NORTH WIND

ANNUAL REPORT
2023

Norwegian Centre for
Environment-friendly
Energy Research

CONTENTS

NORTHWIND IN A NUTSHELL

NorthWind – the 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 research partners NTNU (Norwegian University of Science and Technology), UiO (University of Oslo), NGI (Norwegian Geotechnical Institute) and NINA (Norwegian institute for nature research).

NorthWind is part of the FME-scheme: Norwegian Centres for Environment-friendly Energy Research (in Norwegian: *Forskningssenter for miljøvennlig energi*). These are time-limited centres of excellence 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.

The Centre 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.

Research and innovation is carried out by the research partners in collaboration with the industry partners. The industry partners, numbering 43 in total, cover the full value chain of the Norwegian wind industry including developers and energy companies, supply industry and service companies.

The activities are industry-oriented, with research focused to bring innovations to a Technology Readiness Level (TRL) equivalent to the laboratory testing stage. We have an active strategy to transfer the results from NorthWind to the industry so that they can be further developed and come to practical use. This includes engagement in user cases and preparation of spin-off projects. Our PhD programme and educational activities at bachelor and master's level, carried out by the university partners, provide an excellent pool of highly qualified candidates for the industry. We communicate our results actively through meetings, webinars, conferences, and publishing, bringing value to the industry and society in general.

VISION AND GOALS

Chairperson of the Board Elling Rishoff (DNV) addresses the participants at the 2023 Annual Innovation Forum in Trondheim.

The vision of NorthWind is expressed through our slogan: "Turning wind R&D into a sustainable industry". The overall goal is to bring forward research and innovation to reduce the cost of wind energy, facilitate its sustainable development, create jobs and grow exports.

The research is carried out in five work packages (WPs) addressing these specific research challenges:

- Structure and integrity: De-risk concept selection and enable cost-effective design and fabrication of support structures through reduced uncertainty and novel methods.
- Marine operations and logistics: Develop methods and tools for efficient and safe marine operations and logistic planning for installation and maintenance of offshore wind farms.
- Electrical infrastructure and system integration: Develop reliable and cost-effective electric power components and system solutions for connecting large-scale offshore wind farms.
- Digital twin and asset management: Develop methodologies to elevate the capability level of digital twins of wind farms and components from descriptive to prescriptive or autonomous.
- Sustainable wind development: Develop tools and insights for the sustainable development of wind energy to resolve environmental and societal conflicts.

Our mission is to accelerate the green transition.

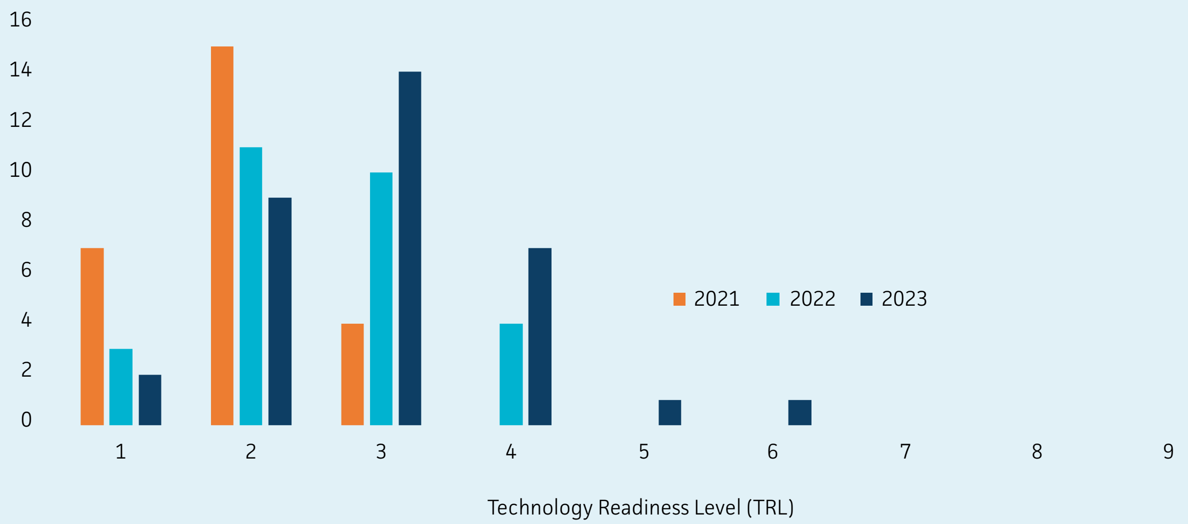
NORTHWIND BY NUMBERS

50 partners

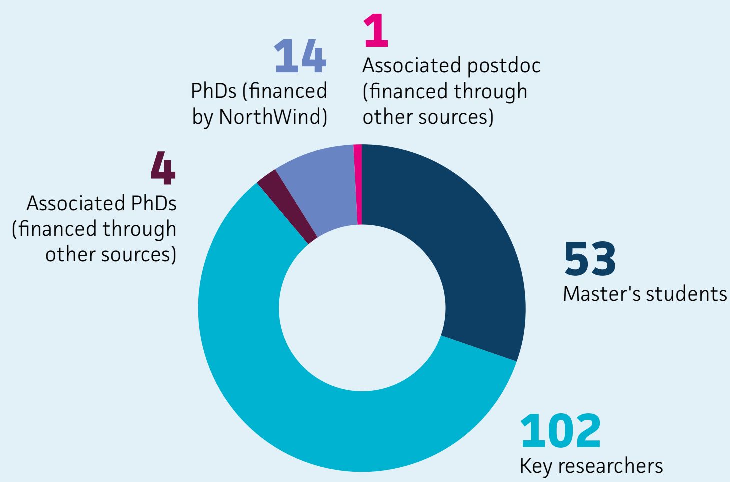
8 years

350 MNOK

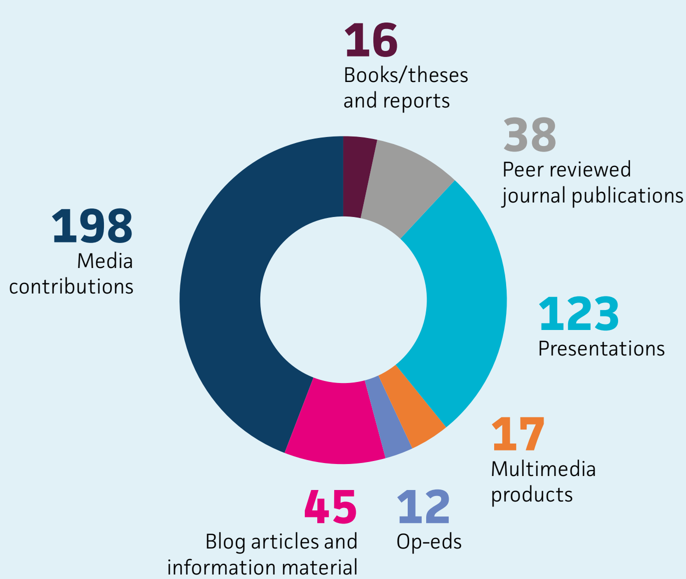
Development of innovations



People



Communication and dissemination*



* Numbers shown are accumulated totals since the beginning of Centre activities

NORTHWIND: FROM RESEARCH TO INDUSTRY EXCELLENCE

Message from the Centre Director

I am very happy with the progress of NorthWind that is now well established as a powerful wind energy centre for research, education, and innovation with more than 50 partners. Our slogan and vision "turning wind R&D into sustainable industry" perfectly encapsulates our activity. We generate results that are important for developing offshore wind farms in Norway and globally, and in areas in which we have leading industry partners that can apply the results. This includes substructures for offshore wind, marine operations, electrical infrastructure, digital solutions for monitoring and control, and sustainable development – with positive coexistence and environmental design as central themes.

In 2023, we engaged an external consulting firm to analyse the innovations we have in development with regards to maturity, potential for commercialisation and benefit to the industry. The Technology Readiness Level (TRL) was used to describe the technological maturity of the innovation, and spans in NorthWind from the idea stage (TRL=1) up to validation in the laboratory or field (TRL=5). The industry partners are engaged in the work, for example through participation in specific user studies enabling them to use and develop knowledge and innovation from the Centre in their activities. The assessment of the innovations forms an excellent basis for prioritisation of our continued research to bring the innovations towards industrial use. Examples include hybrid welding (Aker Offshore Wind and Aibel), wind farm design optimisation (Norconsult) and digital twin technology (DNV).

NorthWind actively contributes to the management of the Offshore Wind Cooperation Forum, under the thematic group Research, Technology Development and Expertise; international forums such as the European Energy Research Alliance EERA JP wind; the European Technology and Innovation Platform, ETIP wind; and in working groups under IEA TCP wind. The work maintains up-to-date and informed engagement through productive dialogue with the authorities, industry and academia, ensuring the relevance and effective dissemination of research within the Centre.

In EERA JP wind, the buzz is all about developing into a European Centre of Excellence for research, education and innovation. The reasoning is that the European ambitions for offshore wind can only be reached through collaboration. Governments, industry, and research need to work together to succeed. There are significant challenges that must be tackled, including supply chain bottlenecks, increased costs, and reduced profitability in industry. The cost (LCOE) of offshore wind must be reduced, the grid must be developed, and it must all be done with respect for nature and in positive coexistence with other users of the sea. This fits perfectly with the agenda of NorthWind, and it is my ambition that NorthWind and Norway shall play a vital role in the European Centre of Excellence.

It is a privilege to work as Centre director with so many talented and extremely skilled colleagues. The engagement from both research partners and the industry is truly inspiring, and I thank you all for the hard work and dedication that you put into NorthWind. I am confident that with our joint efforts we shall make offshore wind a major sustainable industry and a vital part of the future zero-emission energy system.

John Olav Giæver Tande is the director of the NorthWind research centre, and a pioneer in floating offshore wind energy. He is Chief Scientist and Research Manager at SINTEF Energy Research. 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.

Chairperson of the Board Elling Rishoff (DNV) and NorthWind Director John Olav Tande (SINTEF).

STEERING TOWARDS A GREENER FUTURE IN OFFSHORE WIND

Message from the Chair

As the chairman of FME NorthWind, I am proud to report that the FME has made significant progress in 2023. We have seen exciting developments in the offshore wind industry, both globally and in Norway.

For example, the Floating Wind Days arranged by Norwegian Offshore Wind doubled its participation in 2023 compared to 2022. In order to support and sustain this, it is of vital importance that researchers connect properly with the industry at all levels. For example, during our stay in Haugesund, the NorthWind Board had the opportunity to visit Aibel's gigantic substation under final assembly.

As a result of our contact with industry, our Research Centre has grown, with new industry partners joining us, and our activities have expanded to meet the increasing demand for offshore wind research and innovation. Many promising activities have been initiated and continued, several of them are already climbing the TRL ladder.

In the Annual report for 2022, I reflected on the unique role of NorthWind, operating on a holistic national level and contributing to innovation. During 2023 the Northwind network has engaged with the Collaboration forum for offshore wind, established by the Ministry of Energy in 2021 to bridge potential knowledge gaps and coordinate the industry. The Collaboration forum is divided into groups for “Coexistence”, “Industrial and technological development” and “Infrastructure and network” - which all fit very well with Northwind's ongoing work packages.

The working group "Industry and technology development" is divided into three subgroups, of which "Research, technology development and expertise" is an important focus area with a broadly composed working group. The working group has representatives from business, research and relevant stakeholders in offshore wind and is led by John Olav Tande, the Director FME NorthWind. In this way, Northwind has delivered important input to the Norwegian research agenda.

I would like to thank all our talented and skilled Northwind colleagues, research partners, and industry partners for their hard work and dedication. Together, we are making a big positive impact and moving towards a greener future.

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.

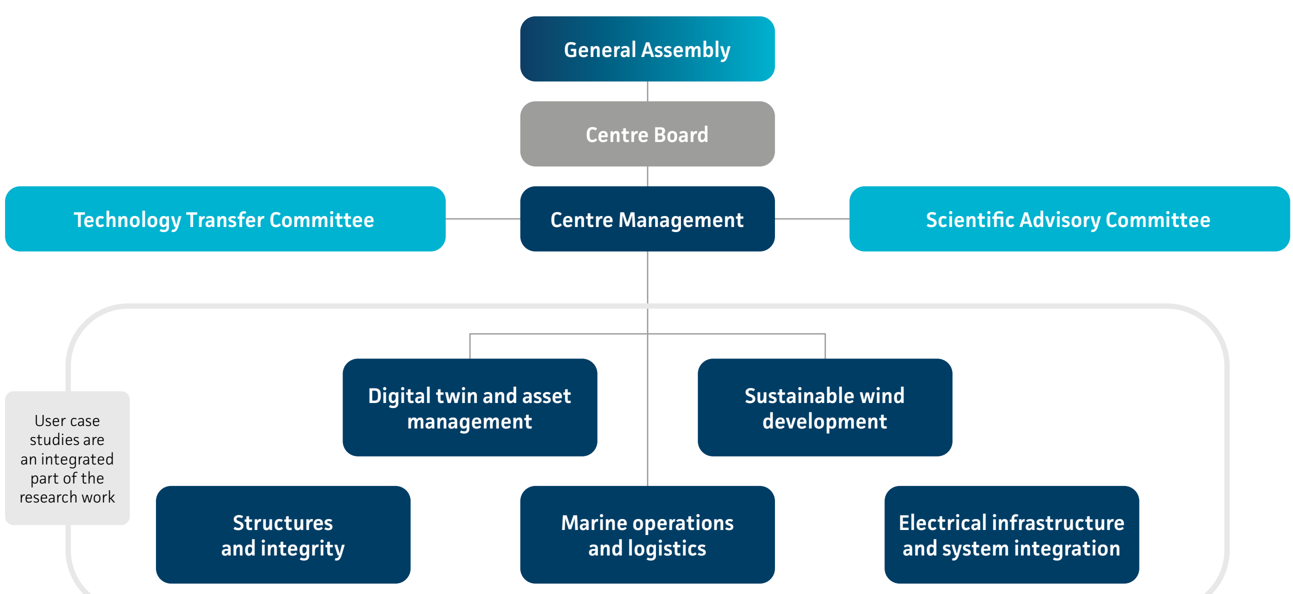
ORGANISATION

NorthWind is composed of a strong team of research and industry partners with complementary expertise and roles. The Centre is organised like a company with a General Assembly, a Board, and a Centre Management Group (CMG) for daily operation. Research work is carried out in the work packages (WPs) that each have a lead and a deputy. The Scientific Advisory Committee (SAC) enhances the academic programme and the Technology Transfer Committee (TTC) enhances the interaction with industry.

The CMG consists of a Centre director, a manager, an administrator, a communication manager, and the heads of the WPs, the SAC and the TTC.

Board

The Board consists of 11 members of which 8 are from industry and 3 are from the research partners. They were elected as part of the startup of the Centre in 2021 for a two-year period. A new election was held recently, which resulted in five members stepping down and an equal number joining the Board. The Board met three times during 2023: once in Haugesund in May, once via videoconference in September, and once in Trondheim on the occasion of the Annual Innovation Forum, in December. The Board oversees the progress of NorthWind, and approves workplans and budgets, but is first and foremost a forum for strategic discussions and advice. Members marked as incoming in the following list are current members, whereas the outgoing ones stepped down at the end of 2023.



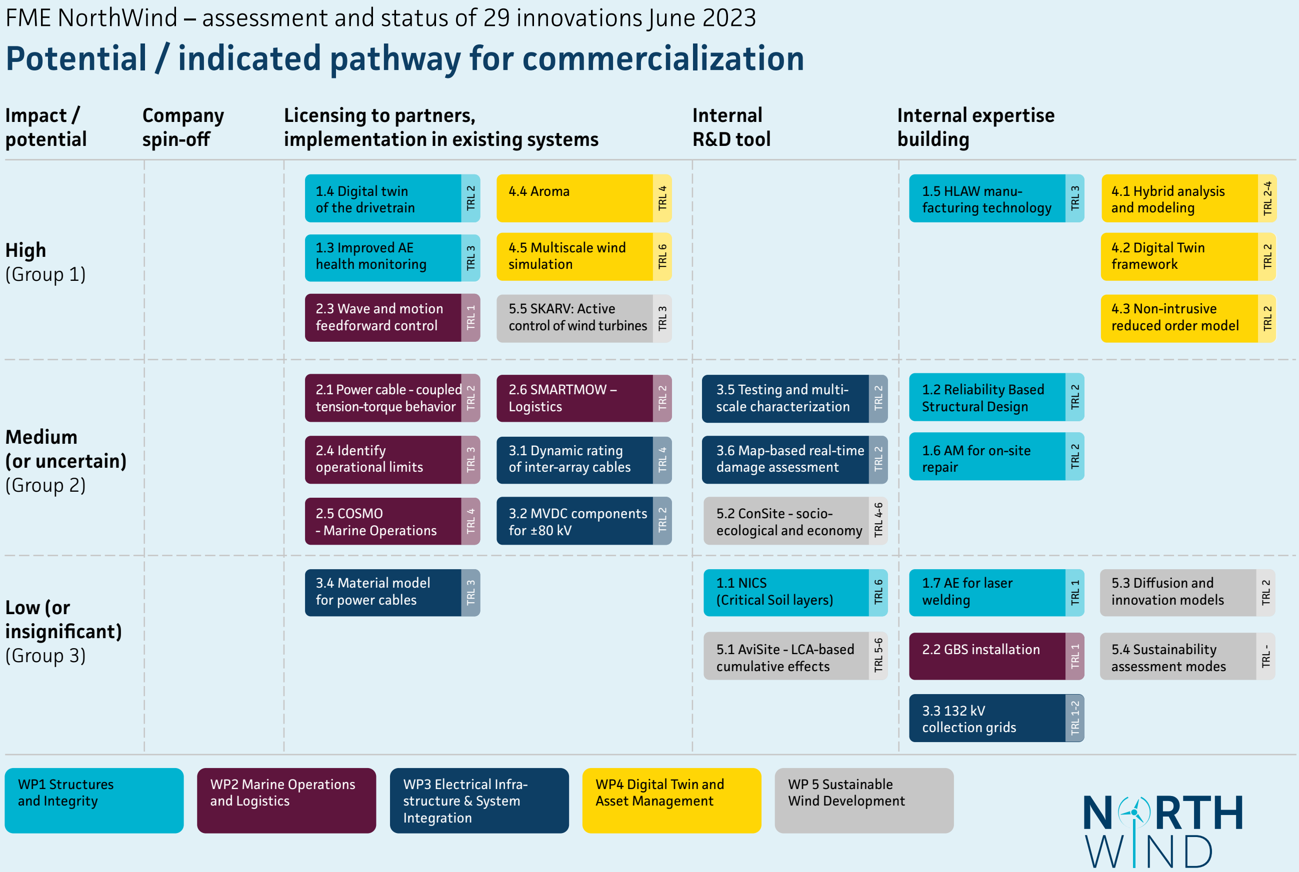
⌃ *Detail of a HVDC platform being assembled at NorthWind partner Aibel's Haugesund yard, for the UK's Doggerbank offshore wind farm.*

- Elling Rishoff (Chairperson), DNV
- Geir Olav Berg, Aker Offshore wind
- Jan-Kristian Haukeland, DOF (outgoing)
- Stein Erik Skilhagen, Norconsult (incoming)
- Ole J. Nordahl, Equinor
- Andreas Stavnes Hallan, Aibel (incoming)
- Håkon Hallem, Force Technology (outgoing)
- Torunn Lund Clasen, Nexans
- Björn Mo Östgren, Statkraft (outgoing)
- Åste Hanto, Statkraft (incoming)
- Anne Brisset, TotalEnergies
- Norunn Myklebust, NINA (outgoing)
- Johan Einar Hustad, NTNU (outgoing)
- Pauline Suziki, NGI (incoming)
- Ole Morten Midtgård, NTNU (incoming)
- Petter Støa, SINTEF

Scientific Advisory Committee

The Scientific Advisory Committee (SAC) is responsible for developing, in collaboration with the Centre Director and WP leaders, a top-quality PhD and postdoc programme. This includes having an active recruitment strategy, inviting international experts to give lectures, organising scientific colloquia and seminars, and exposing scholars to industry and leading international research groups. The Committee also liaises with the associated research partners and gives advice on the scientific content and progress of the Centre.

The Committee is composed of members from the research partner organisations and the associated research partner organisations. It is led by professor Trond Kvamsdal (NTNU). The associate research



Main results of the innovation assessment including TRL level, type of innovation and impact.

partners (DTU, TNO, Fraunhofer, University of Strathclyde, NREL, NCEPU and Florence School of Regulation) are internationally acclaimed and strengthen the Centre. They participate by providing advice on the open research and academic programme of NorthWind to ensure efficiency and quality at the highest international level. The Committee operates with a national core group that meets on a quarterly basis or more frequently as required, and a full committee with the international associate partners that meets twice per year – physically in January in connection with the EERA DeepWind conference and digitally or in a hybrid meeting in the fall.

In August 2023, the SAC organised, together with WP4, the third ECCOMAS Thematic Conference on Computational Science and AI in Industry (CSAI 2023) in Trondheim, Norway. The SAC meeting held in connection with the EERA DeepWind 2024 conference consisted of a review of NorthWind's activities on digital twin technologies.

Technology Transfer Committee

The Technology Transfer Committee is led by Inger Marie Malvik (SINTEF). The main focus in 2023 has been the assessment of the innovations being worked on in the work packages. The assessment was performed by the work package leaders, the Technology Committee leader and Impello Management. The TRL (Technology Readiness Level) of the innovations spans from TRL 1 to TRL 4, with the exception of two of the innovations in WP5 – Sustainable wind development, which are at level 5 and 6 (Online Avisite app and Consite Wind app).

Research partners

SINTEF
Centre lead

NTNU

NGI

UNIVERSITY OF OSLO

NINA
Norwegian Institute for Nature Research

Industry partners

ABB

aibel

AKER OFFSHORE WIND

AMON WIND

ANEO

Baker Hughes

COGNITE

DNV

DR. TECHN. OLAV OLSEN ARTELIA GROUP

DOF

EDR MEDESO

EIDEL EIDSVOLL ELECTRONICS AS

equinor

ESVAGT

ENERGY INNOVATION

Finnmark Kraft

FORCE TECHNOLOGY

Fred. Olsen Seawind

FUGRO

GFMS

Hafslund Eco

Huisman

Hydro

KONGSBERG

Lloyd's Register

Associates

How we work together

The Centre is set up to generate value for the industry and society in general. We strive on the one hand to accomplish research at the highest academic level, and on the other hand to create results and innovations that have practical applications for the industry. We do this through collaboration between partners, leveraging our complementarity with distinct roles and expertise. SINTEF, NGI and NINA do industry-oriented research within their distinct areas of expertise. NTNU and UiO carry out the more academic research with the PhD and postdoc programme, as well as education at master and bachelor level. The industry partners are engaged through a set of activities:

- taking lead or participating with in-kind in user case studies addressing specific challenges
- participating in WP meetings and in direct interaction with the researchers
- being co-advisors for PhDs, master's and bachelors
- engaging in the Board with strategic discussions and advice
- taking part in webinars, the Annual Innovation Forum and other overarching Centre activities
- following up innovations and developing spin-off projects

Recurring events and activities at Northwind

The work is carried out with monthly meetings of the Centre Management Group for coordination of and follow up on the day-to-day activities. The WPs each have at least two meetings annually with the industry partners; one in the spring and one in the fall. These meetings are for sharing progress reports, getting feedback and preparing workplans. Each workplan covers a two-year period and is approved by the Board in December of the preceding year. There are also ad-hoc meetings with smaller groups to address specific issues.

Annual Innovation Forum

Based on comments received from participants last year, the Centre Management Group decided to extend the duration of the Annual Innovation Forum to two days instead of one. The forum is an occasion for scientists and representatives from the industry to update each other about Centre activities, and wind power in general. Like the previous year, the programme featured a series of keynote speeches by members of the industry, and several scientific poster presentations. Scientists from the work packages were also on hand to provide updates on the work being done in their work package.

The second day of the Forum featured a new addition to the programme, namely a series of concurrent workshops examining a variety of research questions. A primary objective of the workshops was to find potential user cases. User cases (see also p. 34-49) are a good way for Centre partners to contribute to research progress on a particular issue that is important to them. The topics discussed during the workshops were as follows:

- Use of aluminium in offshore wind
- Sustainable development goals interlinkages with offshore wind
- Market integration of offshore wind
- Subsea technology
- Sustainability
- Optimised wind farm design

Ana Page presents the Centre Management Group's work on assessing research needs in collaboration with project partners, at the Annual Innovation Forum 2023.

Workshop on aluminium in offshore wind, at NorthWind's Annual Innovation Forum 2023.

Webinar series

The Technology Transfer Committee continued its successful webinar series in 2023, with 11 events held. Several of the webinars were organised in collaboration with NorthWind partners. Topics covered touched a range of interesting topics from all of NorthWind's WPs. The webinars' titles are listed below:

Connecting Large Quantities of Offshore Wind: Offshore Bidding Zones

Model for regulating safety and the working environment in renewable energy production at sea – the long and windy road

Towing of offshore wind structures

Congestion and congestion management in the power grid

New concepts and models in offshore wind – digital twins, predictive maintenance and structural design

Dynamic models, cost-effective installation, regulatory framework and impact assessments

Sustainable Development Goals, circular business development, and the framing of Norwegian wind energy futures

Operation and control of wind energy systems – How to get the most out of your wind farm throughout its lifetime

Norway and IEA Wind

Floating offshore wind permitting – Norway-Portugal – Sharing experiences

Co-creating Sustainability Readiness Levels: How to get ready for sustainable wind energy development

In addition to the webinars listed above, a NorthWind partners-only webinar was organised in January to present Collaborative and Knowledge-building Project (KSP) applications to Centre partners. A total of ten NorthWind-relevant KSP applications were presented, and participants got the opportunity to signal their interest to join them before the mid-February application deadline.

More information about the various webinars can be found on the Events page of the NorthWind website.

A NorthWind delegation visits Aibel's Haugesund yard, with a Doggerbank platform in the background. Left to right: Birgit Hernes (Research Council of Norway); Bjørn Mo Østgren (Board – Statkraft); Petter Støa (Board – SINTEF); Henning Braaten (WP2); Håkon Hallem, Force Technology; Adil Rasheed (WP4); John Olav Tande (Centre director); Marte Gammelsæter (WP3); Inger Marie Malvik (Head of TTC); Audun Johanson (Nexans); Trond Kvamsdal (Head of SAC); Vigdis Olden (WP1); Grethe Kjeilen-Eilertsen (TotalEnergies); Aleksander Sæthereng Gundersen, NGI (WP1); Anne Brisset (Board – TotalEnergies); Elling Rishoff (Board – DNV); Konstanze Kölle (Centre Manager); Rita V. D'Oliveira Bouman (WP5); Jan-Kristian Haukeland (Board – DOF).

NorthWind's visit to Haugesund coincided with the 2023 edition of Norwegian Offshore Wind's Floating Wind Days conference.

Workshop and Board meeting in Haugesund

NorthWind organised a workshop and Board meeting in Haugesund in May. Participants visited NorthWind partner Aibel's Haugesund yard, where a huge HVDC platform was under assembly. The platform was built for the UK's Doggerbank offshore wind farm, to convert the production of 95 wind turbines for transmission to the shore.

Workshop in Haugesund with Norwegian Offshore Wind, 23 May 2023.

EERA DeepWind CONFERENCE 2024

The 2024 edition of the EERA DeepWind offshore wind R&I conference took place 17-19 January in Trondheim, gathering about 300 scientists, experts and representatives from the industry. NorthWind once again played an active role in organising it.

SINTEF NTNU EERA European Energy Research Alliance

Norwegian State Secretary for Energy, Astrid Bergmål, officially opens the EERA DeepWind 2024 offshore wind R&I conference.

The opening session of the Conference included a debate featuring the day's keynote speakers.

MARK YOUR CALENDARS:
The next EERA DeepWind conference will take place in Trondheim, 15-17 January 2025.

The conference was officially opened by State Secretary for the Norwegian Ministry of Energy, Astrid Bergmål, who outlined the various measures put in place by the government to meet its offshore wind targets. Another keynote speaker, Jacob Edmonds, head of innovation at Ørsted and VP of ETIP wind, presented an optimistic picture of the situation for the supply industry, which has been suffering recently due to inflation and supply chain issues. Interest rates and costs are expected to drop again, which should ease the situation. However, he pointed out that the supply side of the renewable energy industry will have to scale up to meet an increasingly heavy demand.

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 and maintenance
- Substructures and mooring
- Marine operations and logistics
- Wind farm optimisation
- Experimental testing and validation
- Wind farm control systems
- Societal impact, controversies, and regulatory framework
- Environmental impact

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 2024.

Most of the work for the planning and arrangement of the conference took place in 2023.

The conference presented a top roster of keynote speakers:

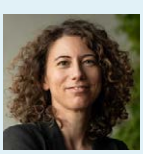
Astrid Bergmål
State Secretary,
Norwegian Ministry
of Energy

Enrico Degiorgis
Policy officer on Wind energy and renewable hydrogen research and innovation, European Commission

Yongqian Liu
Professor of Wind Power Systems, New Energy School, North China Electric Power University

Herbjørn Haslum
Head of floating wind technology,
Equinor

Nenad Keseric
Senior Vice President Innovation and Technology Development,
Statnett



Lena Kitzing
Head of Section, Department of Wind and Energy Systems, Society, Market and Policy, DTU

Jacob Edmonds
Head of Innovation at
Ørsted and VP ETIP wind

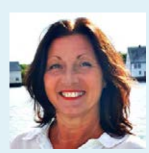
Ignacio Martí
JP Coordinator,
EERA JP wind

Dorothy Dankel
Senior Research Scientist,
SINTEF

Jan-Kristian Haukeland
EVP of Renewables at DOF

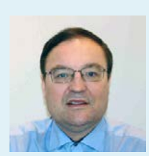
Lars Frøyd
Lead Engineer
– Wind Energy, 4Subsea

Michael Karch
Chief Naval Architect
– Ramboll



Grete Møgster
Business Developer
– Utsira municipality

Paul McKeever
Head of Electrical Research,
ORE Catapult



Trond Kvamsdal
Professor, NTNU, head of NorthWind SAC and co-chair of EERA DeepWind

John Olav Tande
Chief Scientist at SINTEF, director of NorthWind and chair of EERA DeepWind

Some of the participants in the EERA DeepWind hackathon: Ivana Lapšanská (Bundesanstalt für Materialforschung und -prüfung), Daria Cislo (IDCORE), and Olga Usachova (NTNU).

This photo captures the vibrant atmosphere at the EERA DeepWind conference, where scientists and industry professionals convene to exchange ideas and drive innovation.

We have therefore elected to include it in the report for 2023, although the conference itself took place in January of 2024.

First EERA DeepWind hackathon

The EERA DeepWind Conference was preceded this year by the very first EERA DeepWind hackathon, organised by NorthWind partner Equinor. The theme was "Offshore wind integration". Three teams were formed: one working on an ambitious wind farm-scale digital twin; and two working on an an educational energy strategy game to help explain the workings of the energy system to the public.

VALUE FOR INDUSTRY PARTNERS

Chief Scientist Salvatore D'Arco is at work in NTNU and SINTEF's Smart Grid Laboratory. Integrating a large share of wind power into an electrical grid presents challenges in maintaining system inertia and frequency regulation, as wind turbines inherently lack the rotational mass and controllability of conventional generators. Research Scientists at the Smart Grid Laboratory are working on solutions to this challenge.

- 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

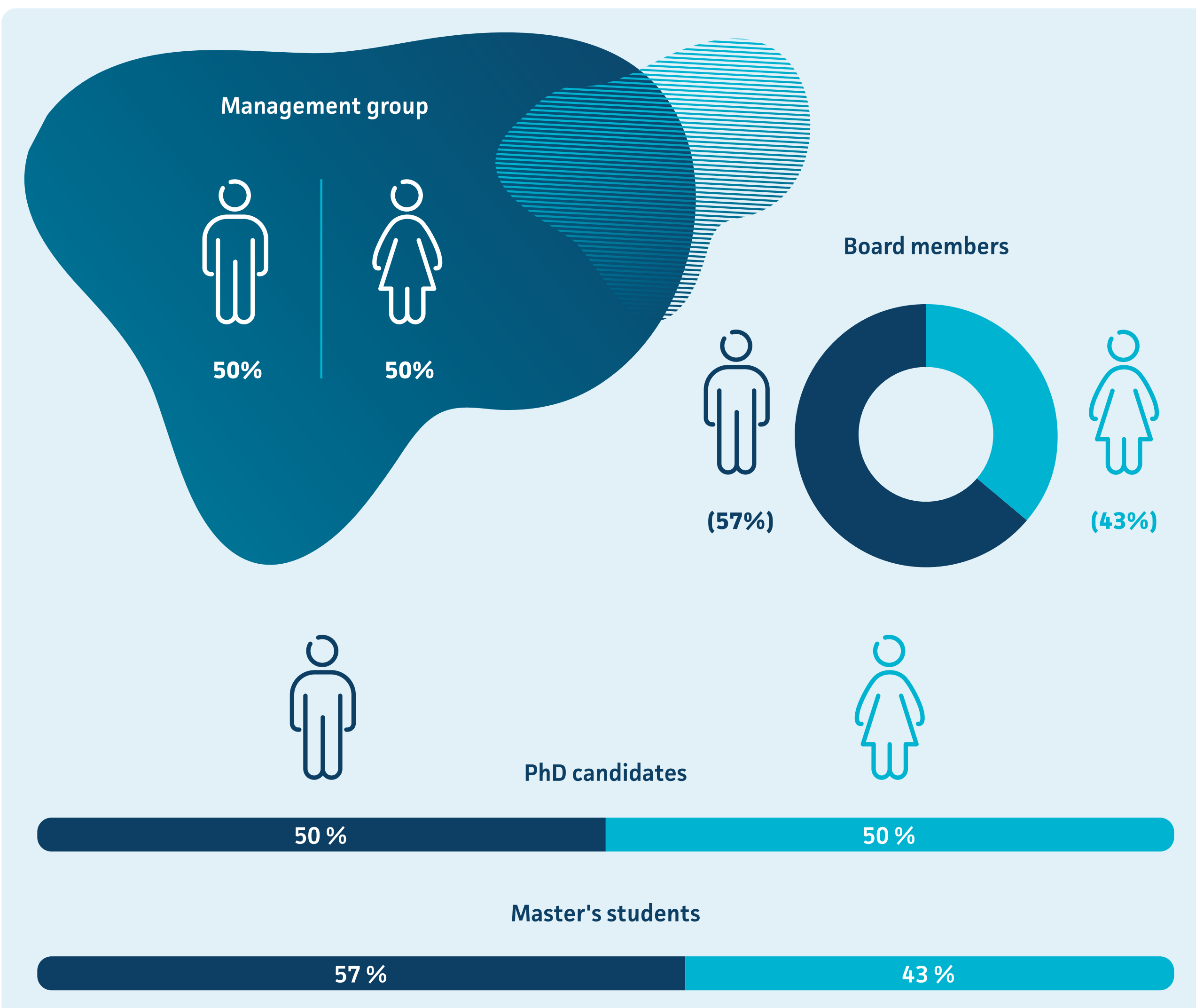
User case studies

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. The case studies are led by industry partners, to ensure that their focus is calibrated to the needs of the industry. You can read descriptions of selected user case studies on which work has started in the Research and results section of this report.

GENDER EQUALITY

NorthWind's management group has good gender balance (50/50). Women were encouraged to apply to our PhD programme, and 7 out of 14 of the funded PhD candidates are women. On the MSc front, 43% of the candidates who completed in 2023 are women.

At the time of printing, the gender balance on the Board has improved slightly, with 4 of its 11 members being women (compared to 3 the previous year). The change was announced at the end of 2023 and became official early in 2024.



OUR CONTRIBUTION TO A MORE SUSTAINABLE WORLD

NorthWind's research in more efficient and sustainable wind energy contributes to reaching 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.

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.

NorthWind's research partners are involved in several EU project applications in the field of wind power, both as partners and as coordinators. In 2023, partners were awarded several relevant EU projects, such as INF4INiTY, MARINERG-i, Digiwind, MADE4WIND, MISSION, TAILWIND and WILLOW. Partners were also involved in projects Scarlet and Wendy, which started at the end of 2022.

Network activities through EERA JP Wind[1] and ETIPWind[2] reinforce the European cooperation. FME NorthWind partners are active in these organisations. SINTEF Ocean's Vibeke Stærkebye Nørstebø leads the EERA JP Wind subprogramme Social, environmental and economic issues while SINTEF Energy Research's John Olav Tande leads the subprogramme on Offshore Balance of Plant, with support from Konstanze Kölle (also from SINTEF Energy Research). John Olav Tande is also a member of ETIPWind's Steering Committee.

The international cooperation aspect of NorthWind is strengthened by the fact that several of the Centre's partners are involved in the International Energy Agency Wind Technology Collaboration Programme (IEA Wind TCP). This strengthens networking possibilities and helps ensure that NorthWind partners are up to date with the latest developments on the international research front. NorthWind's participation includes leadership or participation in IEA Wind Tasks which are thematically relevant to Norway's offshore wind exports. The following NorthWind key researchers are involved: Magnus Korpås, NTNU, Task 25 (Design and Operation of Energy Systems with Large Amounts of Variable Generation); Konstanze Kölle, SINTEF, Task 49 (Integrated Design on Floating Wind Arrays – IdeA); Roel May, NINA, Task 34 (Working Together to Resolve Environmental Effects of Wind Energy – WREN); and: Erin Bachynski-Polić, NTNU, Task 30 (Offshore Code Comparison Collaboration, Continuation, with Correlation and Uncertainty – OC6).

Ongoing efforts to create a European Centre of Excellence

NorthWind is collaborating with EERA JP Wind to promote the establishment of a European Centre of Excellence on wind energy, with research in floating wind and large-scale integration of offshore wind. This envisioned Centre of Excellence would function similarly to NorthWind but on a European scale, and would receive joint financing from European partners. The aim is to accelerate progress by using resources more efficiently in sectors ripe for innovation, thereby creating value and boosting exports. Norway is well-positioned to play a pivotal role in this centre, which would support the growth of a European market for

Norwegian offshore wind technology, expertise, and products. This market is significant, as the European target of achieving 300 GW of offshore wind power by 2050 will necessitate investments of around 1000 billion EUR.

Research deal signed with European research institutions

In May, the directors of NorthWind and ForWind (a German wind energy research centre) signed a Memorandum of Understanding for joint offshore wind energy research. This agreement was meant as a step towards the development of a European Centre of Excellence for Offshore Wind Energy.

This was followed in September by the signing of a memorandum of understanding about the establishment of such a Centre, by representatives of nine European research institutions. The institutions in question include NorthWind partners NTNU and SINTEF; NorthWind associated partners DTU, TNO, and Fraunhofer; and research organisations ForWind, ORE Catapult, CENER, and CIEMAT.

The signing took place at an event organised in collaboration with the Norwegian embassies in the Netherlands, Belgium, Denmark and Germany. The goal of the event was to gather businesses, government, and research institutions to strengthen collaboration on offshore wind between these countries. The event was the first of a series of four meetings organised by the GreenShift project, which aims to serve as a catalyst for European collaboration in offshore wind, CCS and green maritime shipping.

Cooperation countries outside the EU

All of Norway's priority cooperation countries outside of the EU/EEA, namely Brazil, Canada, India, Japan, China, South Africa, the United States, and South Korea, are relevant with regards to collaboration in the field of wind power.

A memorandum of understanding about the establishment of a European Centre of Excellence on offshore wind research and innovation was signed at the Norwegian embassy in The Hague. Left to right: Nils Røkke, VP Sustainability, SINTEF; Bård Ivar Svendsen, Norway's Ambassador to the Netherlands; John Olav Tande, Director of FME NorthWind. Photo: Aurora Haug Lilleløkken, SINTEF.

A wind power research project with China, CONWIND 2020-2023 was completed during the course of the year. Such projects are important for advancing research, but also for network building and developing industrial opportunities. Brazil, Japan, the US, and South Korea have a particular interest in floating offshore wind and stand out as especially relevant cooperation countries, both in terms of research and in terms of opportunities for industrial projects and exports.

1 EERA JP wind: European Energy Research Alliance joint programme on wind energy

2 ETIP wind: European Technology and Innovation Platform on wind energy

At the EERA DeepWind conference: Aurora Andersson, from NorthWind partner organisation Fred Olsen Seawind, presents her company's user case – a collaboration with FME NTRANS and FME NorthWind to determine how to develop Utsira Nord in a just and inclusive way.

COLLABORATION WITH OTHER FMES AND RESEARCH CENTRES

NorthWind has an academic collaboration with several centres. The collaboration with NTRANS is particularly active in the areas of ocean grids and sustainability. The two centres share a user case, led by Fred Olsen Seawind, looking at how to develop Utsira Nord in a just and inclusive way. There is also an ongoing collaboration with SFI BLUES in floating structures, and with LowEmission in electrification of the Norwegian continental shelf.

Arendalsuka

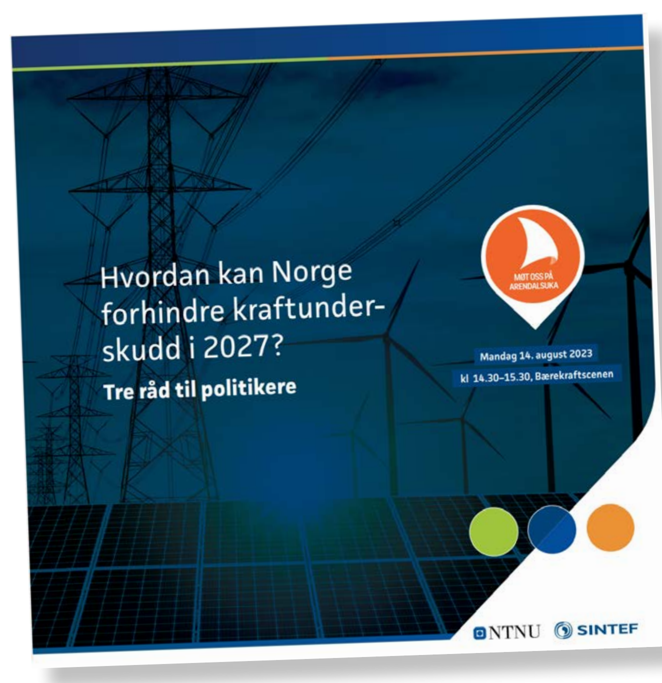
Arendalsuka is a large political gathering that is held annually in Arendal, Norway. The event's mission is to strengthen the belief in political empowerment and democracy through open debate and involvement. NorthWind collaborated with other FMEs (CINELDI, HighEFF, HydroCEN, HYDROGENi, NCCS, NTRANS and ZEN) in providing recommendations to politicians on how to avoid a power shortage in Norway in 2027.

In addition, NorthWind participated to two events: “How to cut emissions on the Norwegian continental shelf in the midst of an electricity price crisis?” (in Norwegian: *Hvordan kutte utslipp på norsk sokkel i en strømpriskrise?*) and “Wind in the sails for Norway’s offshore wind efforts” (in Norwegian: *Vind i seilene for norsk havvindsatsing*). These events were organised in collaboration with FMEs NCCS and HYDROGENi, as well as with the research centre LowEmission.

NTNU Energy Transition Conference

NorthWind’s Magnus Korpås (deputy lead of WP3) participated in a session about the role of infrastructure and storage, at the NTNU Energy Transition Conference on 21 March. The Conference is co-organised by NTNU and several FMEs, including NorthWind.

*The document “How can Norway avoid a power shortage in 2027” (*Hvordan kan Norge forhindre kraaftunderskudd i 2027*) provides recommendations to policymakers.* »



RESEARCH AND RESULTS

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.

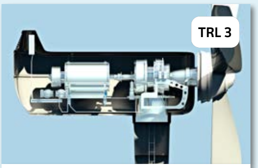
The secondary objectives are to:

- 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).

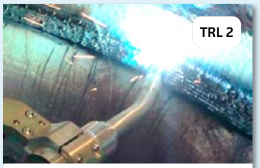
Innovations

2023 saw us further strengthen our work with innovations, and the interplay between research and industry. Consulting firm Impello was contracted to more closely analyse and evaluate the Centre's innovations with regard to their potential for commercialisation and for benefiting the industry, as well as for the status of their development. Innovations touch all of NorthWind's main research topics (offshore wind foundations, marine operations, electrical infrastructure, digital solutions for monitoring and control, and sustainable development). They are categorised according to their technology readiness levels (TRL). A Centre such as NorthWind will typically develop innovations up to TRL=5 (validation in the laboratory or field)). As they develop, the innovations will be adopted as user cases or spin-off projects, led by one or several industry partners, and brought into practical use for the benefit of the industry and society in general.

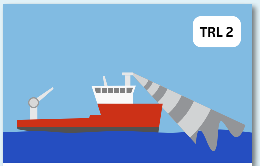
Numerical model for identification of critical soil layers



Digital twin of the drivetrain based on more accurate material and damage data



Acoustic emission for laser welding process monitoring



Methodology for wave and motion feed-forward control for wind turbine blade installation

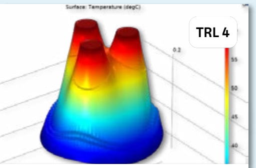
SMARTMOW – Logistics decision support tool for predictive maintenance at offshore wind farms

Reliability-based structural design

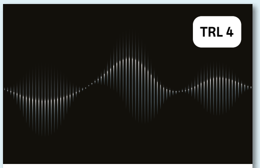
LAWH: A cost-effective manufacturing technology for offshore wind structures

Optimised power cable installation for coupled tension-torque behaviour

New procedures to identify operational limits more efficiently



Dynamic rating of inter-array cables using weather forecast



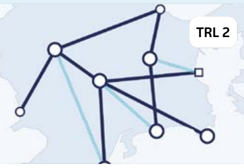
Improved health monitoring by using acoustic emission

Additive manufacturing for on-site repair and maintenance of offshore wind structures

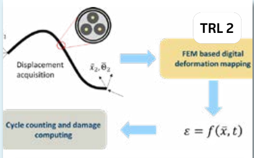
Improved understanding of GBS (gravity-based substructures) installation

COSMO – Computer tool for optimisation and simulation of marine operations for installation of offshore wind farms

MVDC components for ±80 kV



132 kV collection grids



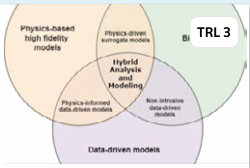
Mechanical map-based real-time damage assessment

Non-intrusive reduced order model

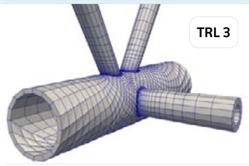
AviSite – LCA-based cumulative effects

Diffusion and innovation models for offshore wind technology

New material model for power cables



Hybrid analysis and modelling



Aroma: Software for generating Reduced Basis Models (RBM) from existing high-fidelity simulation setups

ConSite – Socio-ecological and economy trade-offs (onshore)

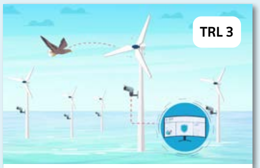
Sustainability assessment modes

Combined testing and multiscale characterisation procedure for high cycle fatigue

Digital twin framework

Multiscale wind simulation

ConSite – Socio-ecological and economy trade-offs (offshore)



SKARV: Preventing bird strikes with active control of wind turbines

WORK PACKAGE 1
STRUCTURES AND INTEGRITY

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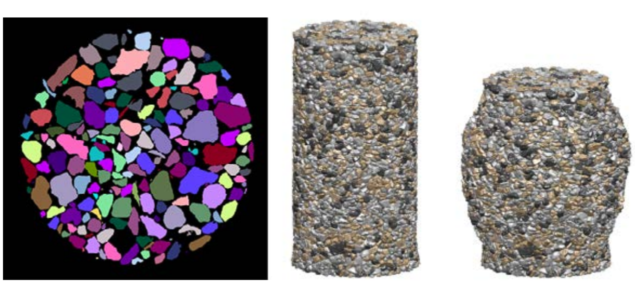
Objective

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 2023

Establishing a sand database

For geotechnical engineering, databases of soil test results have played an important role in the development of offshore energy infrastructure. The availability of these databases provides valuable tools for designers, instilling confidence in the process of determining geotechnical design profiles.



A database, comprising all the physical geotechnical tests conducted at NGI on offshore sands, has been established. This database includes index properties and advanced laboratory test results for sand, which will be made accessible through an Application Programming Interface (API). However, with the growing emphasis on achieving net-zero greenhouse gas emissions, there has been increased pressure on offshore wind supply chains, leading to concerns about the capacity of soil investigation laboratories.

To address this challenge, the Level Set Discrete Element Method (LS-DEM) has emerged as a promising technology for virtual simulations of soil element scale tests. The virtual laboratory employs LS-DEM, a particle-based model that enables the simulation of sands with varying grain size distributions and grain shapes. This tool can be seamlessly integrated with data from the database and used to predict soil behaviour, aiding in decision-making during the early stages of a project before site investigations are conducted. Dogger Bank sand, typically found in the North Sea region, alongside Hokksund sand, Karlsruhe sand, Øysand and Ottawa sand were selected for this study. Three different approaches were used to define grain morphology and create 3D level set avatars: clones based on material descriptions by laboratory technicians, clones based on 2D images with corresponding image processing, and full 3D CT scans with subsequent image processing.

The objective is to subject virtual samples created by these three methods to various stress paths and compare the results to physical laboratory test results available for Dogger Bank sand. A paper detailing the work conducted in 2023 has been submitted to the

ECSMGE 2024 conference, and work on comparing virtual sampling test results to physical laboratory results is currently underway. These findings will eventually be compiled into a journal publication.

Nonlinear hydrodynamic loads

This year, the research focused on several activities. First, a poster presentation and paper on the numerical study examining the nonlinear and viscous loads on the INO WINDMOOR floater in regular waves was prepared and finalised for EERA DeepWind 2023. This study applied computational fluid dynamic (CFD) techniques to investigate the effect of the free surface on the local drag forces. The results from the CFD study provided a good basis for further analysis where drag coefficients for the Morison load model are extracted from the local nonlinear forces. These coefficients can be applied in more efficient global simulation models. This work will continue in 2024 and is expected to lead to another publication. In addition to the above study, a separate work on testing and validating full quadratic transfer functions (QTFs) for wave drift forces for conditions with steep waves and current has been carried out. A summary of the results is currently being prepared in is expected to be published in 2024.

Uncertainty analysis of hydrodynamic experiments of floating wind turbines

The first stage of the uncertainty analysis of a hydrodynamic experiment of the 12MW INO WINDMOOR semisubmersible floating wind turbine was presented at the OMAE2023 conference. This work provided valuable insights into the uncertainties associated with the mooring system modelling and its impact on hydrodynamic testing of floating wind turbines. The next stage of the study will focus on a larger set of uncertainty sources – on how it impacts the model test result. A Monte Carlo method is applied, and a convergence study was carried out in order to determine how many sample simulations are needed to have confidence in the analysis. The work is still ongoing and will continue in 2024 before a full paper on the topic is published.

Materials integrity in the drive train

The research paper 'Material Failures on Offshore Wind Turbines', which includes a literature review and future research outlook, was presented at the Annual Innovation Forum in December, highlighting key findings and insights. Central aspects are that "the lifetime of gears in wind turbines is affected by the operation conditions, the preceding materials selection and manufacturing processes of the gear". New technologies for increasing steel quality and enhance fatigue properties are receiving much attention. More knowledge and technologies are also needed for surface treatment processes to optimise the compressive residual stress field at the contact surface, while considering the contact stresses during operation and reduce shear stresses in the material.

ANEO have proposed to make a failed bearing available for material analyses within FME NorthWind, and we are looking forward to investigating this component in 2024.

How to ensure robust laser-arc welding process and high-quality welds?

Laser-arc hybrid welding (LAHW) is an efficient and promising welding technology for manufacturing offshore wind substructures. In 2022, we performed laboratory testing and demonstrated that LAHW may offer 5-24 times higher productivity, resulting in a significant cost reduction for wind turbines. In 2023, we addressed another important issue related to LAHW: how to ensure good weld quality. Despite LAHW showing high efficiency, it is also important to achieve defect-free welds and fulfil strict material and structural integrity requirement due to offshore wind's harsh service conditions.

We tested the acoustic emission (AE) technique for LAHW process monitoring in our laboratory. After welding, an X-ray Computed Tomography (μCT) scan of the weld was performed, and a full picture of defects was generated. Post-processing of AE sound signals was performed, and a first attempt for correlating defects and signals was made. Unfortunately, the result was not as good as we expected. However, this test has shown the great potential of applying cheap AE sensors for fast defect detection during welding. This test also triggered an exciting discussion between WP1 and WP4 for possible collaboration related to developing a digital twin for anomaly diagnosis in manufacturing of offshore wind substructures. The development will be continued in 2024.

Publications and PhDs

A total of four peer-reviewed publications were produced within this work package in 2023. See the list of all publications in the Appendix. Work package 1 is involved in the supervision and guidance of two PhD candidates (Veronica Liverud Krathe and Afolarinwa David Oyegbile) and one associated PhD (Øyvind Torgersrud). See pages 56-59 for details.

INNOVATION

Laser-arc hybrid welding (LAHW)

The innovation LAHW has been further developed in 2023 in terms of optimising process parameters, improving process stability, and reducing defects in the weld as well as using AE for process monitoring. Some improvement has been achieved; however, the innovation is still at a low TRL (2-3).

User cases

Generic sites (lead: 4Subsea)

The purpose of this user case is to compile site and environmental properties relevant for the Norwegian offshore wind lease sites as a common basis for research within and outside FME NorthWind, and to support the industry's need for data during early site development phases. The industry partners have gathered and processed site data from open access data sources and are in the process of reporting.

Next generation condition monitoring (lead: Kongsberg Maritime)

This user case explores Acoustic Emission as a tool to improve sensitivity and accuracy in health monitoring. The objective is the development of predictive models for fatigue and environmental degradation supporting models for remaining useful lifetime and mitigation strategies. The user case is connected to Task 1.3: Lifetime, performance, and integrity where material investigation of turbine bearings will be carried out. A central activity in 2023 has been the monitoring of two of ANEO's turbines at Bessakerfjellet. A new IPN project, MarCoPoLo (2023-2027), supports the signal processing.

Cost-effective manufacturing (lead: Aker Offshore Wind)

The goal of this user case is to develop high-efficiency manufacturing technologies for mass production of substructures. The user case is led by Aker Offshore Wind. Several other industry companies have contributed to its development as well. In 2023, more industry partners were engaged related to LAHW process and non-destructive (NDT) method.

Aluminium in offshore wind (lead: Hydro Aluminium)

This user case introduced in 2022 explores the potential of aluminium for offshore wind applications, e.g., nacelle parts, cooling parts, turbines, taking advantage of aluminium as a material for lightweight design, increased recyclability, and anticorrosive solutions. A workshop on "Aluminium in Offshore Wind" was held at the Innovation Forum in December, which motivated user case proposals both related to substructures and electric cables (in collaboration with WP3).

WORK PACKAGE 2
MARINE OPERATIONS AND LOGISTICS

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Objective

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

Main results from 2023

Installation and replacement operations

- Presentation of "OWT Installation methods" at EERA DeepWind 2023
- Paper: Jiang, F., Yin, D., Califano, A., Berthelsen, P.A., Application of CFD on VIM of semi-submersible FOWT, Journal of Physics: Conference Series, volume 2626, 2023
- Several master's theses on installation and major component replacement operations of offshore wind
- PhD candidate working on "An approach for safe and cost-effective installation of offshore wind power cables"

Service Operation Vessel (SOV) for offshore wind turbines

- Presentation of "Investigation towards efficient W2W operability simulations" at EERA DeepWind 2023.
- Development of an interface to provide hydrodynamic vessel models for more accurate logistics optimisations in COSMO
- Further development of the calculation procedure for generating relative motion RAOs, enabling the industry to perform operability studies for offshore floating wind more efficiently in the frequency domain
- Investigation of the additional requirements for simulation and execution of marine operations when advancing from bottom-fixed to floating offshore wind

Optimisation models for planning marine logistics operations

- Presentation of "Optimising jack-up vessel chartering strategies to support maintenance at offshore wind turbines" at EERA DeepWind 2023
- Paper: Halvorsen-Weare, E.E., Nonås, L.M., Maritime logistics optimisation for predictive maintenance at offshore wind farms, Journal of Physics: Conference Series, volume 2626, 2023
- PhD candidate working on "Predictive maintenance planning at offshore wind farms"
- Further developed COSMO, a decision support tool for planning the maritime logistics of the installation of large offshore wind farms

INNOVATION

Improved analysis methods for safe personnel transfer to floating offshore wind turbines

For floating offshore wind turbines in harsh environmental areas, the safety of personnel transferred from supporting vessels to the installations

Photo: UPTIME International AS

is of concern. Service vessels equipped with motion-compensated gangway systems are known to represent the state of the art in providing access to offshore wind turbines.

Accurately modelling the motion behaviour of floating bodies in an environment of waves, wind, and current is crucial for precise performance predictions. The traditional efficient way of performing operability studies is to calculate vessel motions, responding to wave excitation forces, by linear first-order wave-induced forces in the global coordinate system. This procedure is only applicable when calculating operations towards stationary, bottom-fixed landing points. For simulations towards floating wind turbines, the motion of the vessel and the floating wind turbine structure must be simulated separately using two discrete Response Amplitude Operators (RAOs) and solved together in the time domain.

To enable the industry to use efficient and well-known frequency-domain simulations further, the data from the two RAOs are combined as one relative motion RAO, describing the motions of the two bodies in one transfer function. This innovation allows the industry to use the same operability assessment strategy for future floating wind projects. It provides a cost-effective simulation method for making quick decisions in ensuring safe and effective personnel transfer to floating offshore wind turbines.

User case

COSMO (lead: SINTEF)

COSMO is a computer tool designed for the analysis of marine operations for an offshore wind farm. The tool offers a digital representation of the maritime logistical operations and is designed to:

- Minimise total time for installation of an offshore wind farm
- Minimise risk of delays, e.g., related to weather
- Minimise total cost of installation of an offshore wind farm

The tool can also be used by vessel and installation concept developers to evaluate the effects of new concepts at an early stage.

A few generic cases are being developed to be available for all NorthWind partners. Furthermore, the industry partners have started identifying realistic case studies where COSMO will be used to evaluate different solutions. The tool will also be further developed based on input from testing by project participants.

WORK PACKAGE 3
ELECTRICAL INFRASTRUCTURE AND SYSTEM INTEGRATION

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Objective

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 2023

Combined User Case and research task: 132kV collection grids

A research task led by Andrzej Holdyk, SINTEF, and a user case led by Jalal Khodaparast from Mainstream with contributions from Statkraft, have both studied power system challenges in a 132 kV collection grid compared to a traditional 66 kV grid. Their joint work was presented as a poster at the EERA DeepWind conference in January 2024.

As wind farms and individual turbines grow in power output, a transition towards higher inter-array voltage level will be necessary to reduce the total number of cables needed and the losses related to power transfer at lower voltages. Increasing voltage level requires careful considerations and design investigations to guarantee the best solution. Two designs of large wind farms were benchmarked, one with a 66 kV collection grid and one with a 132 kV grid. A variety of power system analyses were conducted to assess the feasibility of the voltage transition within the inter-array network. Mainstream Renewable Power (MRP) focused on load flow analysis, reactive power management, export cable voltage, current profiles, and maximum direct connection lengths, while SINTEF performed resonance analysis and harmonic evaluations. The study provided valuable insights for optimising the 132 kV inter-array cable network and advancing the Technology Readiness Level (TRL) to meet the growing demands of offshore wind energy integration.

Publications (peer-reviewed)

Cali, U., Kantar, E., Pamucar, D., Deveci, M., Taylor, P., Campos-Gaona, D., Anaya-Lara, O., Tande, J.O., Offshore wind farm site selection in Norway: Using a fuzzy trigonometric weighted assessment model, Journal of Cleaner Production, Volume 436, 2024, 140530, ISSN 0959-6526.

Gustavsen, B.A., A 2D FEM Model for Impedance and Loss Calculation of Armoured Three-Core Cables with Inclusion of 3D Pitching Effects, IEEE Transactions on Power Delovert 2023, Volume 38.(5) p. 3010-3020.

D'Arco, S., Suul, J.A.W., Phase Angle Feed-Forward Control for Improving the Power Reference Tracking of Virtual Synchronous Machines, IEEE transactions on industry applications 2023; Volume 60 (1) p. 851-864.

Gustavsen, B.A., Rational Function Approximation of Transformer Branch Impedance Matrix for Frequency-Dependent White-Box Modelling, IEEE Transactions on Power Delivery 2023; Volume 38 (5) p. 3045-3057.

Chabaud, V.B., Synthetic turbulence modelling for offshore wind farm engineering models using coherence aggregation, Wind Energy 2023, Volume 27 (2), p. 111-130

Gustavsen, B.A., A 2D FEM Model for Impedance and Loss Calculation of Armored Three-Core Cables with Inclusion of 3D Pitching Effects, IEEE Transactions on Power Delivery 2023, Volume 38 (5), p. 3010-3020

Horstad, T.I., Cali, U., Dynge, M. F., Korpås, M., Chapaloglou, S., Gallego-Calderon, J.F., Co-Simulation Model for Optimal Wind-Hydro Coordination Using Wind Farm Control Dynamics, 2023 International Conference on Smart Energy Systems and Technologies - SEST, IEEE 2023, ISBN 979-8-3503-9790-1

Kantar, E., Hvidsten, S., Aakervik, J., Effect of Radial Pressure and Lubricant Types on Partial Discharge Inception in a Slip/On Medium Voltage XLPE Cable Termination, Jicable'23 - 11th International Conference on Power Insulated Cables, Lyon - France 18-22 June 2023, proceedings, SEE 2023 ISBN 9782959042409

Linhjell, D. Mehammer, E.B., Dynamic moisture diffusion in transformer winding insulation, Journal of Physics: Conference Series (JPCS) 2023, volume 2626

Serk-Hanssen, K., Sletta, H.B., Cali, U., Belsnes, M.M., Kwon, J., Dynge, M.F., Optimization of Wind Scheduling for Improved Power Market Integration Through Up-Regulation Prices, 2023 International Conference on Smart Energy Systems and Technologies - SEST, IEEE 2023, ISBN 979-8-3503-9790-1

Vrana, T.K., Svendsen, H.G., Korpås, M., Couto, A., Estanqueiro, A., Flynn, D., Holttinen, H., Härtel, P., Koivisto, M., Lantz, E., Frew, B., Improving wind power market value with various aspects of diversification, 2023 19th International Conference on the European Energy Market - EEM, IEEE 2023, ISBN 979-8-3503-1258-4

PhDs

Lorrana Faria da Rocha, NTNU: Exploring a novel HVDC Drive to decrease cost of offshore wind energy
Department: Electric Energy
Main supervisor: Associate Professor Pål Keim Olsen
Period: 2021-2024

Arkaitz Rabanal Alcubilla, NTNU: Energy storage for grid services in HVDC connected offshore wind farms
Department: Electric Energy
Main supervisor: Professor Elisabetta Tedechi
Period: 2021-2024

Ingvild Ånestad, UiO: Regulatory aspects for development of offshore grid infrastructures
Department: Scandinavian Institute of Maritime Law
Main supervisor: Professor Catherine Banet
Period: 2023-2027

INNOVATION

132kV collection grids

Design of 132 kV collection grids for decreased harmonic interactions between turbines

A transition towards higher inter-array voltage level will be necessary to reduce the total number of cables needed and losses related to power transfer at lower voltages, as windfarms and individual turbines grow in power output. There are several technical challenges related to this transition – power system stability and power quality among the most important. NorthWind research has shown that a higher voltage level indeed decreases the system resonance frequency, which can potentially lead to more harmonic problems, e.g. resonance interactions with wind turbines and resulting stability issues or increased harmonic emissions and increased costs for filtering. Work is ongoing to improve the harmonic representation of wind turbine models to be able to investigate these phenomena in detail.

Undesired resonance interactions in the electrical system can lead to high overvoltages and the failure of major components, causing long interruptions in production to carry out repairs.

WORK PACKAGE 4
DIGITAL TWIN AND ASSET MANAGEMENT

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Objectives

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

Main results from 2023

Digital Twin adapted for wind energy

Harmonising the definition of digital twin and its capability level: In collaboration with key industry stakeholders, a consensus on the concept of digital twins and their operational capabilities was established and subsequently disseminated. Challenges impeding the advancement and widespread acceptance of this technology were identified, and a compendium of potential remedies was assembled into a scholarly journal article.

- Stadtmann, F., Rasheed A., Kvamsdal, T., Johannessen, K.A., San, O., Kölle, K, Tande, J.O., Barstad, I., Benhamou, A., Brathaug, T., Christiansen, T., Firle, A.L., Fjeldly, A., Frøyd, L., Gleim, A., Høiberget, A., Meissner, C., Nygård, G., Olsen, J., Paulshus, H., Rasmussen, T., Rishoff, E., Scibilia, F., Skogås,J.O., Digital Twins in Wind Energy: Emerging Technologies and Industry-Informed Future Directions, IEEE Access, 11, 110762-110795, 2023

Data consolidation and integration framework: To elucidate the concept of a digital twin, the initial endeavour entailed consolidating data, recognising the pivotal role of high-quality data as the bedrock for a realistic digital twin. Subsequently, data curation involved sourcing information from three distinct channels: (a) publicly available datasets such as weather data, (b) data obtained from project collaborators, and (c) confidential data necessitating anonymisation. Additionally, the incorporation of (d) reverse-engineered data and (e) synthetic data generated through numerical simulations was undertaken.

Following this data compilation, an asset information model was collaboratively developed with DNV to standardise data, thereby facilitating the scalability of digital twin technology. Subsequent to model development, a data integration framework was deployed to seamlessly merge data from diverse sources, ensuring its availability on demand while upholding stringent data quality standards. This integrated dataset served as the foundation for constructing computationally efficient and precise models. The culmination of these endeavours resulted in the establishment of two reference wind farms, one onshore and one offshore. The comprehensive findings and methodologies employed throughout this process are documented in the following papers:

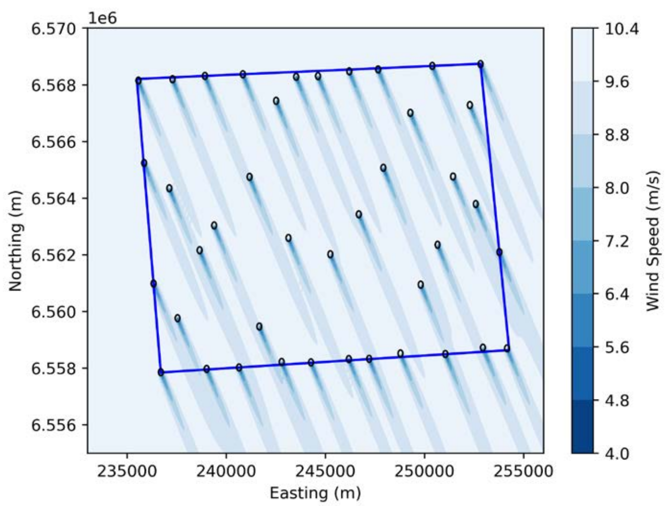
- Stadtmann, Florian; Mahalingam, Hary Pirajan; Rasheed, Adil. (2023) Data Integration Framework for Virtual Reality Enabled Digital Twins. IEEE 9th World Forum on Internet of Things , Aveiro, Portugal 2023-10-12 - 2023-10-27
- Panjwani, B., Development of an aerodynamic and geometric model of wind turbine for Zefyros project, SINTEF Report no. 2024:00244

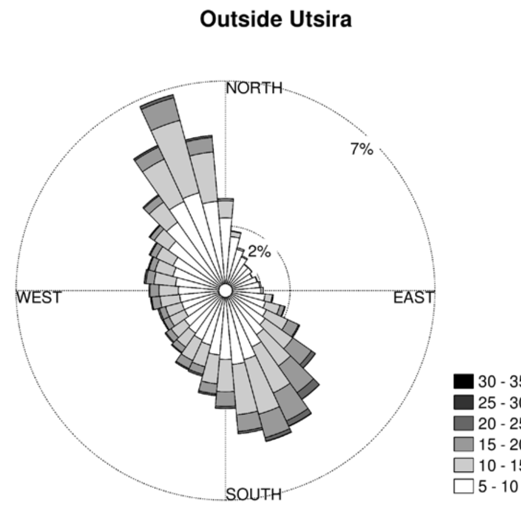
Novel modelling paradigm: This work involved developing a novel modelling paradigm, hybrid analysis and modelling, that combines the strengths of both physics-based modelling and data-driven modelling. Three approaches have recently been developed, known as the Corrective Source Term Approach (CoSTA), Physics-Informed Generative Adversarial Networks (GANS) and Component / Chain Reduced Order Modelling (ROM). The CoSTA method has been applied to model solid mechanics problems in situation where physics is only partially known, massive simplifications are inflicted to gain computational efficiently, or physics input parameters are not precisely known. The GANS model has been used to improve the spatial resolution of the wind field computed in complex terrain. It is shown that through this approach one can get the accuracy of a high-fidelity simulation approach at a fraction of the cost corresponding to a coarse resolution simulation. In the component-ROM, a LEGO based approach is used to develop ROM of simple geometries which can be combined to build more complex geometries. In the current work, the approach was applied to fluid mechanics and solid mechanics applications to solve for flow around airfoils and mechanical stresses in trusses. The work has been compiled in the form of the following articles:

- Sørbø, S., Blakseth, S.S., Rasheed, A., Kvamsdal, T., San, O., Enhancing Elasticity Models with Deep Learning: A Novel Corrective Source Term Approach for Accurate Predictions, Applied Soft Computing, 111312, 2024
- Wold, J.W, Stadtmann, F., Rasheed, A., Tabib, M., San, O., Horn, J., Machine learning for enhancing wind field resolution in complex terrain, Under review
- Fonn, E., Brummelen, H., Eftang, J.L., Rusten, T., Johannessen, K.A., Kvamsdal, T., and Rasheed, A, Least-squares projected models for non-intrusive affinization of Reduced Basis Methods, Under review
- MSc. Thesis 2023: Wold, JW, GAN Based Super-Resolution of Near-Surface 3D Atmospheric Wind Flow with Physics Informed Loss Function

Online park design/optimisation and annual energy prediction (AEP) estimation tool for floating offshore wind farms: In this study conducted by Norconsult, the utilisation of the open-source Julia code (FLOW-Farm.jl) is showcased. The application focuses on the Offshore wind farm use case situated in project area 3 for the Utsira Nord tender announced by the Norwegian Government in 2023. The proposed layout, featuring 41 15MW turbines, is depicted in the figure provided. Observation reveals some clustering along the northern and southern edges, aligning with the sides perpendicular to the primary wind direction. To validate the efficacy of the FLOWFarm optimisation tool, a comparison with the commercial tool WindPRO1 was conducted to bolster confidence. Both tools were configured similarly, accounting for area restrictions, inflow conditions, and wind turbine specifications, albeit utilising the Jensen wake model in WindPRO instead of the Bastankhah model. Wind farm layout optimisation in WindPRO exhibited a preference for turbine placements along the northern and southern borders, mirroring the results obtained from FLOW-Farm.

A comparison of power production between the two layouts, facilitated by importing FLOWFarm solutions into WindPRO, revealed virtually identical results. Notably, there was a significant discrepancy in optimisation time, with WindPRO requiring hours while FLOWFarm completed the task in mere minutes, all while maintaining low wake losses (3.5%).





Further details and comprehensive findings from this study are elaborated in the following reports:

- Barstad I, Layout optimizing at UniTech Zephyros, NORCONSULT Report
- Barstad I, Reducing climatologies in a power consistent way, NORCONSULT, Report
- Lye, K.O., Tabib, M.V., Johannessen, K.A., 2023. A Reinforcement Learning framework for Wake Steering of Wind Turbines. J. Physics Conference Series 2626, 012051.

Predictive maintenance and decision support for wind energy applications: A novel two-stage regression model for accurate remaining useful life (RUL) prediction using the data from supervisory control and data acquisition (SCADA) system of an offshore wind turbine. The first stage employs nine LightGBM regressors to model the normal behaviours of temperatures. Parameter tuning and feature reduction with a unified metric optimise computational resources without sacrificing high prediction accuracy. Techniques like optimal rolling window selection and principal component analysis (PCA) mitigate seasonality and noise in temperature residuals. Integration of Bayesian neural network (BNN) with gated recurrent unit (GRU) models in the final stage significantly improves the prediction accuracy of RUL. Moreover, the estimation of uncertainties given by BNN provides insights into potential ranges of the failure time, aiding maintenance decision-making. This approach offers a balanced solution for predictive maintenance (PdM) of offshore turbines based on normal behaviour modelling (NBM) and demonstrates its potential to support maintenance optimisation. The work is compiled in the form of the following articles:

- Zhang W, Vatn J, Rasheed A, A two-stage model for RUL prediction of offshore wind turbine based on machine learning, Under review
- Statistical analysis of offshore wind turbine failures, ESREL 2024

Evaluation of farm control strategies: A mid-fidelity simulation framework for large offshore wind farms has been developed at SINTEF, for the efficient joint modelling of active power control and structural degradation due to fatigue damage. It bridges two fields of research that are traditionally split: grid integration and mitigation of asset degradation, through multi-objective wind farm control. Component-level damage is brought to farm-level simulations. There, damage and power demand from the grid are linked to stochastic loads and power fluctuations arising from turbulence in the wind, on which a particular emphasis has been set. In a joint project with NTNU, this has been applied to the mitigation of the degradation of power train components (gears and bearings) in curtailed (down-regulated) wind conditions. It is shown that when a farm is requested not to operate at its full available power by the grid operator, it is possible — to some extent — to steer degradation to better fit maintenance scheduling or lifetime extension plans to further reduce LCOE. More details about the work can be found in the following report:

- Chabaud, V., Kölle, K., Chapaloglou, S., Evaluation of Wind Farm Strategies-Coupling with Drivetrain Degradation, SINTEF Report AN22.12.49

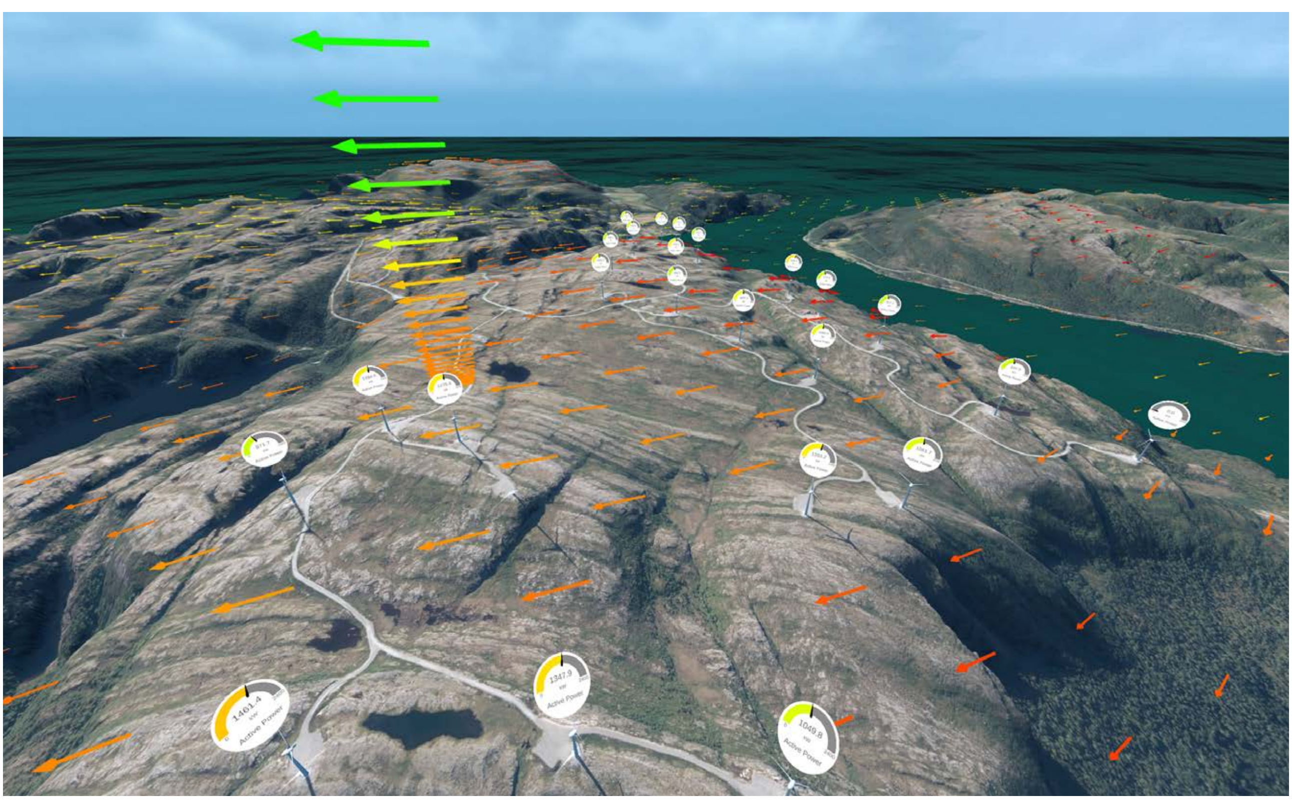
PhDs

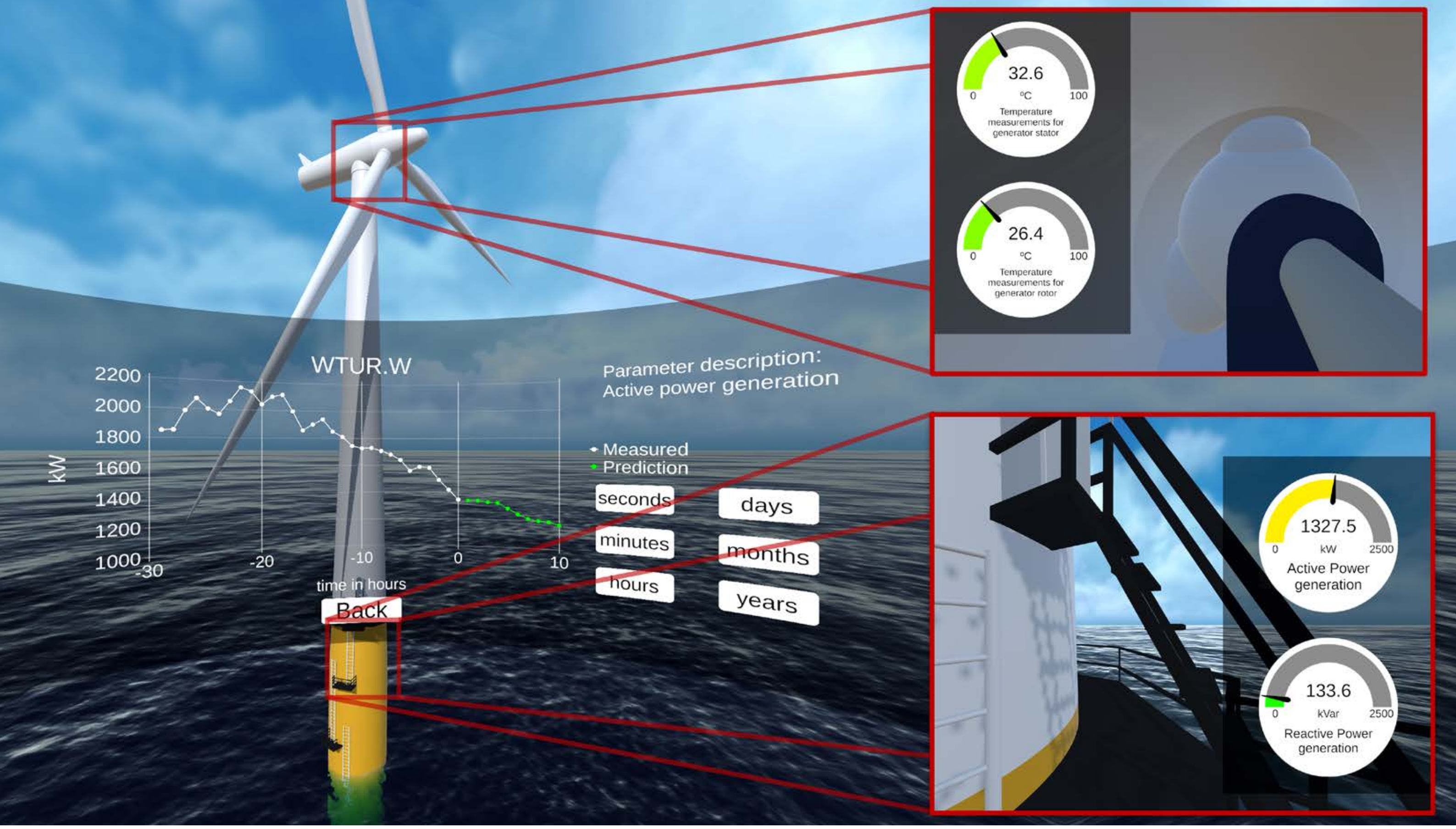
Work package 4 is involved in the supervision and guidance of two PhD candidates, Florian Stadtmann and Wanwan Zhang. See page 57 for details.

User cases

Onshore wind farm (User: ANEO)

This use case involves the creation of digital twins for an onshore wind farm located in complex terrain. Three capability levels have been demonstrated for the Norwegian onshore wind farm Bessakerfjellet: standalone, descriptive, and predictive. First, a standalone digital twin is created using openly available data on the environment and turbines, which is implemented with a 3D interface that can be explored in virtual reality. Second, real SCADA data from the wind farm is utilised to enhance the digital





twin to the descriptive level. In addition to SCADA data, weather forecasts from a microscale model, nested into openly available weather forecasts, are also used to instil further realism. The wind resources are visualised in the virtual reality interface, and hourly power production predictions for up to sixty hours ahead are inferred from the weather data. The wind farm has furthermore been used to demonstrate the potential of using digital twins for decision-making, public outreach, and informed public opinion. Work at the predictive level has shown that numerical microscale weather models are improving the predictions of power production over data-driven approaches and numerical mesoscale weather models, but numerical microscale models are computationally expensive. The usage of generative neural networks has been explored to super-resolve wind fields at the wind farm site.

- Stadtman, F., Rasheed, A., Rasmussen, T., Standalone, Descriptive, and Predictive Digital Twin of an Onshore Wind Farm in Complex Terrain, Journal of Physics Conference Series, 2626, 012030

Offshore wind turbine (User: Sustainable Energy, 4subsea)

In this use case, we introduce the digital twin concept and capability level scale in the context of offshore wind energy. The integration of a standalone, descriptive, and predictive digital twin for the floating offshore wind turbine Zefyros has been demonstrated. The standalone digital twin consists of a virtual representation of the wind turbine and its operating environment, which can be used during the planning, design, and construction phases. The descriptive digital twin enhances the standalone digital twin with real data from the turbine and visualises all the data in virtual reality to aid informed decision-making. The descriptive digital twin serves as a basis for diagnostic, predictive, prescriptive, and autonomous tools. The predictive digital twin is created by utilising weather forecasts, neural networks, and transfer learning. Current work investigates diagnostic capabilities. The prospects of retrofitting wind turbines with diagnostic digital twins for fatigue tracking are explored based on the tower strains of the floating turbine. In a related study, federated learning is suggested as an enabler for digital twins to circumvent data access restrictions. Federated learning allows training machine learning models on decentralised data sets without any need for data sharing.

- Stadtmann, F, Wassertheurer, HAG, and Rasheed, A. Demonstration of a Standalone, Descriptive, and Predictive Digital Twin of a Floating Offshore Wind Turbine. Proceedings of the ASME 2023 42nd International Conference on Ocean, Offshore and Arctic Engineering. Volume 8: Ocean Renewable Energy. Melbourne, Australia. June 11–16, 2023. V008T09A039. ASME.

Future changes in ice induced wind power production losses (lead: Norconsult)

This is a new use case introduced by Norconsult as a result of the expressed interest of NorthWind partners. Atmospheric ice accumulation on the rotor blades of wind turbines causes their power production to decrease due to the influence on their aerodynamic properties. Production losses of 50% or more from land-based wind farms have been observed during winter months characterised by heavy icing. Atmospheric icing is dependent on freezing temperatures, moisture in the form of cloud droplets, and wind. In an increasingly warmer world, it is intuitive to think that the occurrence of icing on wind turbines will decrease. But with warming also comes more moisture. Melting temperatures and hence ice-free periods will occur more frequently in the future, but when icing conditions occur it may be that the icing is more severe. Future projections of temperature and moisture content also vary according to region, and the future icing climate depends strongly on crossings of the 0°C isotherm at specific wind farm locations. Hence, it is not certain how future icing losses will evolve at the local scale. This research will investigate future projections of atmospheric icing frequency and severity from two climate models and three future scenarios, regionally downscaled over Norway, Sweden and Finland. The icing projections will be used to make inferences about changes in ice-induced production losses towards 2050.

INNOVATION

Digital twin framework

The main innovation has been the development of the Hybrid Analysis Modelling (HAM) approaches Corrective Source Term Approach (CoSTA) and Component / Chain Reduced Order Modelling (ROM). These methods have demonstrated high accuracy, computational efficiency, and the ability to model the unknown while utilising existing knowledge to the maximum extent. Consequently, they are seen as powerful enablers for digital twin applications. Without this new family of models, realisation of realistic digital twins is challenging. TRL 2-3.

WORK PACKAGE 5
SUSTAINABLE WIND DEVELOPMENT

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Objective

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 2023

The role of Norwegian wind in the sustainable energy transition

- PhD candidate working on
  - "Circular business development of offshore wind energy" – Pankaj Ravindra Gode (finishing)
  - "Catalysing an Industry: understanding the emerging US offshore wind market through a multi-scalar institutional perspective" – Julian Lahuerta (finishing)
  - "The impact of technological attributes, psychological factors, and personal variables on onshore and offshore wind energy acceptance in Norway" – Chrysi Danelaki
  - "A Revitalisation of the Energy Nation Norway?" – Birgitte Nygaard
- SDG impact analysis from offshore wind development, combined qualitative literature and quantitative global value chain analysis (draft paper version ready)
- Innovation-diffusion model that relates cost and technology learning data of the different components of an offshore wind farm, with the diffusion/uptake of wind offshore (draft paper version ready)
- Workshop on developing scenario pathways

Environmental impacts and options for environmental design

- Above-water impacts: In 2023, we performed the second year of GPS-tracking of black-legged kittiwakes from the colony in Skudeneshavn on Karmøy. The results from the first year of tracking (2022) were presented at the EERA DeepWind conference in Trondheim in January 2023. They demonstrated the importance of the breeding status on the birds' area use. Breeding status and whether the birds are incubating, rearing young, have fledged young or have lost eggs or chicks (failed breeders) therefore affect the exposure to potential threats from offshore wind energy developments. The results from analyses of the 2023 tracking data demonstrate that area use differed from one year to the next, and that the effect of breeding status differed between the two years. We aim to scientifically publish these results which demonstrate the importance of taking breeding status into account and to perform tracking studies over several years for environmental impact assessments of offshore wind energy developments.
- Below-water impacts: A literature review of biological effects on marine communities in Scandinavian waters has been performed and is currently being finalised in a report. In collaboration with the Institute of Marine Research (IMR), NINA has taken eDNA

samples at the Hywind Tampen area, functioning as a baseline, before construction start (see publications below). This will be followed up on in the coming years through the spin-off project WindSys (led by IMR).

- Onshore impacts: The AviSite LCA-mapping application has been published online (see under Innovations below). Also, an MSc student has started analysing white-tailed eagle tracking data to study the effect coastal wind farms have on their movement patterns, and potential collision risks.
- Mitigation options: SINTEF published a scientific paper with a review of four mitigation measures demonstrated in the field and a new patented concept, SKARV, based on active control (not yet tested). This work was also disseminated in popular media outlets (see below). Co-supervision of an NTNU specialisation project on the active control concept to mitigate collisions:
  - Title: Active Wind Turbine Control for Bird Strike Avoidance, Author: Aurora Åsgård Pedersen
  - Supervisors: Prof. Lars Struen Imsland, Kiet Tuan Hoang, Paula Bastos Garcia Rosa
  - TTK4550 - Engineering Cybernetics, Specialisation Project, Department of Engineering Cybernetics, Norwegian University of Science and Technology
- Integrated siting tool: The ConSite tool has been established in a new cloud repository in NINA's Google Enterprise. So far, further development of the ConSite Wind web app includes additional maps, preference weights and new functionality to support a traffic light planning approach. The beta version is now operational. Development of the Online data catalogue is in progress.
- The PhD student working on *"Life-cycle options for ecological restoration: construction to decommission"* has started drafting a literature review on the topic which will be finalised in 2024.

Public engagement, participation and controversy

- PhD candidate working on "The framing of Norwegian wind energy futures – the cases of Svalbard and Sørlige Nordsjø II" – Birgitte Nygaard

Publications

- Skjølsvold, T. M., Heidenreich, S., Henriksen, I. M., Oliveira, R. V., Dankel, D. J., Lahuerta, J., ... & Vasstrøm, M. (2024). Conditions for just offshore wind energy: Addressing the societal challenges of the North Sea wind industry. Energy Research & Social Science, 107, 103334.
- Skjærseth, J. B., Hansen, T., Donner-Amnell, J., Hanson, J., Inderberg, T. H. J., Nielsen, H. Ø., ... & Steen, M. (2023). Wind Power Policies and Diffusion in the Nordic Countries: Comparative Patterns. Springer Nature.
- Oliveira, R. V. (2023, October). Whispers in the Wind: Ethical dimensions of social conflict in offshore wind. In Journal of Physics: Conference Series (Vol. 2626, No. 1, p. 012070). IOP Publishing.
- Utne-Palm, A.C., Søiland, H., Sveistrup, A., Renner, A., Ross, R., Moy, F.E., Paskyabi, M.B., Totland, A., Hannaas, S., de Jong, K., Gonzalez-Mirelis, G., Hovland, T., Pedersen, G., Wilhelmsen, J.F., Majaneva, M., Heum, S.W., Skjold, W., Vågenes, S., Skaret, G., Corus, F., Voronkov, A., Kielland, L. 2023. Cruise report Hywind Tampen 13 to 28 March 2023 - Cruise no. 2023001004 G.O. Sars. TOKTRAPPORT No.10 2023.
- de Jong, K., McQueen, K., Hareide, N.R., Tenningen, M., Macaulay, G., Majaneva, M. 2022. Fisheries survey in the offshore wind power field Hywind Tampen before development. TOKTRAPPORT Nr.15 2022.
- A blog post about the SKARV concept was published on the SINTEF blog: How can control engineering save birds in wind farms? - #SINTEFblog.
- An article about the SKARV concept was published in Gemini (both in Norwegian and English): Vindturbiner endrer fart for å unngå fuglekollisjoner (gemini.no).
- Garcia-Rosa, P.B. and Tande, J.O.G. 2023. Mitigation measures for preventing collision of birds with wind turbines. Journal of Physics: Conference Series 2626: 012072 - IOPscience

User case

Sustainability Readiness Levels (NINA, Aibel)

The draft Readiness levels (technology, societal, environmental) for both turbine design and wind farm development have been presented and discussed at a second workshop with stakeholders. During this workshop, approaches for implementation of the SusRL framework have also been discussed. Further work will consist of finalising the Readiness Levels and proposing the best approach for implementation, as well as applying these in concrete onshore and offshore cases through the Horizon Europe project WENDY and, if of interest, within NorthWind cases.

INNOVATION

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

The AviSite tool has now been launched and is available for use. AviSite has been 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 allows users to 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, the online application constructed and the app publicly released in February 2024. This innovation is currently at TRL 7.

INNOVATION

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. So far, further development of the ConSite Wind web app includes additional maps, preference weights and new functionality to support a traffic light planning approach. The beta-version now operational. Development of the Online data catalogue is in progress. This innovation is currently at TRL 5.

INNOVATION

Diffusion and innovation models for offshore wind technology

A paper was pubished, developing a system dynamics model for the offshore wind industry. The innovative aspect was the explicit consideration of sustainability aspects in the dynamic systems that are modelled. These aspects have a significantly positive influence on the diffusion of offshore wind.

INNOVATION

Sustainability assessment models

As new data and new policy plans became available, we have started updating our Sustainable Development Goals (SDG) impact analysis. We are now using the OECD ICIO 2023 with higher sector and industry resolution. In addition, policy plans have become significantly more ambitious since our first draft analysis in 2021/2022, and global value chains have got more players. We are still lacking the updated data to link the global value chain model to the SDG indicators. We expect draft results during 2024.

SPIN-OFF PROJECTS

The following projects have been awarded or kicked off in 2023 and each include one or more research partners from NorthWind. The projects are carried out with separate contracts, but are in alignment with the research agenda of NorthWind and provide added value.

Financed by the Research Council of Norway and other Norwegian sources

SMART Wind 2025 – This IPN project will research an innovative method for installation and maintenance of floating offshore wind turbines using large offshore subsea construction vessels. Duration: 2023-2025. Project lead: DOF.

ICHzero – This IPN will develop innovative HVAC (Heating, Ventilation and Cooling) design solutions to support energy-efficient and zero-emission operation of service operation vessels. Duration:2023-2025. Project lead: Vard design.

WINDRISE: Revolutionising offshore wind substructures – This Green Platform project aims to develop a sustainable, cost-effective solution for large-scale production and deployment of offshore wind substructures. Project lead: Aker Solutions AS. Duration: 2024-2026

Optimisation of offshore wind turbine maintenance – The goal of this Green Platform project is to develop products and services that enhance the sustainability of offshore wind by facilitating the replacement of main components at sea, thereby achieving significant reductions in time, costs, and lost revenue due to downtime. Project lead: NEKKAR ASA. Duration: 2024-2026

RES100: Modeling a 100% Renewable Electricity System – This KSP project takes the perspective of a 100% renewable European electricity system, where hydropower will play a crucial role together with new technologies on the supply and demand side. Project lead: SINTEF Energy Research. Duration: 2023-2027

SwoP: Impact of switched voltage waveforms on power components and grids – This KSP project will develop methods to measure and characterise the increased stresses power components are exposed to. Project lead: SINTEF Energy Research. Duration: 2023-2026

REWARD: Reliability of eco-friendly cables in future power grids – This KSP will develop new knowledge about what limits the lifespan of cables with new eco-friendly insulation and relevant test methods to ensure high reliability during operations. Project lead: SINTEF Energy Research. Duration: 2023-2027

B-WAVES: Bottom fixed offshore wind turbines in extreme waves – This KSP merges expertise of metocean, wave hydrodynamics, and structural dynamics to gain new knowledge on the extreme waves and wave loads that bottom fixed offshore wind turbines experience during their lifetime. Project lead: SINTEF Ocean. Duration: 2023-2027

NYMOOR: Nylon ropes for mooring of floating wind turbines – The goal of this KSP is to enable design and use of nylon mooring systems for floating wind turbines with high durability in ocean environments. Project lead: SINTEF Ocean. Duration: 2023-2027

Alignment provides added impact

The NorthWind research partners are renowned and engaged in EU-projects. Alignment of research activities enhances impact.

Development of coupled offshore and onshore power grids – This KSP will develop knowledge and methods to enable a socio-economic profitable and robust development of coupled offshore and onshore power grids, against a backdrop of large-scale offshore wind development and a changing onshore energy system. Project lead: SINTEF Energy Research. Duration: 2023-2027

Financed by the EU

INF4INiTY: Integrated designs for future offshore wind farm technology – This project aims to provide nature inclusive design innovations for subsea components of floating offshore wind installations. INF4INiTY provides two major technology innovations: 1) an innovative nature-inclusive design for gravity anchors and their associated scour protection system; and 2) a primary artificial reef structure combined with the floating structure of a floating offshore wind turbine. Project lead: TU Braunschweig. Project duration: 2024-2027

MISSION – This project will develop new and SF6-free switchgear technologies for AC and DC applications, including 550 kV HVDC GIS for offshore applications and 420 kV HVAC live-tank circuit breakers for the European transmission grid. The project will also develop a MVDC circuit breaker for future DC grid applications. The project partners include switchgear manufacturers, transmission system operators and research institutes. Project lead: SINTEF Energi. Project duration: 2024-2027.

Tailwind – The ambition of this project is to shape the next generation of floating offshore wind farms by advancing two critical technologies for single and shared station-keeping systems: mooring lines and anchoring systems. Project lead: NGI. Project duration: 2024-2027

MARINERG-i Distributed Research Infrastructure – This project is developing a scientific and business plan for an integrated European Research Infrastructure in Offshore Renewable Energy. Project lead: University College of Cork. Project duration: 2024-2026.

DigiWind – Supporting Europe's digital and green transition, DigiWind will deliver the interdisciplinary Specialised Education Programmes (SEP) needed to future-proof the careers of Science, Technology, Engineering and Math (STEM) professionals in wind and energy systems through their acquisition of advanced digital skills including the Digital Europe Programme's (DEP) key capacity areas of High-Performance Computing, Artificial Intelligence, Cybersecurity and other emerging technologies. Project lead: DTU. Project duration: 2024-2027.

WILLOW: **Wholistic and integrated digital tools for extended lifetime and profitability of offshore wind farms** – This EU Horizon project will develop an integrated system that will provide an open-source, data-driven smart curtailment solution to the Wind Farm Operators with the basis of an integrated Wind Farm Control system looking for a trade-off between the power production and the lifetime consumption. Project lead: Ceit (Spain). Project duration: 2024-2027.

MADE4WIND: Innovative Circular Materials and Design Methods for the Development of Floating Wind Turbine Components for Offshore Wind Farms of the Future. MADE4WIND aims to develop and test innovative components' concepts for a 15 MW FWT consisting of new designs and manufacturing techniques for blades, substructure, and drivetrain. These innovations will jointly allow future FWT to include new circular lightweighted materials, minimise the impact of sea habitats, increase operational availability, reduce maintenance needs and minimise LCoE. Project lead: SINTEF Industri. Project duration: (2023-2027)

EDUCATION AND RECRUITMENT

Research scientist training constitutes a significant part of NorthWind's activities, and is provided by NTNU and UiO, in collaboration with the associate research partners. The Centre's educational programme will fund 27 PhD and postdoc grants, including 10 in-kind grants by NTNU and UiO. So far, 14 PhDs have already started their work (12 at NTNU and 2 at UiO).

In addition, 4 PhDs and 1 postdoc are associated with NorthWind, but financed through other sources. There is also an effort to have more bachelor and master students at NTNU and UiO specialising in wind energy. In total 53 MSc students presented theses related to wind energy at NTNU in 2023. This represents a unique recruitment base for our industry partners.

Collaboration

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

Report: More student slots needed

According to a report released in August 2023, Norway needs to increase its number of engineering and technology student slots by 380 annually from 2024 to 2028 (reaching a total increase of 1900 in 2028), if it is to meet the demands of the offshore wind sector. The report, titled Gigawatt krever megaløft (Gigawatts Require a Mega-Lift), was commissioned by Norwegian Offshore Wind and Tekna, a Norwegian union representing science and technology professionals.

New course by NTNU

NTNU launched a new, free continuing education course titled "Introduction to offshore wind" in 2023. The course is financed by the Norwegian Directorate for Higher Education and Skills and has proven popular, being successfully completed by 75 students in 2023.

DigiWind

Incorporating the DigiWind project, NorthWind's educational outreach will be further enhanced through the Specialised Education Programmes (SEP), offering advanced digital skills training in key areas such as High-Performance Computing, Artificial Intelligence, and Cybersecurity. This collaboration, led by DTU and running from 2024 to 2027, aligns with Europe's digital and green transition, aiming to future-proof the careers of STEM professionals in the wind and energy sectors. NTNU will lead the work package on Master course development and education. Additionally, it will offer a life-long learning course entitled Introduction to offshore wind.

^ *Trond Kvamsdal (Professor at NTNU), speaks at the launch of the report "Gigawatt krever megaløft". Left: Stine Vethe (VP of Offshore wind foundations at Aker Solutions).*

Our PhD candidates

Veronica Liverud Krathe (WP1)

Affiliation: NTNU
Nationality: Norwegian
Supervisor: Prof. Erin Bachynski-Polić (NTNU), Prof. Amir R. Nejad (NTNU), Dr Jason Jonkman (NREL)
Period: 2021-2025
Thesis: Multiscale/-fidelity wind turbine dynamics models for structural design and control

Afolarinwa David Oyegbile (WP1)

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

Torfinn Ottesen (WP2)

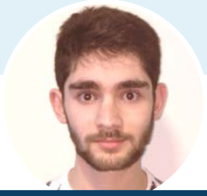
Affiliation: NTNU, SINTEF Ocean
Nationality: Norwegian
Supervisor: Prof. Svein Sævik (NTNU), Prof. Zhen Gao (NTNU), Senior Research Scientist Janne Gjøsteen (SINTEF Ocean)
Period: 2021-2025
Thesis: An approach for safe and cost-effective installation of offshore wind power cables

Vibeke Hvidegaard Petersen (WP2)

Affiliation: NTNU
Nationality: Danish
Supervisor: Prof. Magnus Stålhane (NTNU)
Period: 2022-2026
Thesis: Predictive maintenance of offshore wind turbines

Lorrana Faria da Rocha (WP3)

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



Arkaitz Rabanal Alcubilla (WP3)

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

Ingvild Ånestad (WP3)

Affiliation: UiO
Nationality: Norwegian
Supervisor: Prof. Catherine Banet (UiO), Silke Goldberg (UiO)
Period: 2023-2027
Thesis: The regulatory framework for the development of offshore grid infrastructure in the North Sea, primarily focusing on Norway

Florian Stadtmann (WP4)

Affiliation: NTNU
Nationality: G 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

Wanwan Zhang (WP4)

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

Chrysi Danelaki (WP5)

Affiliation: NTNU
Nationality: Greek
Supervisor: Prof. Dr. Christian A Klöckner (NTNU)
Period: 2023-2027
Thesis: The impact of technological attributes, psychological factors, and personal variables on onshore and offshore wind energy acceptance in Norway

Gullik-André Fjordbo (WP5)

Affiliation: UiO
Nationality: Norwegian
Supervisor: Prof. Ivar Alvik (UiO), Associate Prof. Katrine Broch Hauge (UiO)
Period: 2022-2026
Thesis: Impact assessments of wind power plants

Pankaj Ravindra Gode (WP5)

Affiliation: NTNU
Nationality: Indian
Supervisor: Prof. Arild Aspelund (NTNU), Ass. Prof. Øyvind Bjørgum (NTNU)
Period: 2021-2025
Thesis: Circular Business Development of Offshore Wind Energy

Julian Lahuerta (WP5)

Affiliation: NTNU
Nationality: Norwegian
Supervisor: Prof. Asbjørn Karlsen (NTNU)
Period: 2021-2024
Thesis: The latecomer's dilemma: Transatlantic resource mobilisation in the US offshore wind industry

Birgitte Nygaard (WP5)

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

PhDs associated with NorthWind but financed through other sources

Nikki Luttikhuis (WP5)

Affiliation: SINTEF Industry & NTNU
Nationality: Dutch
Supervisor: Øyvind Bjørgum (NTNU), Kirsten Wiebe (SINTEF)
Period: 2021-2025
Thesis: Technology impacts on the Sustainable Development Goals, an interlinkages approach

Øyvind Torgersrud (WP1)

Affiliation: Laboratoire 3SR, Université Grenoble Alpes & NGI
Nationality: Norwegian
Supervisor: Gioacchino Viggiani (3SR), Hans Petter Jostad (NGI), Jose E Andrade (Caltech), Edward Ando (EPFL)
Period: 2021-2024
Thesis: Numerical and experimental analysis of fabric evolution in granular soil under cyclic loading

Yannick Cyiza Karekezi (WP3)

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

Lukas Seifert (WP5)

Affiliation: NTNU
Nationality: German
Supervisor: Bente Jessen Graae (NTNU)
Period: 2023-2026
Thesis: Ecological restoration in onshore wind energy projects

COMMUNICATIONS

NorthWind's communications strategy has a twofold objective: disseminating research and innovation results achieved within the Centre, and facilitating a fact-based discussion about wind energy in the public sphere. Communications efforts have resulted in significant media coverage for the Centre.

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 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

NorthWind took part in Arendalsuka, together with several FMEs and the LowEmission research centre. The Centres prepared a report laying out three policy recommendations to avoid a power shortage in Norway in 2027.

NorthWind also continued supporting international organisations such as EERA JP Wind in their push for a European Centre of Excellence on wind energy, culminating with the signing in September of a Memorandum of Understanding between 9 European research organisations (including 2 NorthWind partners and 3 associated partners). The Centre is also an active member of a collaboration forum about offshore wind organised by the Norwegian Ministry of Energy. Centre director John Tande heads a working group within the forum about research, technology and competence.

Website and external newsletter

The website performed very well during 2023, with 32 134 pageviews from 1 January to 31 December – up 6.6% compared to the previous year. The site is intended as a central hub for all external communication. It provides information about the Centre and its partners, and disseminates research results and progress. The website was also successfully used to promote various events such as the webinar series, the Annual Innovation Forum and the EERA DeepWind conference.

The news section of the website is intended as a content hub that serves 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. 54 such articles were written in 2023.

The newsletter has over 564 subscribers. Anyone visiting the website can subscribe to it. In total, 17 newsletters were sent in 2023, to promote events and share news.

Internal newsletter

In addition to the external newsletter, to which anyone can subscribe, the NorthWind Centre Management Group also sends an internal newsletter aimed at keeping project partners up to date. Three such newsletters were sent in 2023.

A fact-based approach

The debate about wind energy in Norway is often emotionally charged, and NorthWind meets this with a fact-based approach in its communications towards the general public. Since its launch, the NorthWind website has become a hub of information about wind energy, sharing new developments in the field, as well as articles highlighting areas of concern. On a few occasions, articles were written to debunk myths or highlight particular aspect of an ongoing debate.

Following on the positive experience of 2022, support was given to fact-checking website faktisk.no, which sought help from NorthWind to debunk a false claim that was circulating on social media, about wind power and microplastics. An op-ed was penned by professor Magnus Korpås (deputy leader WP3, NTNU), as a response to his NTNU colleagues supporting nuclear energy, that made claims about wind power that he considered one-sided.

In another op-ed, Centre Director John Olav made the point that offshore wind will not integrate with the power system by itself, highlighting the need for a holistic approach comprising both new technologies and new knowledge. Three op-eds were also written by NorthWind PhD candidate Gullik-André Fjordbo, shedding light on specific aspects of the Fosen wind power controversy.

Appearances in the media

NorthWind scientists penned five op-eds that were published in Norwegian newspapers Dagens næringsliv, Universitetsavisa, VG and Rett24.no. They appeared in six podcast episodes or radio/television interviews. In total, we recorded 52 media contributions by NorthWind, including such wide-reaching media outlets as NRK, VG, Dagens Næringsliv, Aftenposten and Bergens Tidene, as well as more specialised publications such as Teknisk Ukeblad, EnergyWatch and E24. In addition, six blog articles were published on SINTEF blog (4 in English and 2 in Norwegian) – and 54 news pieces for the NorthWind website, as mentioned in the "Website" section above.


DN

John Olav Giæver Tande
John Olav Giæver Tande, sjefforsker i Sintef

Innlegg

Havvind smelter ikke sammen med kraftsystemet av seg selv

Vi har lang vei å gå før store mengder havvind kan sluses effektivt inn i energisystemet. Mye ny teknologi og ny kunnskap må på plass først.

Dersom parkene fordeles langsetter Norges utstrekning, så får vi bedre tilpasning til forbruket og en utglatting av effektvariasjonene, skriver artikkelforfatteren. (Foto: Tommy Ellingsen)

Publisert 26. april 2023, kl. 19.55

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 2024.

Annual Innovation Forum

The Centre's second in-person Annual Innovation Forum took place in December. This annual event is a golden opportunity for partners to learn about the research and innovation activities in the Centre, and an excellent occasion for networking among consortium members. The duration of the event was extended to two days this year, based on the positive feedback from participants last year.

EERA DeepWind conference

NorthWind partners are major participants in the international offshore wind R&I conference EERA DeepWind (see pages 20-24). The conference is an international event aiming to present the best ongoing research and innovation related to deep sea offshore wind farms, both bottom-fixed and floating.

Social media

The NorthWind LinkedIn page continued growing in 2023, with the number of followers going from 630 at the beginning of the year to 988 on 31 December. 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. Project partners are encouraged to share NorthWind news, events and blog articles on their own social media channels to amplify their reach.

Following the rebranding of Twitter to X, the decision by the company to deprioritise core tasks such as content moderation, the exodus of millions of its users and the departure from the platform of key advertisers, a judgement has been made by the communications team that it had lost its usefulness for the purposes of communicating Centre results and activities. The Centre's account has therefore stopped being updated.

FINANCIAL STATEMENT

Costs (1000 NOK)	Amount
Host institution (SINTEF Energi)	7328
Research partners	32381
User partners	11987
Equipment	
Total	**51696**

Funding (1000 NOK)	Amount
Research Council of Norway	21157
Host institution (SINTEF Energi)	1393
Research partners	8950
User partners*	20195
Total	**51695**

*Excess User partner funding transferred to 2024

APPENDIX

PERSONNEL

Key researchers

Name	Institution	Work package
John Olav Tande	SINTEF Energy Research	WP0, WP3, WP4
Hans Christian Bolstad	SINTEF Energy Research	WP0
Konstanze Kölle	SINTEF Energy Research	WP0, WP4
Trond Kvamsdal	NTNU	WP0, WP4, WP5
Inger Marie Malvik	SINTEF Energy Research	WP0, WP5
Vigdis Olden	SINTEF Industry	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 Energy Research	WP0, WP3
Marte Gammelsæter	SINTEF Energy Research	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 Industry	WP1
Erin Bachynski-Polic	NTNU	WP1
Hans Iver Lange	SINTEF Industry	WP1
Ivan Bunaziv	SINTEF Industry	WP1
Magnus Eriksson	SINTEF Industry	WP1
Sparsha Sinduri Nagula	NGI	WP1, WP2
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
Halvor Lie	SINTEF Ocean	WP2
Magnus Stålhane	NTNU	WP2

Name	Institution	Work package
Yauheni Kisialiou	SINTEF Ocean	WP2
George Jagite	SINTEF Ocean	WP2
Pål Olsen	NTNU	WP3
Catherine Banet	UiO	WP3, WP5
Salvatore D'Arco	SINTEF Energy Research	WP3
Elisabetta Tedeschi	NTNU	WP3
Øystein Hestad	SINTEF Energy Research	WP3
Harald Svendsen	SINTEF Energy Research	WP3
Espen Eberg	SINTEF Energy Research	WP3
Bjørn Gustavsen	SINTEF Energy Research	WP3, WP4
Atle Pedersen	SINTEF Energy Research	WP3
Dag Linhjell	SINTEF Energy Research	WP3
Antonio Alvaro	SINTEF Industry	WP3
Anette Brocks Hagen	SINTEF Industry	WP3
Camilla Espedal	SINTEF Energy Research	WP3
Janne Gjøsteen	SINTEF Ocean	WP3
Jørn Vatn	NTNU	WP4
Balram Panjwani	SINTEF Industry	WP4
Valentin Chabaud	SINTEF Energy Research	WP3, WP4
Olimpo Anaya-Lara	SINTEF Energy Research	WP3
Svein Magne Hellesø	SINTEF Energy Research	WP3
Andrzej Holdyk	SINTEF Energy Research	WP3
Sverre Hvidsten	SINTEF Energy Research	WP3
Martin Høyer-Hansen	SINTEF Energy Research	WP3
Emre Kantar	SINTEF Energy Research	WP3
Hans Helmer Sæternes	SINTEF Energy Research	WP3
Kristian Thinn Solheim	SINTEF Energy Research	WP3
Torbjørn Ve Andersen	SINTEF Energy Research	WP3
Håvard Bærug	SINTEF Energy Research	WP3
Thomas Treider	SINTEF Energy Research	WP3
Ivar Bjerkebæk	SINTEF Energy Research	WP4
Mandar Tabib	SINTEF Digital	WP4
Iver Bakken Sperstad	SINTEF Energy Research	WP4
Håkon Toftaker	SINTEF Energy Research	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

Name	Institution	Work package
Ole Øiseth	NTNU	WP4
Kirsten S. Wiebe	SINTEF Industry	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 Industry	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	UiO / 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
Paula Garcia Rosa	SINTEF Energy Research	WP5
Frank Hanssen	NINA	WP5
Jiska van Dijk	NINA	WP5
Robert Næss	NTNU	WP5
Tomas M. Skjølsvold	NTNU	WP5
Christian Klöckner	NTNU	WP5
Vibeke S. Nørstebø	SINTEF Ocean	WP5

Associated postdoc

(financed through other sources)

Name	Nationality	Period	Gender	Work package	Topic
Alex X. Jerves	USA	2021-2023	M	1	Characterising sand behaviour from Level-Set Discrete Element Method (LS-DEM) simulations

PhD students

Name	Nationality	Period	Gender	Work package	Topic
Veronica Liverud Krathe	Norway	2021-2024	F	WP1	Multiscale/-fidelity wind turbine dynamics models for structural design and control
Afolarinwa David Oyegbile	Nigeria	2021-2024	M	WP1	Reliability- and data-based structural design under industrial constraints
Torfinn Ottesen	Norway	2021-2025	M	WP2	An approach for safe and cost-effective installation of offshore wind power cables
Lorrana Faria da Rocha	Brazil	2021-2024	F	WP3	Power electronics architecture and control methods for a HVDC generator for offshore wind
Arkaitz Rabanal Alcubilla	Spain	2021-2024	M	WP3	Energy Storage for Grid Services in HVDC Connected Offshore Wind Farms
Florian Stadtmann	Germany	2021-2024	M	WP4	Enabling Technologies for Digital Twins
Wanwan Zhang	China	2021-2024	F	WP4	Predictive Maintenance and Decision Support for Asset Management
Pankaj Ravindra Gode	India	2021-2024	M	WP5	Circular Business Development of Offshore Wind Energy
Julian Richard Lahuerta	Norway	2021-2024	M	WP5	Harnessing Norwegian maritime industrial capabilities in the emerging US offshore wind industry
Birgitte Nygaard	Denmark	2021-2024	F	WP5	The framing of Norwegian Wind Energy futures – the cases of Svalbard and Sørlige Nordsjø II
Vibeke Hvidegaard Petersen	Denmark	2022-2025	F	WP5	Predictive maintenance planning for offshore wind farms
Gullik-André Fjordbo	Norway	2022-2025	M	WP5	Impact assessments of wind power plants
Ingvild Ånestad	Norway	2023 – 2026	F	WP3	The regulatory framework for the development of offshore grid infrastructure in the North Sea, primarily focusing on Norway
Chrysi Danelaki	Greece	2023 – 2027	F	WP5	The impact of technological attributes, psychological factors, and personal variables on onshore and offshore wind energy acceptance in Norway

PhD students with financial support from other sources

Name	Nationality	Funding	Period	Gender	Work Package	Topic
Øyvind Torgersrud	Norway	NGI	2021-2024	M	WP1	Numerical and experimental analysis of fabric evolution in granular soil under cyclic loading
Yannick Cyiza Karekezi	Norway	NTNU	2021-2024	M	WP3	Novel Modular HVDC Generator for Offshore Wind
Lukas Seifert	Germany		2023 - 2026	M	WP5	Ecological restoration in onshore wind energy projects
Nikki Luttikhuis	Netherlands	SINTEF/NTNU	2021 - 2025	F	WP5	Technology impacts on the Sustainable Development Goals, an interlinkages approach

Master's students

Name	Gender	Topic
Sandra Schultz Karlsen	F	Attitudes Towards Development of Wind Power Plants in Norway
Kari Medhus	F	Analysing the Impact of 30 GW Offshore Wind Power in Norway using the Market Model FanSi
Christian Andre Andresen	M	Stakeholder analysis with regards to large-scale North Sea offshore wind energy developments
Emil Aune Jakobsen	M	Performance Efficiency and Reliability Analysis of Offshore Wind Power Plants: Case Study of Utsira Nord
Peter Flermoen	M	Motvind eller medvind for norske havvindutbygginger
Torbjørn Indrekvam Horstad	M	Co-Simulation Model for Optimal Wind-Hydro Coordination Using Wind Farm Control Dynamics: A Case Study of a Hybrid Wind and Hydro Plant System
Anna Hjerpaasen	F	Development of Control Structure of Large-Scale Renewable Hydrogen Production Plants
Jonas Brøske Danielsen	M	Revenue-Weighted Life Cycle Assessment of two Nordic Energy companies - Exploring a simplification of Organizational LCA as a proxy for Organizational Impact through comparisons with company sustainability reports and third-party impact data
Mathias Frøiland Haugbråten	M	Back to the Future: Rebirth of Pure Wind Propelled Ships
Håkon Caspari	M	Back to the Future: Rebirth of Pure Wind Propelled Ships
Jonas Eidsvåg Rostad	M	Frequency Control Evaluation for a Variable Speed Wind Power Plant in an Isolated Power System
Kyle Lambert	M	Usability of Extrapolation Methods of Wind Speed Profiles in the Arctic
Tor Eivind Tjalvin Alvsåker	M	Manipulating Multi-Regional Input-Output Tables to Evaluate India's COP26 Pledges
Hanne Høyem	F	Production of Methanol from Intermittent Off-grid Renewable Energy: Energy Storage Technologies
Oda Austad Hove	F	Carbon Capture and Utilization from Limestone Calcination
Janne Hansen Eeg	F	A study of Vietnam's energy transition pathway to low-carbon development
Nourhan Alzammar	F	Maintenance Optimization of offshore wind farms using digital technologies and criticality assessment: Techniques for achieving sustainability
Hanna Birgitte Sletta	F	Integration of Renewable Energy Sources into Electricity Markets via Optimized Wind Farm and Hydropower Scheduling
Kristin Serck-Hanssen	F	Integration of Renewable Energy Sources into Electricity Markets via Optimized Wind Farm and Hydropower Scheduling
Jacob Wulff Wold	M	GAN Based Super-Resolution of Near-Surface 3D Atmospheric Wind Flow with Physics Informed Loss Function
Federica Mosca	F	Modelling and simulation of an Offshore Wind-Hydrogen combined system for hydrogen production using an anion exchange membrane electrolyzer
Henrik Lund Finsås	M	Wind power for cooking
Torbjørn Løvik	M	Wind power for cooking
Shirin Sadullaeva	F	Valuation of energy storage technologies in the Nordic power systems and markets context with growing wind power penetration
Ida Nilsen Aure	F	Feasibility of Establishing a Solar PV Power Plant in the Existing Wind Farm at Smøla
Karen Margrethe Husby	F	A comparison of the SDP and SDDP method for medium-term scheduling of Meråker hydropower system
Lars Skjelbred Nygaard	M	Investments in Low-Carbon Power Generation and Energy Storage under Uncertainty
Tobias Sjøli	M	Exploring the Effects of Integrating Power Link Island into the North Sea through Transmission Expansion Planning
Daniel Steinar Holt	M	Exploring the Effects of Integrating Power Link Island into the North Sea through Transmission Expansion Planning

Name	Gender	Topic
Astrid Sigurdsøn	F	Stability Analysis of a New Class of Inner Loops for Voltage Regulations in DC/DC converters
Kristina Nydal	F	Legitimitet og hydrogen
Sophie Holme Stokker	F	Fatigue Design Appropriations for Floating Offshore Wind Turbine Support Structures
Erik Eikeng	M	Power to Ammonia - A Computational Framework for Optimizing Green Ammonia Production from off-grid Wind and Solar Energy
Emilie Bøe Surdal	F	Robust Control of Nonlinear Wind Energy Conversion Systems: A scalable and adaptive energy-based approach for cascaded interconnections
Haiping Shen	M	Holistic economic and environmental optimization of future energy systems
Ingvild Eline Olsen	F	Multimarket Services for Stationary Batteries - Considering Activation of Frequency Containment Normal Operation Reserves
John Håvard Aarvåg	M	Yaw Error Estimation on the NREL 5-MW Offshore Baseline Wind Turbine
Robert Blaszkiewicz	M	Green methanol
Leire Juaristi	F	An experimental study of the performance of a wind turbine model with swept blades, for different inflow conditions
Vegard Yssen Rørstad	M	Experimental verification of control methods for series connected VSCs applied to a modular HVDC power train for offshore wind
Kris Gabriel	M	Experimental investigation of the interaction between two roof-mounted Savonius wind turbines
Nora Hundseid	F	Experimental investigation of the interaction between two roof-mounted Savonius wind turbines
Martinus Aarmo	M	A station-keeping analysis of a damaged floating offshore wind turbine
Fredrik Stennes Jacobsen	M	Effectiveness of Offshore Maintenance Bases in Norwegian Offshore Wind
Ruben Vilnes Iden	M	Design of Superconducting Propulsion Motor for Hydrogen-Powered Zero-Emission Aviation
Jan-Bendik Kristiansen	M	Green Hydrogen Production Optimization with Artificial Intelligence in Northern Norway
Marius Hølen Bakken	M	Green Hydrogen Production Optimization with Artificial Intelligence in Northern Norway
Sanyam Ghimire	M	Analysis of the measured pore pressure and hydraulic data from Roskrepp hydropower plant
Erlend Vabø	M	Electric water heaters as flexible energy resources in the power grid
*Hedda Mortensen Standal	F	Assessing the Relations Between the South Sámi and Norwegian State in the Aftermath of the Fosen Case
*Vilde Aanensen Eriksen	F	Konsultasjonsplikten i samiske saker og dens betydning for gyldigheten av anleggskonsesjon for vindkraftverk

Master's marked with a star were delivered at UiO. All others were at NTNU.

PUBLICATIONS

Peer reviewed journal publications

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

1. **Berthelsen, Petter Andreas; Thys, Maxime; Bachynski-polić, Erin.** A Numerical Assessment of Mooring System Modelling Uncertainties in Hydrodynamic Model Testing of Floating Wind Turbines. *Proceedings of the ASME 2023 42nd International Conference on Ocean, Offshore and Arctic Engineering. Volume 8: Ocean Renewable Energy* 2023. OCEAN NTNU
2. **Bunaziv, Ivan; Ren, Xiaobo; Olden, Vigdis.** A comparative study of laser-arc hybrid welding with arc welding for fabrication of offshore substructures. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. s. - SINTEF
3. **Califano, Andrea; Berthelsen, Petter Andreas; Fonseca, Nuno.** Effect of body motion on the wave loads computed with CFD on the INO-WINDMOOR floater. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. OCEAN
4. **Chabaud, Valentin Bruno.** Synthetic turbulence modelling for offshore wind farm engineering models using coherence aggregation. *Wind Energy* 2023. ENERGISINT
5. **D'Arco, Salvatore; Suul, Jon Are Wold.** Phase Angle Feed-Forward Control for Improving the Power Reference Tracking of Virtual Synchronous Machines. *IEEE transactions on industry applications* 2023 ;Volum 60.(1) s. 851-864 ENERGISINT NTNU
6. **Fonseca, Nuno; Silva de Souza, Carlos Eduardo; Berthelsen, Petter Andreas.** Prediction of Heave and Pitch Low Frequency Wave Forces and Motions of a Semi-Submersible Floating Wind Turbine and Comparison With Model Test Data. I: *IOWTC2022 - Proceedings of the ASME 2022 4th International Offshore Wind - Technical Conference*. The American Society of Mechanical Engineers (ASME) 2023 ISBN 978-0-7918-8661-8. s. - OCEAN
7. **Garcia Rosa, Paula Bastos; Tande, John Olav Giæver.** Mitigation measures for preventing collision of birds with wind turbines. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. ENERGISINT
8. **Gustavsen, Bjørn Alfred.** A 2D FEM Model for Impedance and Loss Calculation of Armored Three-Core Cables with Inclusion of 3D Pitching Effects. *IEEE Transactions on Power Delivery* 2023 ;Volum 38.(5) s. 3010-3020 ENERGISINT
9. **Gustavsen, Bjørn Alfred.** Rational Function Approximation of Transformer Branch Impedance Matrix for Frequency-Dependent White-Box Modeling. *IEEE Transactions on Power Delivery* 2023 ;Volum 38.(5) s. 3045-3057. ENERGISINT
10. **Halvorsen-Weare, Elin Espeland; Nonås, Lars Magne.** Maritime logistics optimisation for predictive maintenance at offshore wind farms. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. s. - OCEAN
11. **Horstad, Torbjørn Indrekvam; Cali, Umit; Dynge, Marthe Fogstad; Korpås, Magnus; Chapaloglou, Spyridon; Gallego-Calderon, Juan F..** Co-Simulation Model for Optimal Wind-Hydro Coordination Using Wind Farm Control Dynamics. I: *2023 International Conference on Smart Energy Systems and Technologies - SEST*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 979-8-3503-9790-1. ENERGISINT NTNU
12. **Hoseini Dadmarzi, Fatemeh; Califano, Andrea; Fonseca, Nuno; Berthelsen, Petter Andreas.** Comparison of Morison Forces With CFD Modelling for a Surface Piercing Column of a FOWT. I: *IOWTC2022 - Proceedings of the ASME 2022 4th International Offshore Wind - Technical Conference*. The American Society of Mechanical Engineers (ASME) 2023 ISBN 978-0-7918-8661-8. s. - OCEAN
13. **Kantar, Emre; Hvidsten, Sverre; Aakervik, Jørund.** Effect of Radial Pressure and Lubricant Types on Partial Discharge Inception in a Slip/On Medium Voltage XLPE Cable Termination. I: *Jicable'23 - 11th International Conference on Power Insulated Cables, Lyon - France 18-22 June 2023 : proceedings*. : SEE 2023 ISBN 9782959042409. ENERGISINT
14. **Khazaeli Moghadam, Farid; Chabaud, Valentin Bruno; Gao, Zhen; Chapaloglou, Spyridon.** Power train degradation modelling for multi-objective active power control of wind farms. *Forschung im Ingenieurwesen* 2023 ;Volum 87. s. 13-30. ENERGISINT NTNU
15. **Linhjell, Dag; Mehammer, Eirill Bachmann.** Dynamic moisture diffusion in transformer winding insulation. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. ENERGISINT

16. **Rivera Arreba, Irene; Wise, Adam S.; Eliassen, Lene Vien; Bachynski-Polic, Erin Elizabeth.** Effect of atmospheric stability on the dynamic wake meandering model applied to two 12 MW floating wind turbines. *Wind Energy* 2023 ;Volum 26.(12) s. 1235-1253. NTNU OCEAN
17. **Serck-Hanssen, Kristin; Sletta, Hanna Birgitte; Cali, Umit; Belsnes, Michael Martin; Kwon, Jongwhan; Dynge, Marthe Fogstad.** Optimization of Wind Scheduling for Improved Power Market Integration Through Up-Regulation Prices. I: *2023 International Conference on Smart Energy Systems and Technologies - SEST*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 979-8-3503-9790-1. ENERGISINT NTNU
18. **Skjølsvold, Tomas Moe; Heidenreich, Sara Lena Brigitte; Henriksen, Ida Marie; Vasconcellos Oliveira, Rita; Dankel, Dorothy Jane; Lahuerta, Julian Richard; Linnerud, Kristin; Moe, Espen; Nygaard, Birgitte; Richter, Isabell Gabriele Maria; Skjærseth, Jon Birger; Suboticki, Ivana; Vasstrøm, Mikaela Lise Modalen.** Conditions for just offshore wind energy: Addressing the societal challenges of the North Sea wind industry. *Energy Research & Social Science* 2023 ;Volum 107. s. - NMBU NTNU UIA OCEAN FNI HVL
19. **Stadtmann, Florian; Rasheed, Adil; Kvamsdal, Trond; Johannessen, Kjetil Andre; San, Omer; Kölle, Konstanze; Tande, John Olav Giæver; Barstad, Idar; Benhamou, Alexis; Brathaug, Thomas; Christiansen, Tore; Firle, Anouk-Letizia; Fjeldly, Alexander; Frøyd, Lars; Gleim, Alexander; Høiberget, Alexander; Meissner, Catherine; Nygård, Guttorm; Olsen, Jørgen; Paulshus, Håvard; Rasmussen, Tore; Rishoff, Elling; Scibilia, Francesco; Skogås, John Olav.** Digital Twins in Wind Energy: Emerging Technologies and Industry-Informed Future Directions. *IEEE Access* 2023 ;Volum 11. s. 110762-110795. NTNU SINTEF ENERGISINT
20. **Stadtmann, Florian; Rasheed, Adil; Rasmussen, Tore.** Standalone, Descriptive, and Predictive Digital Twin of an Onshore Wind Farm in Complex Terrain. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626.(012030) s. - SINTEF NTNU
21. **Stadtmann, Florian; Wassertheurer, Henrik Andreas Gusdal; Rasheed, Adil.** Demonstration of a Standalone, Descriptive, and Predictive Digital Twin of a Floating Offshore Wind Turbine. I: *ASME 2023 42nd International Conference on Ocean, Offshore and Arctic Engineering. Volume 8: Ocean Renewable Energy*. The American Society of Mechanical Engineers (ASME) 2023 ISBN 978-0-7918-8690-8. s. - NTNU SINTEF
22. **Lye, Kjetil Olsen; Tabib, Mandar Vasudeo; Johannessen, Kjetil Andre.** A Reinforcement Learning framework for Wake Steering of Wind Turbines. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. s. - SINTEF
23. **Vasconcellos Oliveira, Rita.** Whispers in the Wind: Ethical dimensions of social conflict in offshore wind. *Journal of Physics: Conference Series (JPCS)* 2023 ;Volum 2626. s. - OCEAN NTNU
24. **Vrana, Til Kristian; Svendsen, Harald Georg; Korpås, Magnus; Couto, António; Estanqueiro, Ana; Flynn, Damian; Holttinen, Hannele; Härtel, Philipp; Koivisto, Matti; Lantz, Eric; Frew, Bethany.** Improving wind power market value with various aspects of diversification. I: *2023 19th International Conference on the European Energy Market - EEM*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 979-8-3503-1258-4. ENERGISINT NTNU
25. **Yan, Jie; Wang, Kaibo; Wang, Hangyu; Chabaud, Valentin Bruno; He, Shukai; Liu, Yongqian.** Impact of wind farm wake steering control on blade root load. I: *12th International Conference on Renewable Power Generation -RPG 2023*. Institution of Electrical Engineers (IEE) 2023 ISBN 978-1-83953-949-7. ENERGISINT

Presentations

Search criteria: *From:* 2023 *To:* 2023 *Main category:* Conference lecture and academic presentation *All publishing channels*

1. **Banet, Catherine.** Legal framework for electricity market design with offshore wind.. EERA DeepWind Conference 2023; 2023-01-20 - 2023-01-20. UiO
2. **Banet, Catherine.** Offshore wind permitting regime in Norway and EU/EEA perspectives.. NSELP-BBA//Fjeldco seminar; 2023-09-18 - 2023-09-18. UiO
3. **Berthelsen, Petter Andreas; Thys, Maxime; Bachynski-Polić, Erin.** A Numerical Assessment of Mooring System Modelling Uncertainties in Hydrodynamic Model Testing of Floating Wind Turbines. 42nd International Conference on Ocean, Offshore and Arctic Engineering; 2023-06-11 - 2023-06-16. NTNU OCEAN
4. **Bunaziv, Ivan; Diez, Anja; Johansen, Tonni Franke; Ren, Xiaobo.** What does the defect say? Acoustic emission (AE) for process monitoring and defect detection in laser welding. FME North-Wind Innovation Forum; 2023-12-06 - 2023-12-07 SINTEF
5. **Califano, Andrea; Berthelsen, Petter Andreas; Fonseca, Nuno.** Effect of body motion on the wave loads computed with CFD on the INO-WINDMOOR floater. EERA DeepWind 2023; 2023-01-18 - 2023-01-20. OCEAN NTNU
6. **Eliassen, Lene Vien; De Vaal, Jacobus Bernardus; Panjwani, Balram; Rivera Arreba, Irene.** Influence of wake meandering paths on floating wind turbine

response. EERA DeepWind Conference 2023; 2023-01-18 - 2023-01-20. OCEAN SINTEF NTNU

7. **Egeland, Ane Sydnes; Fjordbo, Gullik-André.**
Krav til utredning av miljøvirkninger av akvakultur. Havbruksretts-klubb; 2023-02-07 - 2023-02-07. UiO
8. **Fjordbo, Gullik-André.**
Effektivisering av konsesjonsprosessen for vindkraft. Det nasjonale doktorgradsseminaret i Bergen; 2023-10-20. UiO
9. **Fjordbo, Gullik-André.**
Hvordan kan samenes menneskerettigheter ivaretas i vindkraft-saker?. Dilemmaer i rettsstaten: Hvordan gjennomføre det grønne skiftet?; 2023-06-13 - 2023-06-13. UiO
10. **Fjordbo, Gullik-André.**
Krav til konsekvensutredninger ved utvidelse av vindkraftverk. Webinar: Dynamic models, cost-effective installation, regulatory framework and impact assessments; 2023-05-03 - 2023-05-03. UiO
11. **Fjordbo, Gullik-André.**
Presentasjon av masteroppgaven om hensynet til reindriften i vindkraftsaker i forbindelse med tildeling av pris for beste masteroppgave innen energirett. Rettslig handlingsrom for effektiv og storstilt utbygging av kraftproduksjon og strømnett; 2023-03-28 - 2023-03-28. UiO
12. **Fjordbo, Gullik-André.**
Unntak fra krav til prosjektspesifikk konsekvensutredning av havvind. Samling for Advokatforeningens lovutvalg for miljø, klima og bærekraft; 2023-06-21 - 2023-06-21. UiO
13. **Fjordbo, Gullik-André; Ånestad, Ingvild.**
EØS-rettens betydning for havnettet. Faglunsj; 2023-10-10 - 2023-10-10. UiO
14. **Fjordbo, Gullik-André; Ånestad, Ingvild.**
The regulatory framework for the offshore grid in light of EU and EEA law. Bergen Energy and Climate Law Days 2023; 2023-10-23 UiO
15. **Garcia Rosa, Paula Bastos; Tande, John Olav Giæver.**
Mitigation measures for preventing collision of birds with wind turbines. EERA DeepWind Conference 2023; 2023-01-18 - 2023-01-20. ENERGISINT
16. **Gutsch, Martin; Ludvigsen, Halgeir.**
Investigation towards efficient walk-to-work (W2W) operability simulations. EERA DeepWind Conference; 2023-01-18 - 2023-01-20. OCEAN
17. **Heidenreich, Sara.**
Public engagement, participation and controversy. FME North Wind: 'Sustainable Wind Development' Work Package (WP5) Annual Meeting; 2023-05-31. NTNU
18. **Jagite, George; Gao, Zhen; Braaten, Henning.**
On the installation of offshore wind turbines: Challenges and future perspectives. EERA DeepWind Conference 2023; 2023-01-18 - 2023-01-20. OCEAN NTNU
19. **Kantar, Emre; Hvidsten, Sverre; Aakervik, Jørund.**
Effect of Radial Pressure and Lubricant Types on Partial Discharge Inception in a Slip-On Medium Voltage XLPE Cable Termination. Jicable'23; 2023-06-18 - 2023-06-22. ENERGISINT
20. **Kölle, Konstanze.**
How research can contribute to cost-effective operation of wind farms. 4th Edition of Wind Power Data and Digital Innovation Forum; 2023-03-07 - 2023-03-08. NTNU ENERGISINT
21. **Kölle, Konstanze.**
Towards open-access reference sites with key conditions for floating wind arrays. Wind Energy Science Conference; 2023-05-23 - 2023-05-26. ENERGISINT
22. **Kölle, Konstanze; Göcmen, Tuhfe; Eguinoa, Irene.**
Value-oriented wind farm control: considering electricity prices. Wind Energy Science Conference; 2023-05-23 - 2023-05-26 ENERGISINT
23. **Kölle, Konstanze.**
Vindkraft. Forelesning; 2023-08-30 - 2023-08-30. ENERGISINT
24. **Korpås, Magnus.**
Hvordan bør vi omstille samfunnet til et bærekraftig energi-system i Norge og Europa mot 2050?. Faglunsj Miljødirektoratet; 2023-02-10 - 2023-02-10. NTNU
25. **Korpås, Magnus.**
Innledning om kraftsituasjonen. Spørretime om energirapporten; 2023-02-13 - 2023-02-13. NTNU
26. **Korpås, Magnus.**
Integration of 30 GW offshore wind in Norway. IEA TCP WInd Task 25 Meeting; 2023-10-31 - 2023-11-02. NTNU
27. **Korpås, Magnus.**
Large-scale integration of wind power in energy systems. FME NorthWind Scientific Advisory Committee Meeting; 2023-01-17 - 2023-01-17. NTNU
28. **Korpås, Magnus.**
Towards 100 % renewable-based energy systems. Energy seminar; 2023-02-06 - 2023-02-06. NTNU
29. **Korpås, Magnus; Vrana, Til Kristian.**
Addressing Market Issues in Electric Power Systems with Large Amounts of Offshore and Onshore Wind Power. DeepWind 2023; 2023-01-19 - 2023-01-19. NTNU
30. **Krathe, Veronica Liverud; Jonkman, Jason M; Bachynski-Polic, Erin Elizabeth.**
Implementation of drivetrain structural flexibility in OpenFAST. EERA DeepWind 2023; 2023-01-18 - 2023-01-20. NTNU
31. **Krathe, Veronica Liverud; Jonkman, Jason M.; Gebel, Jakob Vincent; Rivera Arreba, Irene; Rasekhi Nejad, Amir; Bachynski-Polic, Erin Elizabeth.**
Main bearing fatigue sensitivity to synthetic turbulence models. NAWEA/WindTech 2023; 2023-10-30 - 2023-11-01. OCEAN NTNU
32. **Kvamsdal, Trond; Fonn, Eivind; Rasheed, Adil; Tsiolakis, Vasileios; Brummelen, Harald van.**

Reduced Order Modelling (ROM) and Hybrid Analysis and Modelling (HAM) as Enablers for Predictive Digital Twins (DT). Invited keynote talk at Math 2 Product (M2P) 2023. Taormina, Italy; 2023-05-30 - 2023-06-01. NTNU SINTEF

33. **Kvamsdal, Trond; Rasheed, Adil; Fonn, Eivind; Tsiolakis, Vasileios.** Enabling Technologies for Predictive Digital Twins. INRIA-LJLL Seminar; 2023-11-06 - 2023-11-06. NTNU
34. **Kvamsdal, Trond; Rasheed, Adil; Fonn, Eivind; Tsiolakis, Vasileios; Brummelen, Harald van.** Digital Twins as an enabling technology for disruptive improvement of computational methods in marine engineering. X International Conference on Computational Methods in Marine Engineering; 2023-06-27 - 2023-06-29. NTNU
35. **Kvamsdal, Trond; Rasheed, Adil; Fonn, Eivind; Tsiolakis, Vasileios; Brummelen, Harald van.** Hybrid Analysis and Modelling to Enable Digital Twins. III International Conference on Computational Science and AI in Industry (CSAI 2023); 2023-08-28 - 2023-08-30. NTNU
36. **Kvamsdal, Trond; Rasheed, Adil; Fonn, Eivind; Tsiolakis, Vasileios; Eftang, Jens Lohne; Brummelen, Harald van.** Enabling Technologies for Predictive Digital Twins. Ecole nationale Superieure d'Arts et Metiers (ENSAM); 2023-12-13 - 2023-12-13. NTNU
37. **Kvamsdal, Trond; Rasheed, Adil; Tsiolakis, Vasileios; Brummelen, Harald van.** Enabling technology for predictive digital twins. CM3-TRANSPORT 2023; 2023-05-15 - 2023-05-17. NTNU
38. **Kvamsdal, Trond; Rasheed, Adil; Fonn, Eivind; Tsiolakis, Vasileios; Eftang, Jens; Brummelen, Harald van**. Enabling Technologies for Predictive Digital Twins. Invited talk at Conservatoire National des Arts et Métiers (CNAM). Paris, France; 2023-12-13.
39. **May, Roelof Frans.** The Nature of Offshore Wind. EERA DeepWind Conference; 2023-01-18 - 2023-01-20. NINA
40. **Nagula, Sparsha Sinduri; Jostad, Hans Petter; Blaker, Øyvind.** Effects of fines content in numerical simulation of CPTu in silty sands. 10th European Conference on Numerical Methods in Geotechnical Engineering; 2023-06-26 - 2023-06-28. NGI
41. **Nygaard, Birgitte.** A revitalisation of the Energy Nation Norway?. Durham Energy Institute Seminar Series; 2023-10-25. NTNU
42. **Nygaard, Birgitte.** A revitalisation of the Energy Nation Norway?. 3S Seminar; 2023-12-01 - 2023-12-01. NTNU
43. **Nygaard, Birgitte.** Place-making, geopolitics and a local energy transition: A qualitative case study of the energy transition process in Longyearbyen, Svalbard. Beyond Oil; 2023-10-17 - 2023-10-18. NTNU
44. **Nygaard, Birgitte.** The Adventure of Norwegian Offshore Wind Power?. EERA DeepWind; 2023-01-18 - 2023-01-20. NTNU
45. **Nygaard, Birgitte.** The quest for Norwegian offshore wind in the age of crisis– moving fairytale to adventure?. Beyond Crisis/Beyond Normal; 2023-09-27 - 2023-09-28. NTNU
46. **Perez-Valdes, Gerardo Alfredo; rocha, fabian; Wiebe, Kirsten Svenja.** A System Dynamics model for Norwegian Offshore Wind. Northwind Annual Conference 2023; 2023-01-12. SINTEF
47. **Petersen, Vibeke; Guericke, Daniela; Stålhane, Magnus.** Optimizing jack-up vessel chartering strategies to support maintenance tasks at offshore wind turbines. EERA DeepWind 2023; 2023-01-18 - 2023-01-20. NTNU
48. **Petersen, Vibeke; Guericke, Daniela; Stålhane, Magnus.** Optimizing jack-up vessel chartering strategies to support maintenance tasks at offshore wind turbines. The 6th Commodity Markets Winter Workshop; 2023-03-08 - 2023-03-10. NTNU
49. **Petersen, Vibeke; Guericke, Daniela; Stålhane, Magnus; Wallace, Stein William.** Optimizing vessel chartering strategies to support maintenance tasks at offshore wind farms. 2023 XVI International Conference Stochastic Programming; 2023-07-24 - 2023-07-28 NTNU NHH
50. **Rasheed, Adil.** Digital Twinning of Autonomous Systems. International Conference on Computational Science and AI in Industry; 2023-08-28 - 2023-08-30. NTNU SINTEF
51. **Skjølsvold, Tomas Moe; Heidenreich, Sara Lena Brigitte; Linnerud, Kristin; Vasstrøm, Mikaela; Richter, Isabel; Skjærseth, Jon Birger; Moe, Espen; Dankel, Dorothy Jane; Suboticki, Ivana.** Identifying and addressing societal aspects of offshore wind power in the North Sea. Deep Wind; 2023-01-20. NTNU UiB NMBU FNI UIA
52. **Stadtmann, Florian; Rasheed, Adil.** Digital Twins - Framework, Industry Perspective, and Prototypes. EERA DeepWind 2023; 2023-01-18 - 2023-01-20. NTNU
53. **Tabib, Mandar Vasudeo; Rasheed, Adil.** Hybrid Analytics and Modellling Applications in Fluid Flow: Case Study - Wind Energy, Drilling, Greenhouse and Urban City.. CSAI,2023; 2023-08-28 - 2023-08-30. NTNU SINTEF
54. **Tande, John Olav Giæver.** Mitigation measures for preventing collision of birds with wind turbines. EERA DeepWind Conference 2023; 2023-01-18 - 2023-01-20. ENERGISINT
55. **Tande, John Olav Giæver.** Mitigation measures for preventing collision of birds with wind turbines. EERA DeepWind Conference 2023; 2023-01-18 - 2023-01-20. ENERGISINT
56. **Tande, John Olav Giæver.** Research to accelerate the development of offshore wind. Science impact 2023 - tomorrow's solutions; 2023-05-27. ENERGISINT

57. **Tande, John Olav Giæver.**
The role of research to succeed with offshore wind. Statkraft-konferansen; 2023-06-12. ENERGISINT
58. **Tsiolakis, Vasileios; Kvamsdal, Trond; Rasheed, Adil; Fonn, Eivind; Brummelen, Harald van.**
Coupled reduced order model components for flow problems. Coupled Problems 2023: X International Conference on Computional Methods for Coupled Problems in Science and Engineering; 2023-06-05 - 2023-06-07. NTNU
59. **Vasconcellos Oliveira, Rita.**
Societal challenges of offshore wind in the North Sea. FME North Wind: Annual Innovation Forum 2023; 2023-12-06 - 2023-12-07 NTNU
60. **Ånestad, Ingvild.**
Regulatorisk rammeverk for utviklingen av nett (infrastruktur) til havvind i Nordsjøen, med hovedfokus på Norge. Webinar: Dynamic models, cost-effective installation, regulatory framework and impact assessments; 2023-05-03 - 2023-05-03. UiO

Books/theses and reports

Search criteria: *From:* 2023 *To:* 2023 *Main category:* Report/thesis *sub-category:* Encyclopaedia *sub-category:* Reference material *sub-category:* Popular scientific book *sub-category:* Textbook *sub-category:* Non-fiction book *All publishing channels*

1. **Belsnes, Michael Martin; Bjørndal, Mette; Elverhøi, Anders; Espegren, Kari Aamodt; Fæhn, Taran; Jaehnert, Stefan; Kjølle, Gerd Hovin; Korpås, Magnus; Marstein, Erik Stensrud; Røkke, Petter Egil; Sandberg, Nina Holck; Tande, John Olav Giæver; Thiis, Thomas Kringlebotn; Winther, Tanja; Inderberg, Tor Håkon Jackson; Tomasgard, Asgeir.**
Energikrisen i Europa og det norske kraftmarkedet. Trondheim: NTNU 2023 36 s. NTNU Rapport 429810(01/2023)
IFE UiO ENERGISINT SSB NHH NTNU NMBU SINTEF FNI CICERO
2. **Fjordbo, Gullik-André.**
Presisering knyttet til uttalelsene om omdefinering av strøm til et nødvendighetsgode. : Høringssvar til Strømprisutvalgets rapport 2023 2 s. UiO
3. **Tande, John Olav Giæver.**
NorthWind Annual report 2022. Trondheim: SINTEF Energi AS 2023 64 s. ENERGISINT

Multimedia products

Search criteria: *From:* 2023 *To:* 2023 *sub-category:* Multimedia product *All publishing channels*

1. **Tande, John Olav Giæver.**
Arendalsuka: Vind i seilene for norsk havvindforskning. SINTEF 2023. ENERGISINT
2. **Tande, John Olav Giæver; Gardarsdottir, Stefania Osk.**
Arendalsuka: Hvordan kutte utslipp på norsk sokkel i en strømpriskrise?. SINTEF 2023. ENERGISINT

Op-eds

Search criteria: *From:* 2023 *To:* 2023 *sub-category:* Feature article *sub-category:* Editorial *All publishing channels*

1. **Fjordbo, Gullik-André.**
Neppe slutt for all vindkraft i reinbeiteområder. *Dagens næringsliv* 2023. UiO
2. **Fjordbo, Gullik-André.**
Nye utredninger er ikke en omkamp i Fosen-saken. *VG : Verdens gang* 2023. UiO
3. **Fjordbo, Gullik-André.**
Staten ga en stor fordel til utbygger i forhandlingene med reineierne på Fosen. *Rett24.no* 2023. UiO
4. **Korpås, Magnus.**
Interessant om kjernekraft, unyansert om vindkraft. *www.universitetsavisa.no* 2023. NTNU
5. **Nygaard, Birgitte.**
Konflikten om vindmøller på samernes land viser en universel tendens til grøn kolonialisme. *Information.dk* 2023. NTNU
6. **Tande, John Olav Giæver.**
Havvind smelter ikke sammen med kraftsystemet av seg selv. *Dagens næringsliv* 2023. ENERGISINT

Blogs and information material

Search criteria: *From:* 2023 *To:* 2023 *Main category:* Information material(s) *All publishing channels*

1. **Albert, Daniel.**
EERA DeepWind offshore wind R&I conference gathers record crowd. ENERGISINT
2. **Albert, Daniel.**
Rekorddeltagelse på havvindforskningskonferansen EERA DeepWind. ENERGISINT
3. **Garcia Rosa, Paula Bastos.**
Active control of wind turbine speed can lead to fewer bird strikes. ENERGISINT
4. **Garcia Rosa, Paula Bastos.**
How can control engineering save birds in wind farms? ENERGISINT
5. **Garcia Rosa, Paula Bastos.**
Hvordan kan reguleringsteknikk redde fugler i vindparker?. ENERGISINT
6. **Røkke, Nils Anders.**
Research institutions agree on offshore wind EU Centre of Excellence. ENERGISINT
7. **Tande, John Olav Giæver.**
COP28: Making offshore wind a pillar of the decarbonised energy

system. ENERGISINT

8. **Tande, John Olav Giæver.**
   Floating offshore wind: Cost reductions will come with deployment. ENERGISINT
9. **Tande, John Olav Giæver.**
   Flytende havvind: Kostnadsreduksjoner vil komme med utbygging. ENERGISINT
10. **Tande, John Olav Giæver.**
    Høringsinnspill fra SINTEF, prekvalifiseringskriterier og auksjons-modell for Sørlige Nordsjø II. ENERGISINT
11. **Tande, John Olav Giæver.**
    NorthWind at Arendalsuka. ENERGISINT
12. **Tande, John Olav Giæver.**
    NorthWind partner SINTEF responds to government consultation about offshore wind. ENERGISINT
13. **Tande, John Olav Giæver.**
    NorthWind represented at Statkraftkonferansen 2023. ENERGISINT
14. **Tande, John Olav Giæver.**
    NorthWind visits HVDC platform assembly site. ENERGISINT
15. **Tande, John Olav Giæver.**
    NorthWind's "Sustainable Wind Development" work package holds annual meeting in Trondheim. ENERGISINT
16. **Tande, John Olav Giæver.**
    Research deal signed with Germany. ENERGISINT
17. **Tande, John Olav Giæver; Svendsen, Harald Georg.**
    No correlation between windy conditions in northern and southern Norway means money in the bank for the offshore wind sector. ENERGISINT

Media contributions

Search criteria: *From:* 2023 *To:* 2023 *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 *sub-category:* Short communication *All publishing channels*

1. **Fjordbo, Gullik-André.**
   Aksjoner mot Fosen-dommen. NRK [TV] 2023-10-11. UiO
2. **Garcia Rosa, Paula Bastos; Tande, John Olav Giæver.**
   Endrar fart på vindturbinar for å unngå fuglekollisjonar. Firdaposten [Avis] 2023-08-03. ENERGISINT
3. **Garcia Rosa, Paula Bastos; Tande, John Olav Giæver.**
   Endrar farta på vindturbinar for å unngå fuglekollisjonar. Fjordens Tidende [Avis] 2023-08-07. ENERGISINT
4. **Garcia Rosa, Paula Bastos; Tande, John Olav Giæver.**
   Vindturbiner endrer fart for å unngå fuglekollisjoner. TU [Fagblad] 2023-08-20. ENERGISINT
5. **Tande, John Olav Giæver.**
   - Litt som da vi fant oljen Venter havvind-utlysing om kort tid. VG [Avis] 2023-02-24. ENERGISINT
6. **Tande, John Olav Giæver.**
   Active control of wind turbine speed can lead to fewer bird strikes. Norwegian SciTech News [Fagblad] 2023-09-11 ENERGISINT
7. **Tande, John Olav Giæver.**
   Angepasste Geschwindigkeit der Windräder soll Vogel-Kollisionen verhindern. heise online [Internett] 2023-09-20. ENERGISINT
8. **Tande, John Olav Giæver.**
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