating the impacts of these on the drivetrain. Today's aero-hydro-servo-elastic analysis tools simplify the drivetrain model (requiring decoupled analysis), neglect hydroelastic responses of the hull, and account for wake effects through conservative wind field models. Especially, there are some effects for larger, more flexible substructures that can be important. I will start by looking into shortcomings in state-of-the-art methods with respect to multi-fidelity modelling, and possible improvements that can be implemented in current design tools. Subsequently, key objectives are to enable more optimal control, more efficient substructure design and more efficient park layout design.

Lorrana Faria da Rocha

Affiliation: NTNU
Nationality: Brazilian
Supervisor: Pål Keim Olsen (NTNU), Co-supervisors: Hendrik Vansompel (UGent), Elisabetta Tedeschi (NTNU), Erik Grøndahl (SGRE)
Period: 2021-2024
Thesis: Power electronics architecture and control methods for a HVDC generator for offshore wind

The objective of my PhD project is to investigate suitable topologies for the converter modules and overall architecture design, as well as developing control algorithms for all operation modes of a modular HVDC generator for offshore wind energy. The proposal of a HVDC modular generator is to remove the use of the offshore substation/platform, which constitutes the energy conditioning elements for the HVDC transmission, by the connection in series of modules of a segmented HVDC generator. This modular series connection of converters has promising characteristics, such as cost reduction, increased efficiency and weight reduction. However, it is a system that has not yet been implemented commercially and needs many studies and tests to validate a practical application. Thus, the main scope of my PhD study is to prove the feasibility of operating a modular HVDC generator for offshore wind energy focusing on the architecture and control of the electronic power converters.

Yannick Cyiza Karekezi

Affiliation: NTNU
Nationality: Norwegian
Supervisor: Pål Keim Olsen. Co-supervisors: Robert Nilssen (NTNU), Hendrik Vansompel (UGent), Erik Grøndahl (SGRE)
Period: 2021-2024
Thesis: Novel Modular HVDC Generator for Offshore Wind

In this PhD project, a compact and modular HVDC generator is seen as a feasible solution to higher energy efficiency and lower cost in offshore wind energy generation and distribution. By producing high DC voltage, above 100 kV, in the first conversion step, the subsequent conversion steps are eliminated. In addition, the modular structure of the HVDC generator has in-built fault tolerance capability, potentially increasing the availability of wind turbines. The drastic reduction in conversion steps due to the use of the HVDC generator may help the market to meet its goals for reducing the cost of energy from renewable energy sources. The concept may increase the benefits of HVDC power systems and make it feasible to replace parts of the HVAC system that is used today. The challenges with the technology are multidisciplinary and range from electromechanical to thermal and high voltage insulation design of the generator modules, choice of module converter topology and optimum control strategies, as well as a protection system able to clear internal DC faults within the machine. The focus of my PhD study is the design of an HVDC generator for offshore wind, primarily studying electromechanical and thermal design.

This PhD is associated with NorthWind but financed through other sources.

Arkaitz Rabanal Alcubilla

Affiliation: NTNU
Nationality: Spanish
Supervisor: Elisabetta Tedeschi (NTNU). Co-Supervisors: Salvatore D'Arco (Sintef Energy), Nicolaos Cutululis (DTU), Pål Keim Olsen (NTNU)
Period: 2021-2024
Thesis: Energy Storage for Grid Services in HVDC Connected Offshore Wind Farms

This PhD project will research different options to provide grid ancillary services for offshore wind power plants by means of integrating energy storage into the HVDC transmission system. The main aim is to embed and/or exploit energy storage into the different converters in the offshore wind power plants or offshore grid, in relation to the type of grid services required. Considering suitable storage technologies, aspects such as most convenient storage location, storage sizing and control implementation will be discussed. Finally, the feasibility of the proposed control solutions is expected to be validated in a laboratory environment at the National Smart Grid Lab of NTNU, reaching the Technology Readiness Level 4.

Pankaj Ravindra Gode

Affiliation: NTNU
Nationality: Indian
Supervisor: Prof. Arild Aspelund (NTNU), Ass. Prof. Øyvind Bjørgum (NTNU)
Period: 2021-2024
Thesis: Circular Business Development of Offshore Wind Energy

My research is focused on the integration of circular economy (CE) with the offshore wind energy industry (OWE). Throughout the period of my research, I will be looking at different circular business models, product design strategies and CE frameworks that are compatible with the OWE industry. The initial aim of this research is to contribute its share to the development of circular practices to decommission the near end-of-life offshore wind farms in an environmental-friendly way, using the best possible waste management strategies to minimise the generated waste. However, the key focus of this research is about developing circular business models, product design strategies and CE frameworks that will allow to better design future offshore wind farms and extend their designated lifespan.

Afolarinwa David Oyegbile

Nationality: Nigerian
Supervisor: Prof. Michael Muskulus (NTNU), Prof. Gudmund Eiksund (NTNU), Senior Researcher Anand Natarajan (DTU), Dr. Amy Robertson (NREL)
Period: 2021-2024
Thesis: Reliability- and data-based structural design under industrial constraints

In my project, I will look to learn from existing industrial experiences and develop a holistic framework for structural design optimisation of wind turbine support structures with the aim of achieving cost effective support structures. The design process involves uncertainties in the assumptions, models and results obtained. Considering such uncertainties generally requires the use of probabilistic mathematical models that severely complicate the design optimisation problem that needs to be solved. My research will consider relevant design drivers (e.g. fatigue loads and soil conditions) as well as practical issues such as installation complexity and fabrication constraints while leveraging on recent developments in gradient-based design optimisation methods to address these uncertainties.

Birgitte Nygaard

Affiliation: NTNU
Nationality: Danish
Supervisor: Prof. Tomas Moe Skjølsvold (NTNU), Ass. Prof. Robert Næss (NTNU)
Period: 2021-2024
Thesis: The framing of Norwegian Wind Energy futures – the cases of Svalbard and Sørlige Nordsjø II

In my project, I am to examine how wind energy is framed in Norway, which directions for development are envisioned, and which role(s) wind will play in Norwegian energy futures. I will focus on two cases – land-based wind power in Svalbard and the opening of the area Sørlige Nordsjø II for offshore wind power. The cases will be studied using a mix of qualitative methods such as interviews with various stakeholders, observations, debates in public media, and analysis of policy documents. As part of my research, I am to study territorialisation of wind power, justice aspects related to competing storylines and perceptions of burdens and benefits, as wells as how this shapes and is shaped by Norwegian identity as an energy nation.

Torfinn Ottesen

Affiliation: NTNU, SINTEF Ocean
Nationality: Norwegian
Supervisor: Prof. Svein Sævik (NTNU), Prof. Zhen Gao (NTNU), Senior Research Scientist Janne Gjøsteen (SINTEF Ocean)
Period: 2021-2025
Thesis: An approach for safe and cost-effective installation of offshore wind power cables

The power cable is an essential part of any wind turbine since the produced energy cannot be delivered without the power cable. To assure power cable functionality, the mechanical integrity of the power cable system must be assured in all phases – from cable manufacturing, through the offshore installation operation and during the operational life of the wind turbine plant. Strang-Moran (2020, Offshore Renewable Energy Catapult) has reviewed causes of cable failures in the UK offshore wind industry. She reports that nearly half (46%) of cable failures are caused by installation errors. The rest is due to manufacturing issues (31%), inadequate cable design (15%) and mechanical damage after installation (8%). In my project I will improve the simulation models for predicting cable load during installation. Also, safe limits for combined tension, torsion and bending loads are studied. This may help reduce the number of cable failures caused during installation.

Wanwan Zhang

Affiliation: NTNU
Nationality: Chinese
Supervisor: Prof. Jørn Vatn (NTNU), Prof. Adil Rasheed (NTNU)
Period: 2021-2024
Thesis: Predictive Maintenance and Decision Support for Asset Management

This project is aimed at the predictive maintenance of offshore wind turbines. Predictive maintenance is a regime for optimal and timely maintenance. It predicts exactly when the system will fail and when to maintain it before the failure actually happens. Remaining useful lifetime (RUL) predictions based on sensor measurements will be the basis for research. Statistical reliability data interfaced with predictions for weather windows, operation planning and logistic resources will give support for decision making in maintenance scheduling. My research will focus on developing the hybrid model integrating machine learning methods, mathematical models, and physical-based models to predict and optimize the maintenance of offshore wind turbines.

COMMUNICATIONS

NorthWind enjoyed significant media coverage in its first few months of activity as a result of the sustained media relations work of its communications team.

During the starting phase of the Centre's activity, much effort has been expended to establish a brand and a communications platform, namely the NorthWind website and the newsletter. The importance of these channels and the audiences they reach will grow as the centre evolves and produces even more results and innovations.

Against the backdrop of the pandemic, digital communication played a vital role for NorthWind since its very inception. Covid-19 restrictions mean that no major in-person events have been held so far, and we look forward to an improvement on that front in the coming year.

Why communications matter for NorthWind

The success of NorthWind relies in large part on efficiently communicating both its objectives and results to the industry, the research community, the government and its various agencies, and the general public.

By sharing new knowledge and information and contributing to an informed debate about wind energy, the Centre can help foster public acceptance, and ensure the political and industrial willingness necessary for the continued development of wind energy. Communication is therefore a core strategic activity of NorthWind.

Strategic communication efforts

Together with several FMEs and the LowEmission research centre, NorthWind took part in the important political events Arendalsuka in Norway and COP26 in Glasgow. NorthWind and its communications team supported the conception and development of a North Sea strategy document in both Norwegian and English.

During 2021, the Ministry of Petroleum and Energy sent out a consultation letter on its guide for land allocation, licensing process and applications for offshore wind power, and proposals for amendments to the Marine Energy Act and the Marine Energy Act regulations. NorthWind management supported LowEmission, NTNU and SINTEF in their formal response.

Website and newsletter

The **website** got off to a flying start with an impressive 15 712 pageviews between its launch in June of 2021 and December 31st of the same year. It is intended as a central hub for all external communication, and provides information about the Centre and its partners, and disseminates research results and progress. The website was also successfully used to promote the webinar series and enable interested parties to register for participation.

The news section of the website is intended as a content hub that will serve a dual purpose as a communications platform for the centre and a public engagement tool about wind energy. As such, it contains articles not only about Centre activities and results, but also about wind energy in general. Some of the articles are written by Centre staff and hosted

on the website itself, while others are found on other pages and linked to from the news section.

The **newsletter** already has nearly 300 subscribers. Anyone visiting the website can subscribe to it. In total, 8 newsletters were sent in 2021. So far, the newsletter was mostly used to promote upcoming events. It will be used to share results as well in the future, as they start coming in.

Webinar series

The communications team supported the Technology Transfer Committee in the organisation of its popular webinars, particularly with respect to promoting the events and facilitating registration. More webinars are planned for 2022.

Annual Innovation Forum

The first Annual Innovation Forum took place in December – online, because of Covid-19 restrictions. This annual event will be a golden opportunity for partners to learn about the year's innovations from the scientists who developed them, as well as an occasion for networking among consortium members.

EERA DeepWind conference

NorthWind is a major participant in the international offshore wind R&I conference EERA DeepWind (summarised in its own section of this report, on pages 17-19. The communications team will continue promoting the event, facilitating media coverage and maintaining the DeepWind website in close collaboration with the organising committee.

Social media

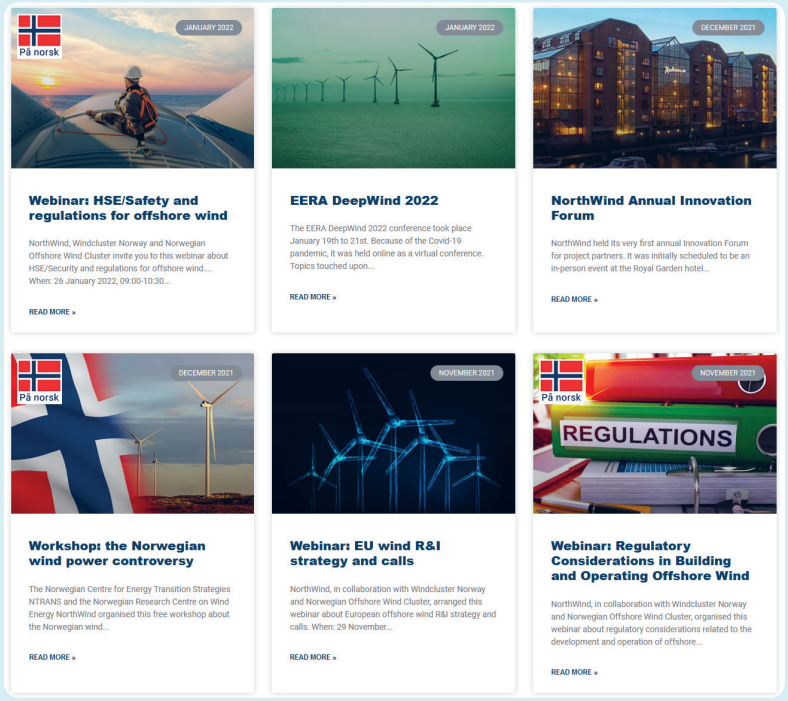
The NorthWind communications team maintains a LinkedIn page, that had 239 followers at the end of 2021. LinkedIn has proven an efficient social media channel for sharing scientific news and results, and we anticipate the number of followers to continue growing as the centre publishes more results. NorthWind also has a Twitter account – @NorthWind_FME. At the end of 2021, it had 79 followers.

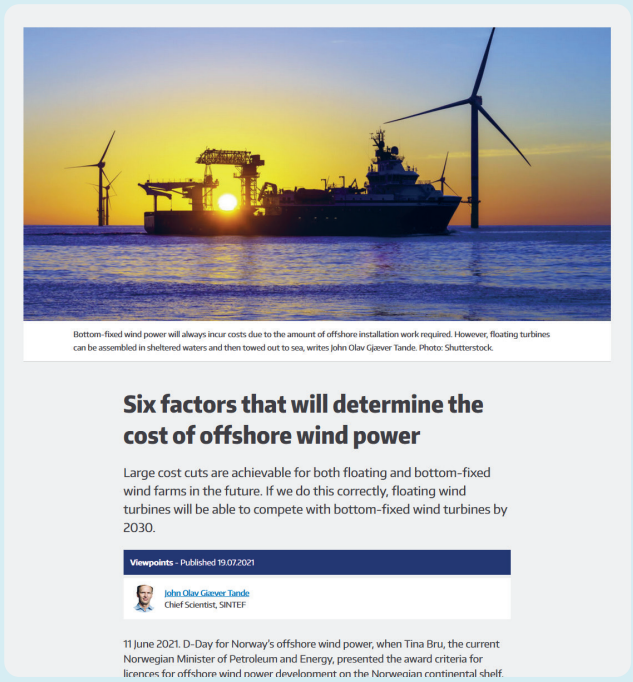
Project partners are encouraged to share NorthWind news, events and blog articles on their own social media channels to amplify their reach.

Looking forward

The communications focus this coming year will be to explain ongoing research through blog articles, to leverage the centre's first in-person events to ensure an even closer collaboration with partners, and to continue the brand-building efforts initiated in 2021.

The website was successfully used to promote the webinar series and enable interested parties to register for participation.





FINANCIAL STATEMENT

Costs (1000 NOK)	Amount
Host institution (SINTEF Energi)	2614
Research Partners	8917
User Partners	2497
Equipment	
Total	**14028**

Funding (1000 NOK)	Amount
Research Council of Norway	5513
Host institution (SINTEF Energi)	503
Researh Partners	3387
User Partners *	4625
Total	**14028**

* Excess User partner funding transferred to 2022

PERSONNEL

Key researchers

Name	Institution	Main Research area
John Olav Tande	SINTEF Energi	WP0
Hans Christian Bolstad	SINTEF Energi	WP0
Trond Kvamsdal	SINTEF Energi	WP0, WP4, WP5
Inger Marie Malvik	SINTEF Energi	WP0, WP5
Vigdis Olden	SINTEF Industri	WP0, WP1
Ana Page	NGI	WP0, WP1, WP2
Henning Braaten	SINTEF Ocean	WP0, WP2
Petter A. Berthelsen	SINTEF Ocean	WP0, WP1, WP2
Zhen Gao	NTNU	WP0, WP2
Eirill Bachmann Mehammer	SINTEF Energi	WP0, WP3
Magnus Korpås	NTNU	WP0, WP3, WP5
Adil Rasheed	SINTEF Digital	WP0, WP 4
Kjetil Johannessen	SINTEF Digital	WP0, WP4
Marianne Ryghaug	NTNU	WP0, WP5
Sara Heidenreich	NTNU	WP0, WP5
Roel May	NINA	WP0, WP5
Michael Muskulus	NTNU	WP1
Xiaobo Ren	SINTEF Industri	WP1
Erin Bachynski-Polic	NTNU	WP1
Ivan Bunaziv	SINTEF Industri	WP1
Magnus Eriksson	SINTEF Industri	WP1
Martin Gutsch	SINTEF Ocean	WP2
Lars Magne Nonås	SINTEF Ocean	WP2
Svein Sævik	SINTEF Ocean	WP2
Anne Bruyat	SINTEF Ocean	WP2
Halgeir Ludvigsen	SINTEF Ocean	WP2
Elin Espeland Halvorsen-Weare	SINTEF Ocean	WP2
Yauheni Kisialiou	SINTEF Ocean	W2
Pål Olsen	NTNU	WP3
Catherine Banet	UiO	WP3, WP5
Salvatore D'Arco	SINTEF Energi	WP3
Elisabetta Tedeschi	NTNU	WP3
Øystein Hestad	SINTEF Energi	WP3
Harald Svendsen	SINTEF Energi	WP3
Espen Eberg	SINTEF Energi	WP3
Bjørn Gustavsen	SINTEF Energi	WP3

Name	Institution	Main Research area
Atle Pedersen	SINTEF Energi	WP3
Dag Linhjell	SINTEF Energi	WP3
Antonio Alvaro	SINTEF Industri	WP3
Anette Brocks Hagen	SINTEF Industri	WP3
Jørn Vatn	NTNU	WP4
Balram Panjwani	SINTEF Industri	WP4
Valentin Chabaud	SINTEF Energi	WP4
Mandar Tabib	SINTEF Digital	WP4
Jon Vegard Venås	SINTEF Digital	WP4
Florian Stadtmann	NTNU	WP4
Wanwan Zhang	NTNU	WP4
Daniel Wennstrøm	NTNU	WP4
Sondre Sørbø	NTNU	WP4
Sebastien Gros	NTNU	WP4
Ole Øiseth	NTNU	WP4
Kirsten S. Wiebe	SINTEF Industri	WP5
Asbjørn Karlsen	NTNU	WP5
Arild Aspelund	NTNU	WP5
Asgeir Tomasgaard	NTNU	WP5
Øyvind Bjørgum	NTNU	WP5
Ruud Egging	NTNU	WP5
Fabian Rocha Aponte	SINTEF Industri	WP5
Børge Moe	NINA	WP5
Signe Christensen Dalsgaard	NINA	WP5
Carolyn Rosten	NINA	WP5
Johanna Järnegren	NINA	WP5
Elisabet Forsgren	NINA	WP5
Diego Jordán-Pavón	NINA	WP5
Bård Stokke	NINA	WP5
Katrine B. Hauge	UiO	WP5
Ole K. Fauchald	FNI	WP5
Ola Mestad	UiO	WP5
Ivar Alvik	UiO	WP5
Knut Kaasen	UiO	WP5
Bente Graae	NTNU, IBI	WP5
Dagmar Hagen	NINA	WP5
Ana Silva	NINA	WP5
Karl Merz	SINTEF Energi	WP5
Frank Hanssen	NINA	WP5
Jiska van Dijk	NINA	WP5
Robert Næss	NTNU	WP5
Tomas M. Skjølsvold	NTNU	WP5
Christian Klöckner	NTNU	WP5

PhD students

PhD students with financial support from the Centre budget

PhD candidate	Nationality	Period	Gender	WP	Thesis
Veronica Liverud Krathe	Norwegian	2021-2024	F	1	Multiscale/-fidelity wind turbine dynamics models for structural design and control
Afolarinwa David Oygbile	Nigerian	2021-2024	M	1	Reliability- and data-based structural design under industrial constraints
Torfinn Ottesen	Norwegian	2021-2025	M	2	An approach for safe and cost-effective installation of offshore wind power cables
Lorrana Faria	Brazilian	2021-2024	F	3	Power electronics architecture and control methods for a HVDC generator for offshore wind
Arkaitz Rabanal Alcubilla	Spanish	2021-2024	M	3	Energy Storage for Grid Services in HVDC Connected Offshore Wind Farms
Florian Stadmann	German	2021-2024	M	4	Enabling Technologies for Digital Twins
Wanwan Zhang	Chinese	2021-2024	F	4	Predictive Maintenance and Decision Support for Asset Management
Pankaj Ravindra Gode	Indian	2021-2024	M	5	Circular Business Development of Offshore Wind Energy
Julian Richard Lahuerta	Norwegian	2021-2024	M	5	Harnessing Norwegian maritime industrial capabilities in the emerging US offshore wind industry
Birgitte Nygaard	Danish	2021-2024	F	5	The framing of Norwegian Wind Energy futures – the cases of Svalbard and Sørlige Nordsjø II
Vibeke Videgaard Petersen	Danish	2022-2025	F	5	Predictive maintenance planning for offshore wind farms

PhD students with financial support from other sources

PhD candidate	Nationality	Period	Gender	WP	Thesis
Yannick Cyiza Karekezi	Norwegian	2021-2024	M	3	Novel Modular HVDC Generator for Offshore Wind

Master's students

Name	Gender	Thesis
Vibeke Hvidegaard Petersen	M	Predictive maintenance planning at offshore wind farms
Lea Bakkevig Thorsen / Marie Tyssen Bru	F/F	Design of chartering contracts for installation vessels at offshore wind farms using CVar
Thijs Bron	M	Dynamic object positioning by use of wires for offshore wind foundation installation
Servaas Sanders	M	Upscaling of offshore installation methods and appliances for ultra large wind turbines
Isabelle van der Kaaij	F	Installation of 15MW wind turbines using a floating vessel
Sofie Stein	F	Design and testing of insulation system for a HVDC generator for offshore wind
Mikkel Nærby	M	Towards a fully renewable power system and implications for a financial investor
Daniel Vennstrøm	M	Asset Administration Shell
Sondre Sørbø	M	HAM for structures
Marte Austenå	F	Use of knowledge in wind power controversies and decision-making processes
Tina Berntsen Flobak	F	Hvilke typer næringsinteresser kan påvirke ulike aktører i utbyggingen av flytende havvindkraft ved Utsira?
Julia McDowell	F	Beacon Wind project
Siri Marthe Lyngstad Aulie	F	Offshore wind
Therese Christina Tjeldflåt	F	Offshore wind

PUBLICATIONS

Peer reviewed journal publications

Search criteria: *sub-category:* Academic article *sub-category:* Academic literature review *sub-category:* Short communication *All publishing channels*

1. **Afewerki, Samson; Karlsen, Asbjørn.**
   Policy mixes for just sustainable development in regions specialized in carbon-intensive industries: the case of two Norwegian petro-maritime regions. *European Planning Studies* 2021 p. 1-22. OCEAN NTNU

Presentations

Search criteria: *From:* 2021 *To:* 2021 Main category: Conference lecture and academic presentation All publishing channels

1. **Banet, Catherine.**
   Planleggingskrav for energisystemet og havvind (Planning requirements for the energy system and offshore wind). Regulatory Considerations in Building and Operating Offshore Wind; 2021-11-17 - 2021-11-17. UiO
2. **Heidenreich, Sara.**
   Beyond technological solutions: Considering social aspects in environmental design. FME NorthWind webinar; 2021-10-29 - 2021-10-29. NTNU
3. **Heidenreich, Sara.**
   Ute av syne, ute av sinn? Kontroversen om vindkraft til havs. Workshop: Den norske vindkraftkontroversen; 2021-12-07 - 2021-12-07. NTNU
4. **Korpås, Magnus.**
   Electricity markets with high RES shares - Price formation and cost recovery. WinGrid Scientific Workshop on Power System Balancing and Operation with Large Shares of Wind Power; 2021-06-15 - 2021-06-18. NTNU
5. **Korpås, Magnus.**
   Market Challenges for Planning and Operations. Wind Integration Workshop 2021; 2021-09-28 - 2021-09-30. NTNU
6. **Korpås, Magnus.**
   The role of wind energy in hydrogen futures. Wind Finland; 2021-10-08 - 2021-10-08. NTNU
7. **Korpås, Magnus.**
   Transition to integrated electricity and hydrogen systems. WEBINAR ON THE NORDIC TSO STRATEGY FOR WIND AND SECTOR INTEGRATION; 2021-10-15 - 2021-10-15. NTNU
8. **Korpås, Magnus; Holttinen, Hannele.**
   Task 25 Webinar - Design and Operation of Energy Systems with Large Amounts of Variable Generation: The Market Challenge. Task 25 Webinar - Design and Operation of Energy Systems with Large Amounts of Variable Generation; 2021-09-16 - 2021-09-16. NTNU
9. **Korpås, Magnus; Tarel, Guillaume; Botterud, Audun.**
   On the profitability of market participants in decarbonized power systems. Applied Energy Symposium MIT A+B; 2021-08-11 - 2021-08-13. NTNU
10. **Nygaard, Birgitte.**
    Framing af norske vindkraftfremtider - når udviklingen rykker til havs. Den norske vindkraftkontroversen; 2021-12-07 - 2021-12-07. NTNU
11. **Røkke, Nils Anders; Hustad, Johan Einar.**
    Nordsjøen som plattform for grønn omstilling. Nordsjøen som plattform for grønn omstilling; 2021-08-06 - 2021-08-06. ENERGISINT NTNU
12. **Røkke, Nils Anders; Tomasgard, Asgeir.**
    The North Sea as a springboard for the green transition Three recommendations. The North Sea as a springboard for the green transition Three recommendations; 2021-11-09 - 2021-11-09. ENERGISINT NTNU
13. **Tande, John Olav Giæver.**
    Flytende havvind. Norsk offshoredag; 2021-06-01 - 2021-06-01. ENERGISINT
14. **Tande, John Olav Giæver.**
    Nytt norsk forskningssenter for vindkraft (2021-2029). SmartGrid webinar; 2021-05-20 - 2021-05-20. ENERGISINT
15. **Tande, John Olav Giæver.**
    Tuerning wind R&D into sustainable industry. Ocean Week; 2021-05-03 - 2021-05-05. ENERGISINT
16. **Tande, John Olav Giæver.**
    Turning wind R&D into sustainable industry. National Offshore Wind R&D Consortium; 2021-03-23 - 2021-08-23. ENERGISINT

Multimedia products

Search criteria: *From:* 2021 *To:* 2021 *sub-category:* Multimedia product *All publishing channels*

1. **Røkke, Nils Anders.**
   Arendalsuka: Nordsjøen som plattform for grønn omstilling. SINTEF Energ 2021. ENERGISINT
2. **Røkke, Nils Anders.**
   Møt oss på Arendalsuka 16 august. SINTEF Energ 2021. ENERGISINT
3. **Røkke, Nils Anders; Hustad, Johan Einar.**
   North sea - three recommendations. SINTEF Energ 2021. ENERGISINT NTNU
4. **Røkke, Nils Anders; Hustad, Johan Einar.**
   3 råd: Slik kan Nordsjøen bli en plattform for grønn omstilling. SINTEF Energ 2021. ENERGISINT NTNU
5. **Tande, John Olav Giæver.**
   Havvind kan dekke verdens energibehov mange ganger.. SINTEF Energ 2021. ENERGISINT

Blog articles and information material

Search criteria: *From:* 2021 *To:* 2021 *Main category:* Information material(s) *All publishing channels*

1. **Aam, Sverre.**
   Hva i all verden skjer med kraftmarkedet?. ENERGISINT
2. **Røkke, Nils Anders; Hustad, Johan Einar.**
   Arendalsuka 2021:Tre råd til politikere for grønn omstilling av Nordsjøen. ENERGISINT NTNU
3. **Røkke, Nils Anders; Tomasgard, Asgeir.**
   #COP26: The North Sea as a springboard for the green transition Three recommendations. ENERGISINT NTNU
4. **Røkke, Petter Egil; Hustad, Johan Einar.**
   Tre råd til politikere for grønn omstilling av Nordsjøen. ENERGISINT NTNU
5. **Tande, John Olav Giæver.**
   DeepWind 2022: one week left to submit your abstracts. ENERGISINT
6. **Tande, John Olav Giæver.**
   EERA DeepWind'2021 Offshore Wind R&D Digital Conference. ENERGISINT
7. **Tande, John Olav Giæver.**
   Marine spatial planning and cumulative impacts of blue growth on seabirds. ENERGISINT
8. **Tande, John Olav Giæver.**
   NorthWind Board elected. ENERGISINT
9. **Tande, John Olav Giæver.**
   NorthWind director featured in energy podcast. ENERGISINT
10. **Tande, John Olav Giæver.**
    NorthWind gets FME plaque from Research Council. ENERGISINT
11. **Tande, John Olav Giæver.**
    NorthWind kicks off its activities. ENERGISINT
12. **Tande, John Olav Giæver.**
    Offshore wind featured on SINTEF podcast. ENERGISINT
13. **Tande, John Olav Giæver.**
    The DeepWind 2021 papers are published. ENERGISINT
14. **Tande, John Olav Giæver.**
    The North Sea as a platform for the green transition. ENERGISINT
15. **Tande, John Olav Giæver.**
    The North Sea as a springboard for the green transition. ENERGISINT
16. **Tande, John Olav Giæver.**
    The time is now for the EU to invest in offshore wind research. ENERGISINT
17. **Tande, John Olav Giæver.**
    The time is now for the EU to invest in offshore wind research Offshore wind can become the backbone of the EU's zero-emission energy system – but it requires a concerted effort. ENERGISINT
18. **Tande, John Olav Giæver; Kvamsdal, Trond.**
    Høringssvar om havvind fra SINTEF og NTNU Kunnskapsbasert utvikling, kvalitative konkurranser og raskt tempo. ENERGISINT NTNU
19. **Tande, John Olav Giæver; Røkke, Nils Anders.**
    SINTEF at COP26: SINTEF Climate Fund, North Sea, market mechanisms and green shipping on the agenda. ENERGISINT

Media contributions

Search criteria: *From:* 2021 *To:* 2021 *Main category:* Media contribution *sub-category:* Popular scientific article *sub-category:* Interview Journal *sub-category:* Article in business/trade/industry journal *sub-category:* Sound material *All publishing channels*

1. **Korpås, Magnus.**
   Her er tre forutsetninger for norsk havvindsuksess. *Dagens næringsliv* 2021. NTNU
2. **Mehammer, Eirill Bachmann.**
   Substation on the seabed could reduce floating wind costs. riveramm.com [Business/trade/industry journal] 2021-05-06 ENERGISINT
3. **Røkke, Nils Anders.**
   COP26 Event: Hvilken rolle har CCS i nullutslippssamfunnet 2050?. [Internet] 2021-11-03. ENERGISINT
4. **Røkke, Nils Anders.**
   Dette skriver avisene om norsk politikk onsdag 11. august.. Nettavisen [Newspaper] 2021-08-11. ENERGISINT

5. **Røkke, Nils Anders.**
NTNU og SINTEF har tre råd til politikere for grønn omstilling av Nordsjøen. NTNU [Internet] 2021-08-17. ENERGISINT
6. **Røkke, Nils Anders; Hustad, Johan Einar.**
Norge treng EU for grøn omstilling av Nordsjøen: - Feil, meiner Senterpartiet. [Newspaper] 2021-08-17. ENERGISINT NTNU
7. **Tande, John Olav Giæver.**
Champions Corner: John Olav Tande develops tomorrow's wind power technology. [Internet] 2021-06-18. ENERGISINT
8. **Tande, John Olav Giæver.**
Dette skriver avisene om norsk politikk fredag 11. juni. Nettavisen [Newspaper] 2021-06-11. ENERGISINT
9. **Tande, John Olav Giæver.**
Electrifying the North Sea: a gamechanger for wind power production?. Engineering and Technology [Business/trade/industry journal] 2021-09-17. ENERGISINT
10. **Tande, John Olav Giæver.**
Equinor ASA : - Offshore wind, New Ocean Grid project in the North Sea. Marketscreener [Internet] 2021-09-06. ENERGISINT
11. **Tande, John Olav Giæver.**
Equinor leads Norwegian offshore wind grid project. reNews [Business/trade/industry journal] 2021-09-03. ENERGISINT
12. **Tande, John Olav Giæver.**
Et fugleperspektiv. E24 [Newspaper] 2021-09-07. ENERGISINT
13. **Tande, John Olav Giæver.**
Forskingssenter for vindkraft i gang. Nationen [Newspaper] 2021-06-18. ENERGISINT
14. **Tande, John Olav Giæver.**
Får støtte til å utvikle lønnsomme løsninger for havvind – og tilknytning til strømnettet. Verified News Explorer Network [Newspaper] 2021-09-03. ENERGISINT
15. **Tande, John Olav Giæver.**
Havvind kan dekke verdens energibehov flere ganger. SINTEF Energ 2021. ENERGISINT
16. **Tande, John Olav Giæver.**
Havvind-anlegg kan gi over 7000 arbeidsplasser. NRK Rogaland [Internet] 2021-10-13. ENERGISINT
17. **Tande, John Olav Giæver.**
Høringssvar om havvind fra SINTEF og NTNU. Gemini.no [Business/trade/industry journal] 2021-08-30. ENERGISINT
18. **Tande, John Olav Giæver.**
In Norway: Large wind research center starts its activities. Aqua [Newspaper] 2021-06-18. ENERGISINT
19. **Tande, John Olav Giæver.**
Kick-off for stort vindforskningssenter. Maritimt magasin [Business/trade/industry journal] 2021-06-18. ENERGISINT
20. **Tande, John Olav Giæver.**
Major Wind Research Centre Kicks Off Its Activities. Agilitypr [Internet] 2021-06-16. ENERGISINT
21. **Tande, John Olav Giæver.**
Major Wind Research Centre Kicks Off its Activities. Maritime-executive [Business/trade/industry journal] 2021-06-21. ENERGISINT
22. **Tande, John Olav Giæver.**
Major Wind Research Centre Kicks Off its Activities. North American Clean Energy [Business/trade/industry journal] 2021-06-16. ENERGISINT
23. **Tande, John Olav Giæver.**
Major wind research centre kicks off its activities. SINTEFblog [Internet] 2021-06-16. ENERGISINT
24. **Tande, John Olav Giæver.**
Major wind research centre kicks off its activities. Maritimt magasin [Business/trade/industry journal] 2021-06-18. ENERGISINT
25. **Tande, John Olav Giæver.**
Major wind research centre kicks off its activities. NINA [Internet] 2021-06-16. ENERGISINT
26. **Tande, John Olav Giæver.**
Major wind research centre starts operations. Modern Power Systems [Business/trade/industry journal] 2021-06-22. ENERGISINT
27. **Tande, John Olav Giæver.**
Mangfald eller konsentrasjon innan energiforskinga?. Khrono [Newspaper] 2021-08-07. ENERGISINT
28. **Tande, John Olav Giæver.**
New Ocean Grid project in North Sea. Ocean Energy Resources [Business/trade/industry journal] 2021-09-03. ENERGISINT
29. **Tande, John Olav Giæver.**
New Ocean Grid Project in the North Sea. Offshore Source [Business/trade/industry journal] 2021-09-03. ENERGISINT
30. **Tande, John Olav Giæver.**
New Ocean Grid Project in the North Sea. Gulf oil & gas [Business/trade/industry journal] 2021-09-06. ENERGISINT
31. **Tande, John Olav Giæver.**
NorthWind: A New Wind Power Research Centre for Norway. [Internet] 2021-04-13. ENERGISINT
32. **Tande, John Olav Giæver.**
NorthWind: inside Norway's new wind power research centre. Power Technology [Business/trade/industry journal] 2021-01-18. ENERGISINT
33. **Tande, John Olav Giæver.**
NorthWind Research Center Kicks Off its Activities. Global Renewable News [Newspaper] 2021-06-17. ENERGISINT
34. **Tande, John Olav Giæver.**
NorthWind Research Center Kicks Off its Activities. EE Online [Internet] 2021-06-17. ENERGISINT
35. **Tande, John Olav Giæver.**
NorthWind research centre begins activities. Energy Global [Internet] 2021-06-16. ENERGISINT

36. **Tande, John Olav Giæver.**
NorthWind to explore cheaper, more sustainable wind energy options. Oil and gas press [Newspaper] 2021-06-16. ENERGISINT
37. **Tande, John Olav Giæver.**
Norway Awards Grants for Offshore Wind Energy and Ammonia Bunkering. infomarine on-line [Internet] 2021-09-04. ENERGISINT
38. **Tande, John Olav Giæver.**
Norway Awards Grants for Offshore Wind Energy and Ammonia Bunkering. The Maritime Executive [Business/trade/industry journal] 2021-09-03. ENERGISINT
39. **Tande, John Olav Giæver.**
Norway: Fact checks of nine disputed wind power claims. energycentral [Business/trade/industry journal] 2021-08-17 ENERGISINT
40. **Tande, John Olav Giæver.**
Norway gets new wind energy research centre. w3.windfair.net [Business/trade/industry journal] 2021-06-16. ENERGISINT
41. **Tande, John Olav Giæver.**
Norway: Leading offshore wind development. Enlit Europe 2021 ENERGISINT
42. **Tande, John Olav Giæver.**
Norway: NorthWind kicks off its activities. Energy-pedia [Business/trade/industry journal] 2021-06-16. ENERGISINT
43. **Tande, John Olav Giæver.**
Norway offers funding for Ocean Grid project in North Sea. NS Energy [Newspaper] 2021-09-06. ENERGISINT
44. **Tande, John Olav Giæver.**
Norway to back grid project for offshore wind. WindPower monthly [Business/trade/industry journal] 2021-09-03. ENERGISINT
45. **Tande, John Olav Giæver.**
Norway to Support Ocean Grid Offshore Wind Project. OEDigital [Business/trade/industry journal] 2021-09-03. ENERGISINT
46. **Tande, John Olav Giæver.**
Norwegian offshore grid project secures funding. 4COffshore [Business/trade/industry journal] 2021-09-03. ENERGISINT
47. **Tande, John Olav Giæver.**
Norwegian Offshore Wind Industry Working on New Grid Solutions. OffshoreWind [Business/trade/industry journal] 2021-09-03. ENERGISINT
48. **Tande, John Olav Giæver.**
Norwegian Offshore Wind Project Receives Additional Support. North American Windpower [Business/trade/industry journal] 2021-09-07. ENERGISINT
49. **Tande, John Olav Giæver.**
Norwegian Wind Energy Research Centre Begins with Activities. OffshoreWind [Business/trade/industry journal] 2021-06-16. ENERGISINT
50. **Tande, John Olav Giæver.**
Ocean Grid offshore wind project receives funding. Energy Northern Perspective [Business/trade/industry journal] 2021-09-03. ENERGISINT
51. **Tande, John Olav Giæver.**
Ocean Grid project secures funding. Energy Global [Business/trade/industry journal] 2021-09-03. ENERGISINT
52. **Tande, John Olav Giæver.**
Offshore wind energy: New Ocean Grid project in the North Sea. EVWind [Business/trade/industry journal] 2021-09-03. ENERGISINT
53. **Tande, John Olav Giæver.**
OFFSHORE WIND: NEW OCEAN GRID PROJECT IN THE NORTH SEA. Cable Technology News [Business/trade/industry journal] 2021-09-03. ENERGISINT
54. **Tande, John Olav Giæver.**
OFFSHORE WIND: NEW OCEAN GRID PROJECT IN THE NORTH SEA. Energy Projects & technology [Business/trade/industry journal] 2021-09-03. ENERGISINT
55. **Tande, John Olav Giæver.**
Offshore Wind: New Ocean Grid Project In The North Sea. Public [Internet] 2021-09-03. ENERGISINT
56. **Tande, John Olav Giæver.**
Offshore wind: New Ocean Grid project in the North Sea. OGV Energy [Business/trade/industry journal] 2021-09-03. ENERGISINT
57. **Tande, John Olav Giæver.**
Offshore wind: New Ocean Grid project in the North Sea. Equinor [Internet] 2021-09-03. ENERGISINT
58. **Tande, John Olav Giæver.**
Offshore wind: New Ocean Grid project in the North Sea. Global Renewable News [Internet] 2021-09-07. ENERGISINT
59. **Tande, John Olav Giæver.**
Offshore wind: New Ocean Grid project in the North Sea. Sea Wanderer [Business/trade/industry journal] 2021-09-03. ENERGISINT
60. **Tande, John Olav Giæver.**
Offshore wind: New Ocean Grid project in the North Sea. Electric Energy Online [Business/trade/industry journal] 2021-09-07. ENERGISINT
61. **Tande, John Olav Giæver.**
Offshore wind: New Ocean Grid project in the North Sea. Cyprus shipping news [Business/trade/industry journal] 2021-09-06. ENERGISINT
62. **Tande, John Olav Giæver.**
Oppstart for internasjonalt forskningssenter innen vindkraft. [Internet] 2021-06-16. ENERGISINT
63. **Tande, John Olav Giæver.**
#Podcast: Norway – Leading offshore wind development. Power Engineering International [Business/trade/industry journal] 2021-11-10. ENERGISINT

64. **Tande, John Olav Giæver.**
Research super-cluster has Norwegian export opportunities as its goal. Riviera [Newspaper] 2021-06-05. ENERGISINT
65. **Tande, John Olav Giæver.**
Samling rundt havvind. Nett [Internet] 2021-06-18. ENERGISINT
66. **Tande, John Olav Giæver.**
Sant och osant om vindkraft. Verified News Explorer Network [Internet] 2021-08-16. ENERGISINT
67. **Tande, John Olav Giæver.**
Sant og usant om vindkraft. Er egentlig vindkraft miljøvennlig?. TU [Business/trade/industry journal] 2021-06-15. ENERGISINT
68. **Tande, John Olav Giæver.**
Seks forhold avgjør hva vindkraft til havs vil koste. Gemini [Business/trade/industry journal] 2021-06-14. ENERGISINT
69. **Tande, John Olav Giæver.**
Seks forhold avgjør hvor mye vindkraft til havs vil koste. DN [Newspaper] 2021-06-10. ENERGISINT
70. **Tande, John Olav Giæver.**
Six factors that will determine the cost of offshore wind power. *Norwegian SciTech News* 2021 . ENERGISINT
71. **Tande, John Olav Giæver.**
Skal gi svar på store samfunnsutfordringer, Forskningsrådet med 90 millioner til NINA. [Internet] 2021-01-19. ENERGISINT
72. **Tande, John Olav Giæver.**
WIND: Norwegian Ocean Grid project gets 82.7 million NOK under Green Platform Scheme. the OGM [Newspaper] 2021-09-03. ENERGISINT
73. **Tande, John Olav Giæver.**
Wind power research centre powers up. MotorShip [Business/trade/industry journal] 2021-06-21. ENERGISINT
74. **Tande, John Olav Giæver.**
World's Top Researchers & Innovators at the EERA DeepWind 2021 Conference. Offshore Source [Business/trade/industry journal] 2021-01-07. ENERGISINT
75. **Tande, John Olav Giæver; Korpås, Magnus.**
An ocean of opportunity. *Energy Global magazine* 2021 (Spring) p. 52-55. ENERGISINT NTNU
76. **Tande, John Olav Giæver; Stakkeland, Øyvind.**
PODCAST - Ut mot havet. Agder Energi 2021 ENERGISINT

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

The Research Council of Norway

www.northwindresearch.no

alldesign.no