BERGEN OFFSHORE WIND CENTRE (BOW) ANNUAL REPORT 2020

UNIVERSITY OF BERGEN

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Foreword

2020 was the second full year of operation for Bergen Offshore Wind Centre (BOW). 2020 has been a challenging year in general, and for a young and ambitious centre as BOW as well. The pandemic has made the rapid development of national and international networks and tight interdisciplinarity challenging. Despite this, BOW has been very active, and we have learned a great deal about digital communication, both the new possibilities and the challenges.

We have gained momentum and volume in our research activity. Several new PhD students and postdocs have joined us across different disciplines. We have also been active in submitting research applications. Coordinating work between different disciplines is time consuming and demanding, but we believe that this is a key to solve the challenges ahead.

Great ambitions have been made official for offshore wind as part of the solution to obtain a carbon neutral energy supply by 2050, with the EU and the UK as clear examples. The planned up-scaling for offshore wind capacity involves both opportunities and barriers. Previously, the focus has been on developing technical solutions to reduce the cost of energy. This effort will certainly continue; however, other topics are still in need for research. Among these we highlight the need to develop an improved understanding of the wind as a resource, the environmental implications and consequences of large-scale deployment of offshore wind farms, the regulatory mechanisms for use of the ocean space, as well as power exchange across national borders. To solve these challenges a real cross-disciplinary approach is needed. This is where BOW will contribute and make a difference.

Norway has one of the world's best wind resources. We see an increasing interest and debate in Norway related to how our offshore wind resources can be utilized. We want to contribute to this debate with knowledge and facts. This requires relevant and up-to-date research activity as well as relevant meeting places.

In this report some of our researchers are presented. You will see the breadth of knowledge represented. We also describe our main ongoing research projects. These projects show that we are working on research that is on the front of several areas and that we combine the specialized knowledge into a holistic understanding of how offshore wind may become a key contributor to our future energy supply in a sustainable way. We also have included some valuable considerations from the director of the Centre for Climate and Energy Transformation (CET), Håvard Haarstad and Dorothy Jane Dankel, researcher at the Department of Biological Sciences (BIO). They discuss if offshore wind presently is at a tipping point.

Finn Gunnar Nielsen, Professor, director of BOW

A tipping point for offshore wind and coexistence of marine space?

The past few years offshore wind has seen several different dramatic upturns with more efficient technology, lower costs and strong political will to open offshore areas and start projects. A fascinating concept in social science is the "***tipping point***", a term from systems thinking used casually in studies of sustainability and energy transitions. The popular science book "The Tipping Point" by Malcom Gladwell refers to it as "the moment of critical mass, the threshold, the boiling point." We can understand it as the moment when several different tendencies converge, reinforce one another, and create quick and rapid change.

Over the past few years, the winds have been changing in favor of offshore wind farms. The combination of more efficient technologies, lower development and running costs, and stronger political will to open offshore areas has resulted in the onset of more projects. This movement towards renewable energy is moving Norwegian society towards a 'tipping point', in this case the point of change between reliance on fossil fuels and reliance on renewable energy. Will different forces converge with enough momentum to reinforce one another, creating quick and rapid energy transformation in Norway?

For offshore wind in Norway, it appears that we may be arriving at a tipping point. Many have suggested that the publication of the International Energy Agency (IEA)'s much publicized Roadmap for the Global Energy Sector in May 2021 (you know, the one that said there is no need to invest in new fossil fuel developments) as a clear sign of this. The fact that the IEA, which has traditionally been conservative in its prospects for renewables has shifted to this favorable position on renewables may suggest that we are in a new era. In Norway, the public favors this new green era but has a strong 'Not-in-my-back-yard' response to onshore wind which will probably result in a focus on wind power generation at sea.

In fact, evidence of this new area, even beyond Norway, has been accumulating for some time. The EU Green Deal has signaled plans for strong investment in offshore wind. In the US, President Biden has unlocked plans for offshore wind as part of a well-funded infrastructure and clean energy package. Both energy companies and financial investors have increased investment in offshore wind developments as well, which will likely increase the rate of technological innovation and further decrease costs. In addition, the idea of climate risk seems to have hit home in financial sectors, meaning that many investors worry that large oil companies may lose value quickly if (or when) the world crests this tipping point and becomes completely reliant on renewables. The idea behind a tipping point in an energy transition is that these different **political**, **economic**, and **public pressures** mutually reinforce one another, creating rapid and deep change as we go over the tipping point and roll towards renewables. For example, if public opinion demands more of a policy on climate, it is easier for green politicians to pass ambitious goals and implement a credible long-term policy. If a long-term climate policy is implemented, it becomes easier for companies to invest in renewable innovation. If companies invest in renewable innovation, it becomes easier for green politicians to demand more renewables. And so on and so forth.

For the challenge of climate change, however, this only works if we reduce consumption of fossil energy at the same time. Because even though these positive reinforcements are happening around offshore wind, we keep producing and consuming more fossil energy, and thus challenging the 'tipping point' perspective. Put another way, we are growing our energy budget with renewables rather than transitioning to a fully renewable system. In order to reach

the desired and perceived transformative tipping point, offshore wind must not complement fossil energy, it must displace it.

Some may think that crossing the tipping point is like crossing the finish line of a race. But unlike the metaphor of a running race, the policy narrative of renewable energy transformation should not be constrained by tunnel vision and pure speed. Offshore energy projects have strong consequences for other marine sectors. Forgetting these ripple effects can lead to negative feedbacks on new offshore wind projects, resulting in a so-called "tripping point". A tipping point can reverse and become a *tripping point* if one or more political, economic, or public opinion forces fight against Norwegian offshore wind energy.

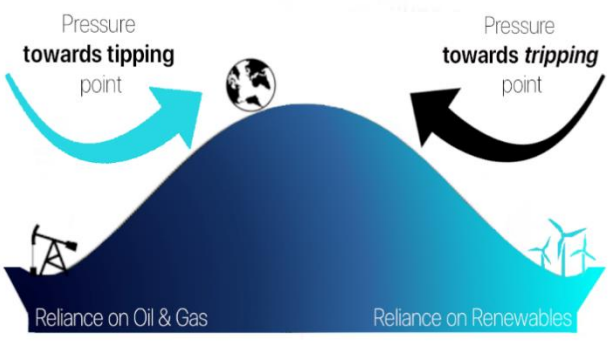
Why might this happen? The fact is many hundreds or thousands of square kilometers of Ocean space all around the world are needed for offshore wind energy to be successful at a large enough scale to contribute to a global energy transformation. This space is not immediately useable or navigable for use in other sectors, such as fishing, shipping, tourism, or transportation. Offshore aquaculture is often named as a synergistic sector with offshore energy, but even that is disputable as some farmers still wonder how the underwater noise and electromagnetic fields associated with large wind turbines would affect their fish.

Another potential tripping point is the continued lack of knowledge of how offshore wind parks will impact marine mammals, fish, habitats, and biodiversity. Ecological impact assessments are currently missing and require both focus and resources to create. Besides an ecological backlash which could occur due to lack of ecological assessments, a *social backlash* could also erupt against a sector that favor energy over responsible ecological stewardship. The concept of a **social license to operate** is relevant here - social trust is something that is essential for a sustainable sector and business to have. And trust is hard-earned.

Marine spatial planning is the default process for marine sectors to meet to discuss the pros and cons of new projects. These processes must have competent representation from all relevant actors in a respectful dialogue to prevent and mitigate all the inevitable tripping points along the path of energy and social transformation needed to meet our climate goals.

The institutional location of Bergen Offshore Wind Centre at the University of Bergen offers a myriad of new collaborations to help analyze both the potential tipping *and* tripping points of an offshore renewable energy transition. Indeed, we feel that these types of industry-academic-societal collaborations are what is needed to fulfill the UiB motto of "Knowledge that forms society."

Håvard Haarstad, director CET & Dorothy J. Dankel, researcher (BIO)



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BOW - our mission and focus areas

Bergen Offshore Wind Centre (BOW) was established as a part of the University of Bergen's priority area "Climate and Energy Transition". By the end of 2020, BOW has been in operation for about 2 years. Our vision is that BOW will provide new knowledge for the sustainable development of offshore wind energy. To work towards that vision, our goal is to be an interdisciplinary wind energy research centre at a leading international level, by:

- Identifying key challenges and opportunities related to large-scale utilization of offshore wind energy and addressing topics aligned with our core competence areas.
- Being a leading actor in research, as well as an attractive partner for academia, industry, and the public sector.
- Actively communicating our research in the most relevant international journals and key conferences.
- Contributing a factual basis to the public debate on offshore wind energy.
- Being the preferred point of contact for offshore wind competence in Norway.
- Contributing to a top-level education within offshore wind energy.

To support us towards these goals, we have a steering committee (SC) with representatives from UiB and NORCE, and a Scientific Advisory Committee (SAC) with representatives from academia and the industry. The SC met twice in 2020 (March and June) while the SAC met in September, in conjunction with the yearly conference Science Meets Industry (SMI).

The focus areas of BOW are presently:

- Physics of wind
  - Experimental mapping of wind inside and outside of wind farms.
  - Numerical simulations of wind and wakes.
- Load and response of wind turbines
  - Dynamic interaction between wind, waves, and structure.
  - Characterization of marine sediments for foundation purposes.
- Optimization
  - Use of advanced optimization tools for design and operations.
  - Decisions under uncertainty related to weather windows.
- Governance and financing
  - National and international regulatory frameworks, licenses, network, and power transmission.
  - Opportunities, risks, and challenges related to private and public project financing.

BOW has no employees. All staff is employed by the University departments. BOW's mission is thus to coordinate the research effort and applications relevant to offshore wind energy. We also strive to make all the relevant competence at UiB relevant for offshore wind energy visible in the national and international research community and thus contribute to understanding the opportunities and challenges in the future development of offshore wind energy.

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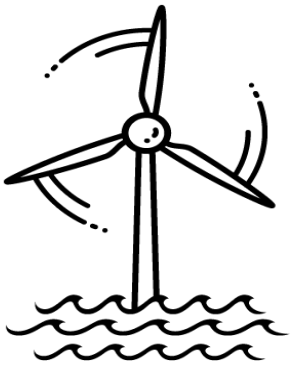


Summary of 2020

2020 was a very special year with very few opportunities for physical meetings. For a young organization such as BOW, this hampered the development, since we depend upon meeting fellow researchers and building networks. Despite this, our activity has significantly increased compared to our first year of operation. In the following, we present a short overview of our researchers and activities during 2020.

Personnel. By the end of 2020, 37 researchers were affiliated with BOW. They are using everything from a small fraction to their full worktime on BOW related projects. Common for everybody is the interest and research activity relevant to offshore wind energy. The departments involved range from the Geophysical Institute, via Physics and Technology, Earth Science and Biology to Law. Table 1 gives a summary of the research personnel involved at BOW.

Publications and dissemination /outreach. The publication results increased significantly in 2020. In Table 2 a summary of the publication activity is listed. The Covid-19 pandemic has not had any significant impact on the opportunities for submitting journal publications. However, most physical conferences have been cancelled. This had led to a significant number of presentations being held through web-based conferences and workshops. BOW personnel have been invited to contribute with various important presentations for organizations and stakeholders interested in learning more about opportunities and challenges related to offshore wind energy. Similarly, we have contributed to society at large through chronicles and debate contributions in the news media. The contributions have dealt with issues ranging from resources to technical, environmental as well as legal issues.

Table 1: BOW affiliated personnel. GFI: Geophysical Institute, PHYS: Physics and Technology, BIO: Biology, GEO: Earth Science, SOC SC: Social Sciences and Geography.

	GFI	PHYS	INF	BIO	GEO	SOC SC	LAW	SUM
Prof. / Assoc. Prof.	6	1	3	1	3	2	3	**19**
Researcher / post docs	5	1		1				**7**
PhD students	7	1			1	1	1	**11**
SUM	**18**	**3**	**3**	**2**	**4**	**3**	**4**	**37**

BOW co-organized the yearly “Science Meets Industry” (SMI) conference in September. This year the conference was digital, and 210 participants were registered, more than has ever been present at the physical conferences.

On 22 April 2020 BOW and GCE Ocean Technology arranged a seminar entitled “Webinar on Financing of Norwegian Offshore Wind”. More than 100 people joined this event, including members of the Norwegian Parliament. Two speakers affiliated to our center, were represented at the webinar: Professor Berte-Elen Konow and Associate Professor Ignacio Herrera Anchustegui. They discussed what the legal regime that serves as the backbone of financing of offshore wind events in Norway is from a private and public investment perspective. The discussion included aspects related to mortgages and bank warranties, public

support and state aid options, and the need for a solid legal framework to allow for projects to take off.

BOW, together with Energiomstilling Vest (EOV) had planned for a workshop in Brussels in April to provide input to EU's strategy work on offshore energy to be published in the autumn of 2020. The workshop was replaced by a series of web-meetings with important stakeholders within industry, authorities, and research. The input was summarized and a statement document "Offshore Wind. Grasping the opportunities and solving the challenges" was submitted to the European Commission in July.

Even if web-based meetings and seminars are not suited for building networks and personal relations, we have observed that the web makes it possible to reach out to people that would normally not attend arrangements with a specialized focus.

Table 2: Publications in 2020 by category

Publication category	Number
Peer reviewed research articles	23
Books	4
Bluepapers	1
Poster presentations	4
Conferences, oral presentations	23
Popular presentations	10
Debate contributions (News)	12

Education. The number of Ph.D. and master students working on offshore wind related topics increased in 2020. However, only a few master students submitted their thesis this year. The integrated five-year master programme in energy attracts many highly qualified students. Last year more than fifty students started. We see an increasing number of students who wish to specialize within offshore wind energy. This is promising for the future recruitment of highly qualified candidates for the coming industrial and academic needs.

Offshore regulation was also of interest in the Law Faculty. In addition to the work by PhD student Eirik Finseraas (see below), three students wrote their master's thesis on regulatory issues connected to offshore wind. Additionally, discussions on offshore wind regulation were incorporated into the "International and comparative Energy and Climate Law" subject.

In 2020 a seminar within "offshore wind energy" was arranged. The seminar dealt with issues like boundary layer meteorology, aerodynamics of wind turbines and wave loads on fixed and floating wind turbines. The seminar, running over approximately two weeks, attracted both MSc and PhD students as well as people from the industry. The plan is to repeat the seminar in 2021 and extend it into a regular course.

Research activity. External funding for offshore wind related research activity amounted in 2020 a total of 8.8 mill NOK. This includes externally funded adjunct professor positions. The key sources of funding are EU Horizon2020, Research Council of Norway (RCN), the Akademia agreement with Equinor, Regional Forskningsfond, as well as direct industrial funding. The activities in some of the key projects are summarized in more detail below.

We submitted 10 research project applications in 2020. Some of them have been granted, some are being reviewed and some were rejected. A general challenge has been the priorities in the calls, which had a strong technical and industrial focus at high technological readiness level (TRL) not fitting our research profile and priorities very well. However, we foresee a stronger focus on the areas prioritized by BOW in future calls, in particular within Horizon Europe.

Late August RCN made a call for a FME (Centre for Environment-Friendly Energy Research) within wind energy. The application deadline was already 11 November. We formed a broad consortium together with NORCE, UiS, UiA, UiO, HVL, NHH and IFE. In the submitted application we included several aspects outside the technical issues related to wind energy. Issues we assume will be key to the significant up-scaling of the offshore wind industry in the years to come. Despite this, or because of this, we did not win the competition for the centre. However, the application work created several ideas and identified research needs that will be pursued in future calls. Additionally, this process strengthened the will for cooperation among the eight institutions involved.

The COTUR-project at Obrestad. © Kristin Guldbransen Frøysa

Meet our researchers

In the 2019 report we presented some of our key researchers. This year we follow up by presenting some more to illustrate the width of the competence areas of BOW.

Eirik Finserås Eirik.Finseras@uib.no is a PhD student at the Law Faculty. He joined UiB in 2020 and is affiliated with both BOW and the Research Group for Natural Resource Law, Environmental Law and Development Law. Before moving to Bergen, he was a student in the UK specializing in matters of international law. He took an LLB in international law at Kingston University, followed by an LLM at University College London where he specialized in international environmental law and maritime law. Presently he is involved in the project "Designing a Refined Legal Framework for Offshore Wind in the North Sea Basin (DeWindSea)", see below.

Hannah Elizabeth Petrie Hannah.Petrie@uib.no is a PhD student at the Department of Geoscience. She joined BOW in 2020. She has a BSc in Geology from the University of Edinburgh (2013) and an MSc in Petroleum Geoscience from Imperial College London (2014). She worked as an exploration geologist for several years and then as a geoscientist in well execution before joining UiB where she currently works on the project "An integrated geological characterization of marine ground conditions for offshore wind foundations in the North Sea". In doing this, she can build upon her experience in petroleum geoscience towards offshore wind energy.

Stephan Kral Stephan.Kral@uib.no is a researcher at the Geophysical Institute. He joined BOW in 2020 after completing his PhD at UiB. For his PhD, Stephan studied the stable atmospheric boundary layer over sea ice based on a novel observational approach, combining a variety of different observation systems. He holds a Diploma (equivalent to MSc) degree in Meteorology from the University of Munich (2011) and has previously been employed at the Finnish Meteorological Institute (2013–2014). In his current position, which is connected to the Academic Agreement between UiB and Equinor, he is analyzing more than 10 years of observational data from a micro rain radar, to give insight in the size distribution of hydrometeors during precipitation events and their potential to cause erosion to the leading edge of offshore wind turbines along the Norwegian coast.

Ida Marie Solbekke Ida.Solbrekke@uib.no is a PhD student at the Geophysical Institute. She has a BSc in meteorology and oceanography (2012) and a MSc in meteorology (2014), both from UiB. For her MSc she investigated how strong winds interact with the complex topography in Norway, through a case-study of the storm "Dagmar". After her MSc she worked as a weather forecaster at the Norwegian Meteorological institute (2014-2016). The job involved analyzing complex output from weather models and conveying the forecast to various users and non-experts. In her PhD project (2016-) she investigates the large-scale effect of interconnecting wind power plants to achieve a higher and more stable wind energy production. In addition, she has developed a wind power data set (NORA3-WP, available to everyone) to use in future studies and investigations on wind power related topics.

Christiane Duscha Christiane.Duscha@uib.no is a PhD student at the Geophysical Institute. She joined BOW in 2019. She has a BSc and an MSc in Meteorology from the University of Hamburg, Germany. During her studies, she specialized in satellite, aircraft and ground-based remote sensing. Parallel to her studies, she worked as a consultant for renewable energy resource assessments. Her work at BOW involves the evaluation and development of Doppler wind Light Detection and Ranging (LIDAR) strategies on moving platforms at sea for offshore wind energy applications.

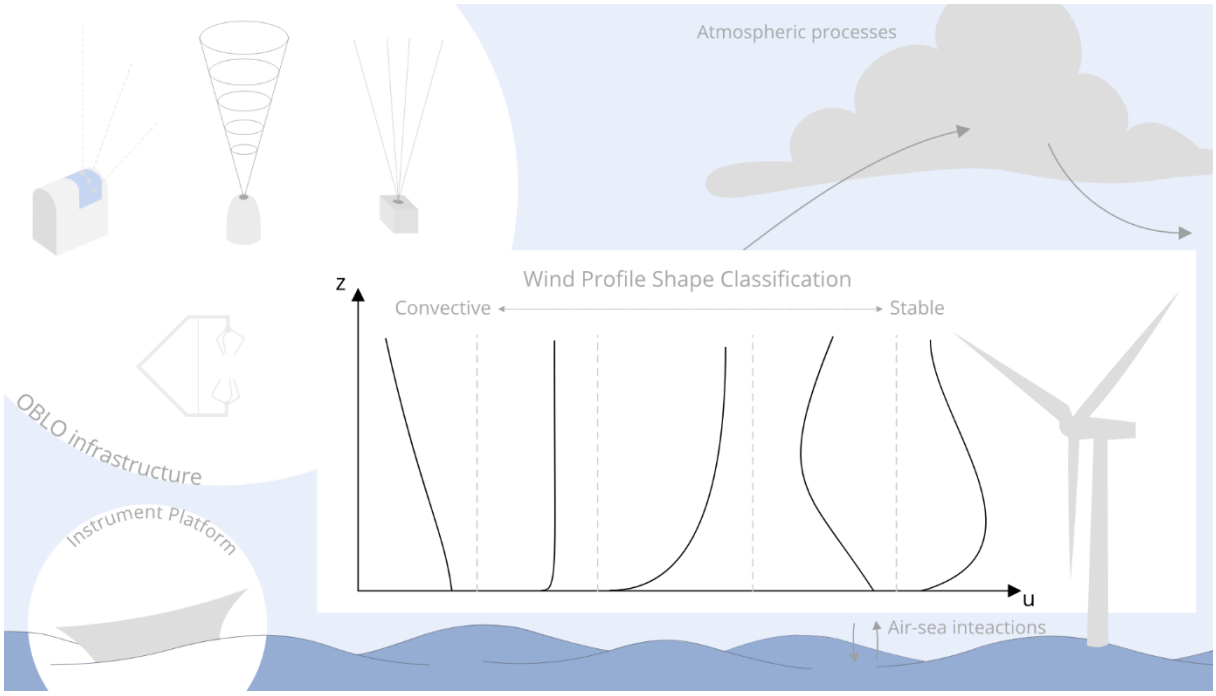


Illustration: Measurements to characterise the wind field.

Marte Godvik magodv@equinor.com joined Geophysical Institute and BOW as an adjunct associate professor in 2019. Her main position is as a principal researcher at Equinor. She holds a PhD in mathematics from NTNU (2008) and has been working on wind energy in DNV (2008 - 2011) before she joined Equinor (2011). She works with technology development related to both fixed and floating offshore wind turbines. Her field of research is within loads and responses of offshore wind turbines. More specifically, she focuses on description and modelling of wind and wakes and their influence on the turbines, both for structural design and in the operational phase.

Charlotte Bay Hasager cbha@dtu.dk joined Geophysical Institute and BOW as an adjunct professor in 2019. Her main position is as professor at DTU Wind Energy in Denmark. She works with offshore wind energy meteorology. Her main interests are in offshore wind farm planning and measurement techniques such as remote sensing using wind lidar and satellite data. Recently a new research area related to leading edge erosion of wind turbine blades mainly due to rain hitting the blades, has caught her interest. This topic falls within research of meteorology, materials, aerodynamics and control of turbines in a multi-disciplinary way. She is Co-operating Agent for the newly established IEA Wind TCP Task 46 Erosion of wind turbine blades.

Christian Haug Eide Christian.Eide@uib.no is an Associate Professor in Sedimentology (2018-) at the Department of Earth Science. He holds a PhD in geology from UiB and Uni Research (now NORCE). His research is broad and based in sedimentary geology, focusing how uplands and sedimentary basins are connected in space and time, how sedimentary architecture impacts the flow of fluids and intrusions in sedimentary basins, and how sedimentary processes may be hazards to society. Recently, he has been co-leading a project to investigate how marine soil conditions on previously glaciated shelves impact mooring conditions for offshore wind, and how geological investigations for offshore wind farms can be conducted in an effective manner.

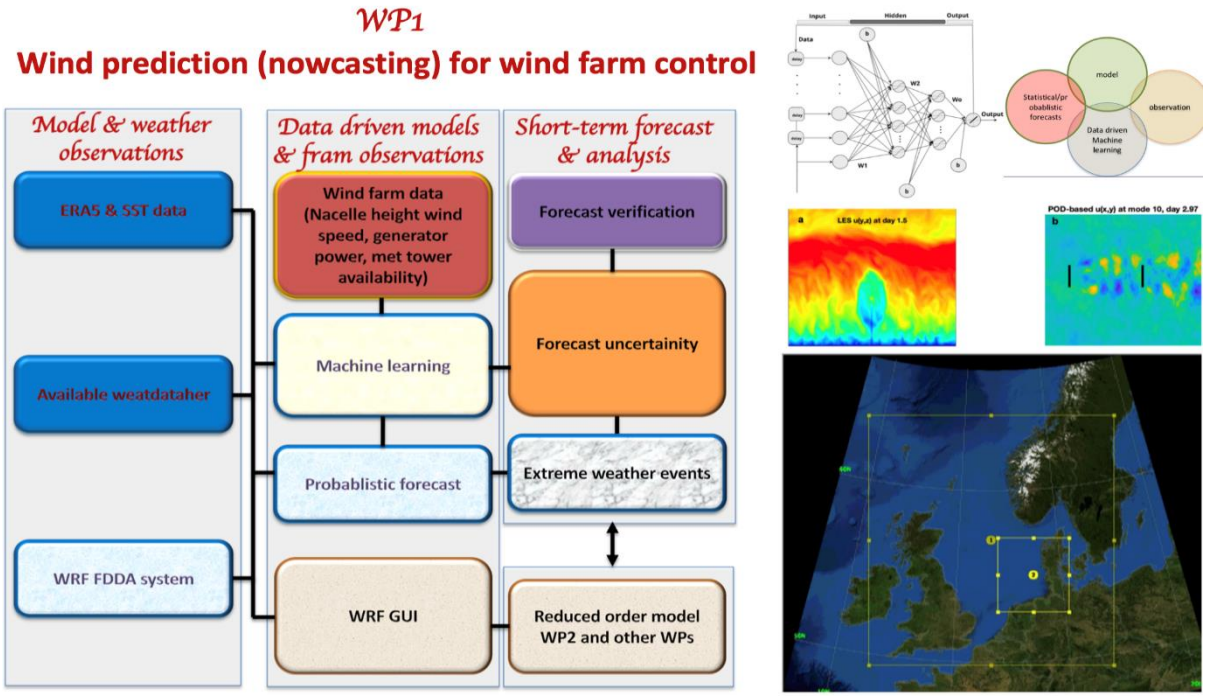
Birgitte Rugaard Furevik
Birgitte.Furevik@uib.no joined Geophysical Institute and BOW as an adjunct professor in 2020. Her main position is as a senior scientist at Meteorological Institute. She holds a PhD in geophysics from UiB (2001). She works with wind and wave related problems through mesoscale modeling and analysis of measurements. Lately her work has been focused on coastal areas and connected to fjord crossings in the large infrastructure project Coastal Highway E39. She is involved in SFI Blues - a research centre for large floating structures, among others floating wind turbines.

Ongoing projects 2020

CONWIND. (Research on smart operation control technologies for offshore wind Farms). PI at BOW: Associate professor Mostafa Bakhoday-Paskyabi, Geophysical Institute.Mostafa.Bakhoday-Paskyabi@uib.no

CONWIND is a Norwegian Research Council funded, Norwegian-Chinese collaborative project on offshore wind technologies, running over three years. The project is led by NORCE and have partners from both former Norwegian research centers for environmentally friendly energy (FME) on offshore wind: NORCOWE and NOWITECH.

UiB / BOW leads work package 1 on wind prediction (nowcasting) and wind farm control. A three-year post doc will be in place in 2021. UiB is using observational data for data assimilation purposes and model-observation validation and verification. These datasets include lidar data, and high frequency sonic data, measured at a FINO1 offshore meteorological mast. In cooperation with NORCE, measured data are implemented in a wind prediction model (using WRF) as well as for transient events (low level jets). These results will be used for the short-term data-driven forecast (using machine learning). Further, UiB has conducted a few hours of WRF simulation in the Southern North Sea by including the effects of turbines/farms. Results were presented on the EERA Deep Wind 2020 conference, and a research article has been submitted.

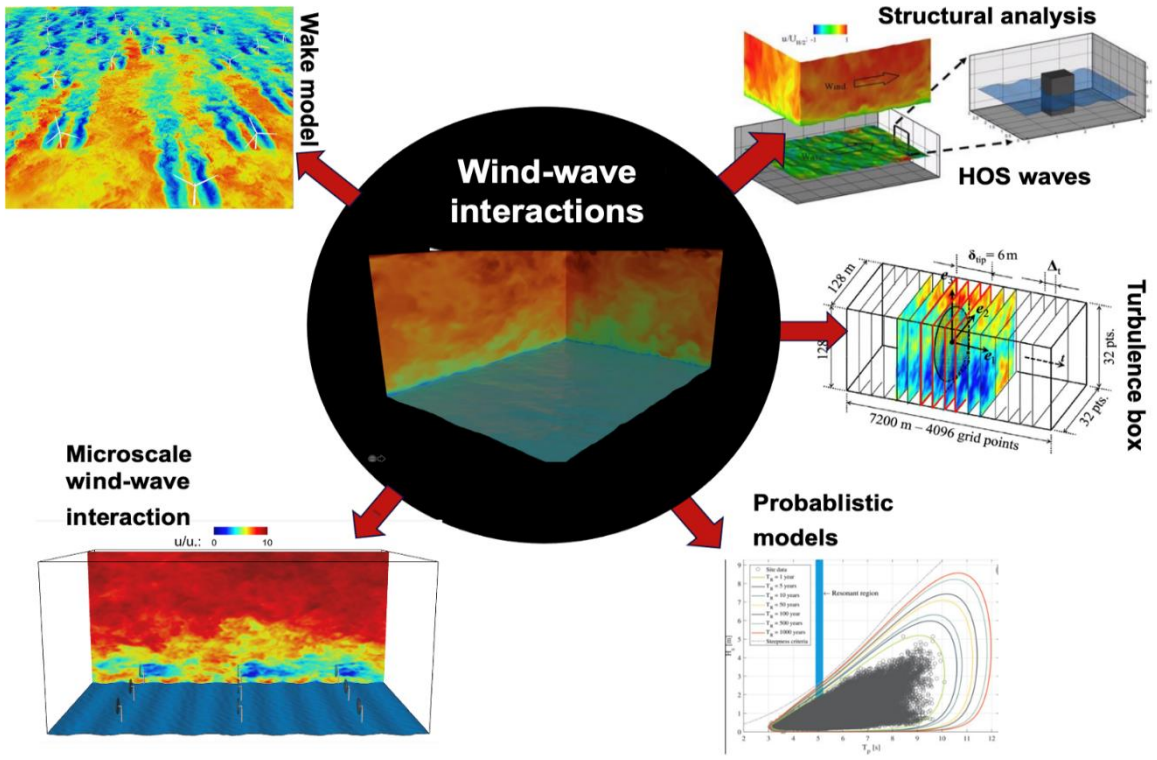


(Left) Flowchart of different tasks and sub-activities in WP1 of the CONWIND project categorized into three groups: Mesoscale modelling and observations, data assimilation and data-driven methods, and short-term forecast using Machine Learning (ML), mesoscale model, and hybrid probabilistic-ML methods; and (right) snapshot plots of the study area (bottom), LES simulation results (middle), and short-term forecasting using ML and probabilistic models.

Large Eddy Simulation Modeling of Offshore Wind Farms Under the Influence of Varying Atmospheric Stability and Sea-State Conditions PI at BOW: Associate Professor Mostafa Bakhoday-Paskyabi, Geophysical Institute. Mostafa.Bakhoday-Paskyabi@uib.no

This project aims to understand the air-flow characteristics inside a wind farm using an advanced numerical microscale Large Eddy Simulation (LES) model i.e., Parallelized Large-eddy Simulation Model (PALM). While this LES model can capture a wide range of time and spatial scales, it cannot resolve the processes related to the ocean surface gravity waves. The primary objective of this project is to: Implement effects of waves in PALM model; and provide more realistic representation of flow field through offline nesting of PALM with a mesoscale WRF model. From September 2020, Xu Ning started as PhD student at BOW/GFI working on this project.

An article has been published in Journal of Physics (Paskyabi et al. *On Stochastic Reduced-Order and LES-based Models of Offshore Wind Turbine Wakes*). A 2D version of wave model under wavy surface using sigma coordinate (Also presented at the EERA DeepWind 2020 conference). Two presentations have been submitted to the EERA DeepWind 2021 conference. Two different LES models (PALM and SOWFA) have been compared statistically and spectrally

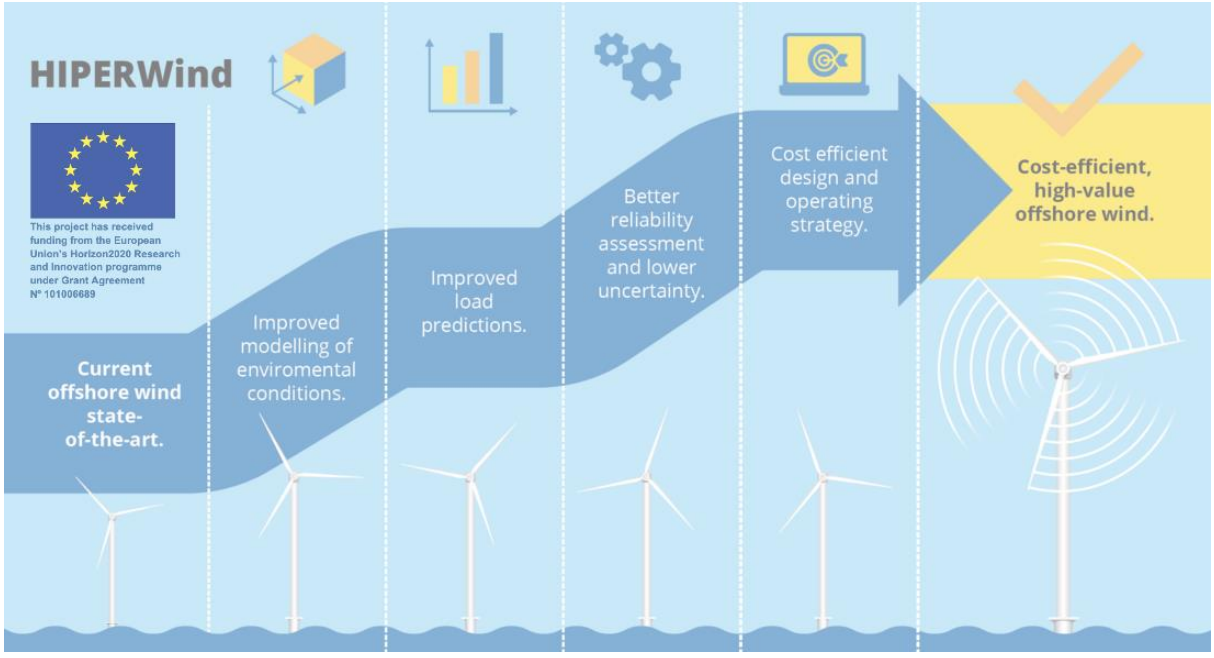


Microscale wind-wave interaction using wave-modified PALM LES model. Shown in this figure contains different applications of this project such as probabilistic analysis of offshore wind turbine using environmental contour method (bottom-right), constraint turbulence box (middle-right), structural analysis (top-right), and wave meandering and evolution (left).

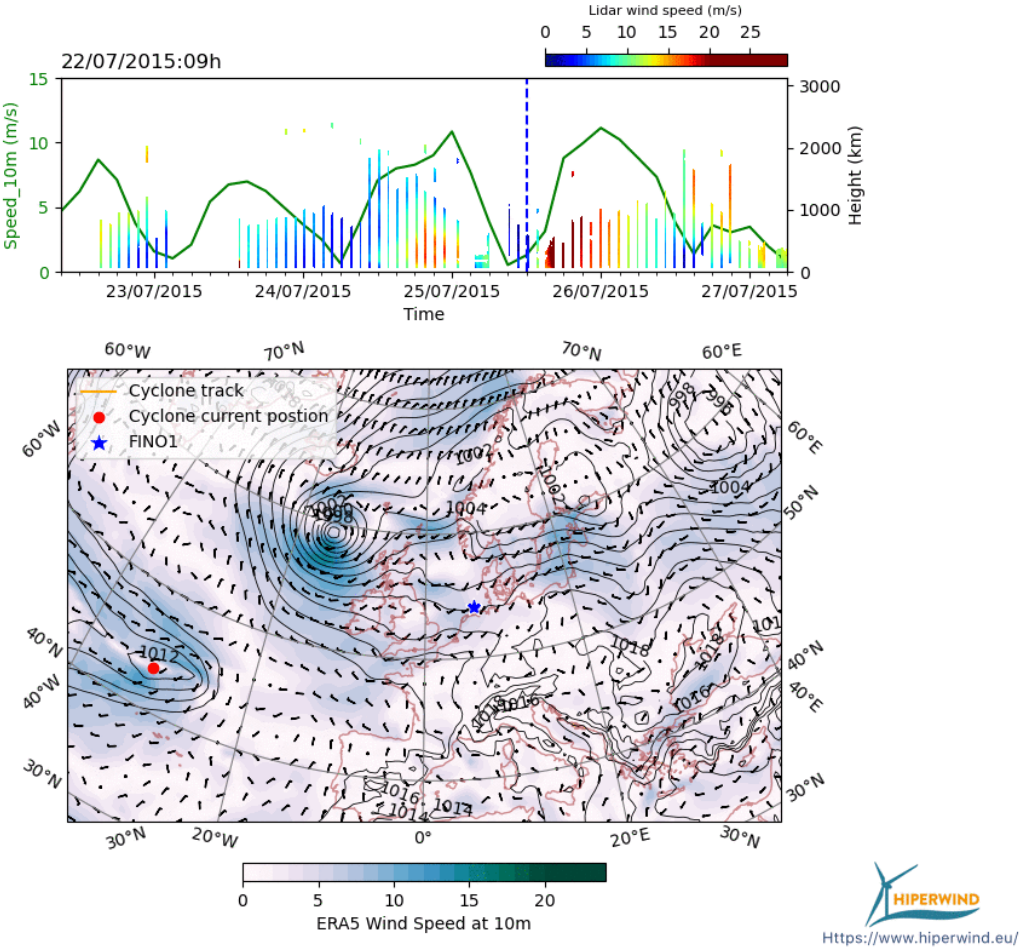
HIPERWind. (HIghly advanced Probabilistic design and enhanced Reliability methods for high-value, cost-efficient offshore WIND.) PI at BOW: Associate professor Mostafa Bakhoday-Paskyabi, Geophysical Institute. Mostafa.Bakhoday-Paskyabi@uib.no

Significant cost savings in offshore wind industry can be achieved through the technological advancements as well as comprehensive knowledge of environmental conditions and physical processes relevant for the operation of large offshore wind farms can deliver significant cost savings to wind farm. HIPERWind aims therefore to decrease the cost of energy from offshore wind turbines by at least 9% through reduction of risk and uncertainty. HIPERWind aims at using a sophisticated numerical model chain of different fidelity, highly advanced probabilistic design, and enhanced reliability methods to optimize the offshore farm operating strategy. Further, to enhance the reliability prediction, and improve state of the art in the wind energy design. UiB is responsible for WP2on multiscale modelling of the wind field. A major part of the work starts in March 2021. However, since December 2020, UiB has contributed to WP1 with data collection and processing to be used in WP2 as well as uncertainty assessments in other WPs. Part of a report and two sets of lidar-based datasets were processed for these tasks.

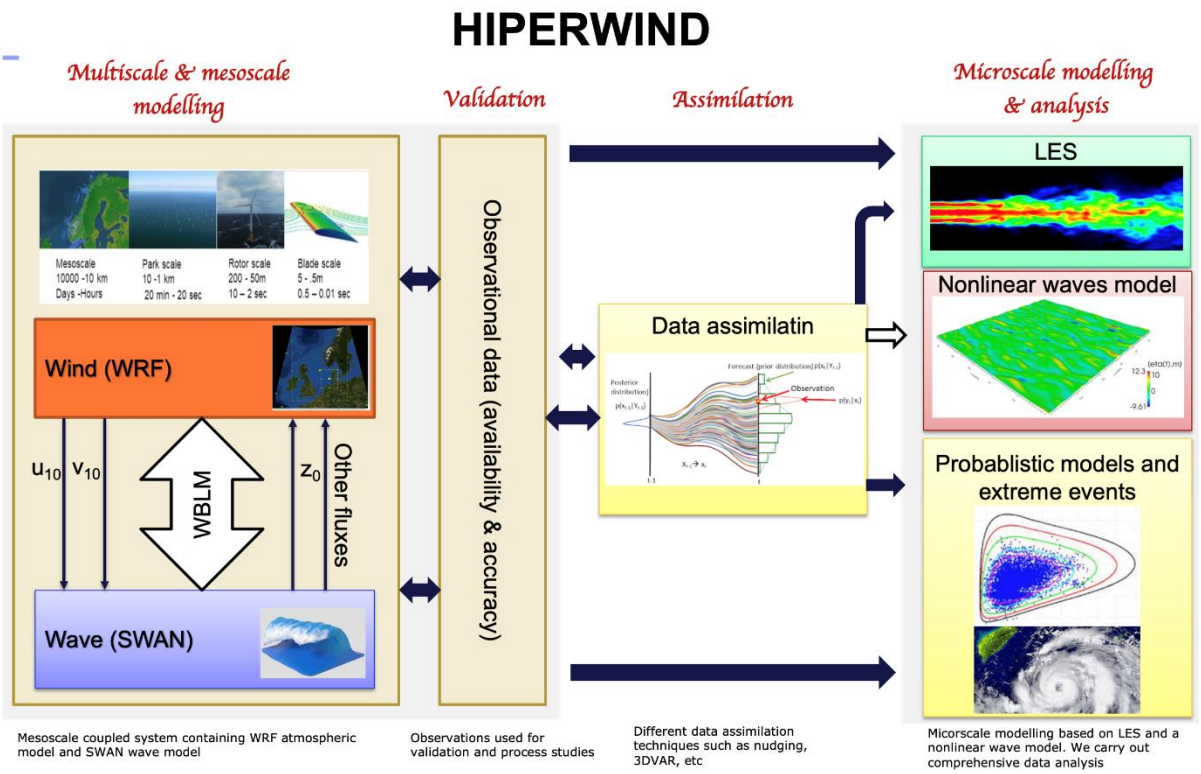
We have developed several modelling/processing tools for conducting multiscale modelling of the wind field in the offshore wind park area. We have developed a constrained turbulence box model and started to apply a module for WRF model to better account for the sea surface roughness length in the presence of waves. The COAWST coupled system was compiled and run in our high-performance computing system. In 2021 two researchers will be hired UiB for this project.



The building blocks of HIPERWind.



(Top) Time evolution of LiDAR measurements at FINO1 collected during the OBLEX-F1 campaign (colored bars), wind speed time series (red curve). Left and right vertical axes in this figure show wind speed in m/s and height of LiDAR measurement in meter; and (Bottom) map of ERA5 surface wind intensity and streamlines. Orange curve shows trajectory of a cyclone passing through the FINO1 offshore meteorological mast (asterisk marker). © Hai Bui



From mesoscale to microscale in wind modelling

COTUR – coherence analysis (part II) PI at BOW: Professor Joachim Reuder, Geophysical Institute, executed together with post. doc Etienne Cheynet, Geophysical Institute. joachim.reuder@uib.no

The COTUR campaign, a joint collaborative field project involving Bergen Offshore Wind Centre (BOW/UiB), the University of Stavanger, NORCE and Equinor, took place between February 2019 and April 2020. The deployment of 3 scanning lidar systems (Leosphere WindCube 100S), one lidar wind profiler (Leosphere, WindCube v1) and a passive microwave temperature and humidity profiler (Radiometer Physics HATPRO RG4) resulted in the collection of a comprehensive data set of the coastal offshore wind field and the thermodynamic structure of the coastal atmospheric boundary layer [1]. A follow-on joint research project between Equinor and UiB/BOW will be started in 2021. The following 10 months, a thorough analysis of the COTUR data set will be performed. The main objective is to study the coherence of turbulence, which is one of the governing parameters for the design and optimized operation of offshore wind turbines. The main focus will be on the influence of the environmental conditions, in particular, atmospheric stability, on wind and turbulence conditions offshore in the vicinity of the coast.

[1] Cheynet, E., Flügge, M., Reuder, J., Jakobsen, J. B., Heggelund, Y., Svardal, B., ... & Godvik, M. (2021). The COTUR project: Remote sensing of offshore turbulence for wind energy application. Atmospheric Measurement Techniques Discussions, 1-32.

Meteorological masts installed at Obrestad lighthouse in March 2020 during the COTUR campaign. © University of Stavanger

GOV-WIND (Governing Offshore wind: Legal Challenges, Market Opportunities and Policy Perspectives) PI at BOW: Associate professor Ignacio Herrera Anchustegui, Law Faculty. Ignacio.Herrera-Anchustegui@uib.no

The GOV-WIND project, financed by the University of Bergen, is well on its way and producing some results already. GOV-WIND seeks to understand the regulatory framework in which offshore wind takes place from a market, comparative, and interdisciplinary perspective. Herrera Anchustegui, the principal investigator, has authored different publications already and organized and participated in different events as well.

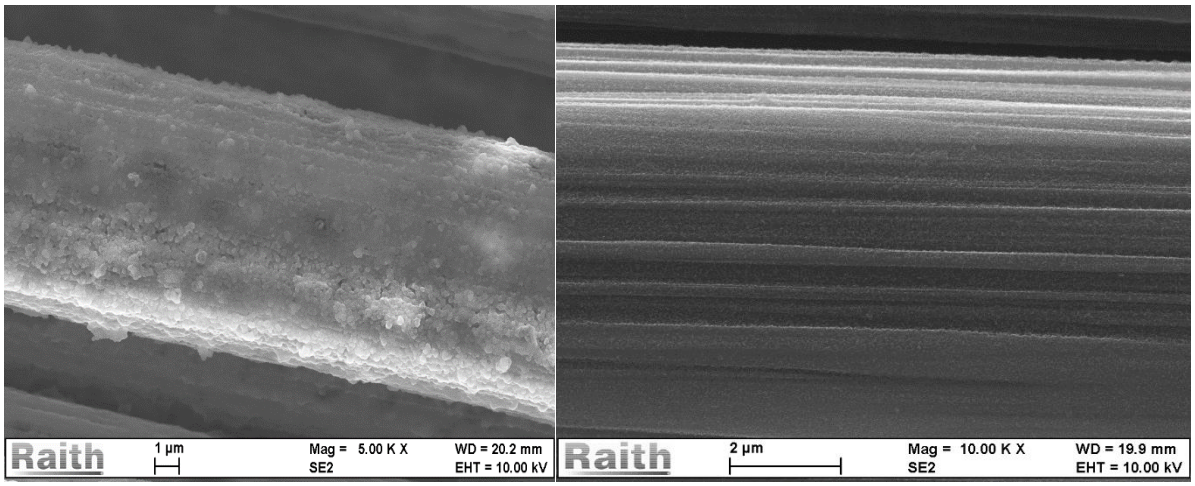
As part of the GOV-WIND project, Herrera Anchustegui was part of the BOW team that submitted his opinion concerning the offshore energy strategy of the European Union. Additionally, along with Lecturer Daria Shapovalova and Lecturer Eddy Wifa from the University of Aberdeen, they submitted a Response to the EU offshore energy strategy in which they highlighted key legal issues to be addressed in the future for wind energy to take off.

Additionally, Herrera Anchustegui and Prof. Tina Soliman Hunter have secured a book contract with Elgar to edit the upcoming Offshore Wind Licensing book, including more than 15 jurisdictions all over the world discussing the most relevant topics on what the regulation requires for licenses to be assigned. This book, part of the GOV-WIND project, is expected in late 2022.

Estimation and Prevention of Erosion on Off-Shore Wind Turbine Blades. PI at BOW: Professor Bodil Holst, Department of Physics and Technology (IFT), Nanophysics Group. Bodil.Holst@uib.no The project is carried out within the framework of the Academia agreement with Equinor. The project is a collaboration with the Institute of Geophysical Institute where Professor Joachim Reuter is co-PI. joachim.reuder@uib.no

A new nano diamond coating for wind turbine blade leading edges was developed. Three paths are pursued: Coating fibres with Nano Crystalline Diamonds (NCD) layer, coating composite surface with NCD or a combination of both. Therefore, equipment for a resin-infusion set-up was purchased and installed at the IFT workshop and a carbon fibres composite manufacturing process has been established. The aim is to create materials using NCD coated fibre material. We were able to produce carbon/epoxy sheets consisting of 2 to 4 layers with 2x2 twill carbon fibre fabric. First samples with a PVC-foam core were also fabricated. It is important to get a defect-free surface on the composite material, since the smallest defects, like pinholes in the matrix material, will act as starting points for the erosion process. This work is still in progress with the aim to suppress surface defects density by tuning process parameters. Regarding the direct coating of the carbon fibres, we found that etching of the carbon fibres during the deposition process is the biggest issue. In addition, we have worked on tuning the plasma parameters to obtain NCD growth at low substrate temperatures suitable for wind turbine blades. This has been the special topic of the Master Thesis of John Benjamin Lothe, to be submitted in June 2021. Further, post doc Justas Zalieckas and PhD student Carsten Peter Hinzmann are heavily involved in the activities.

Professor Charlotte Hasager is, together with Professor Joachim Reuder and post doc Stephan Thomas Kral involved in the meteorological part of the erosion project. This gives a unique interaction between the DTU and UiB activities in this field and provides a close link towards the IEA Wind TCP Task 46, Erosion of wind turbine blades.

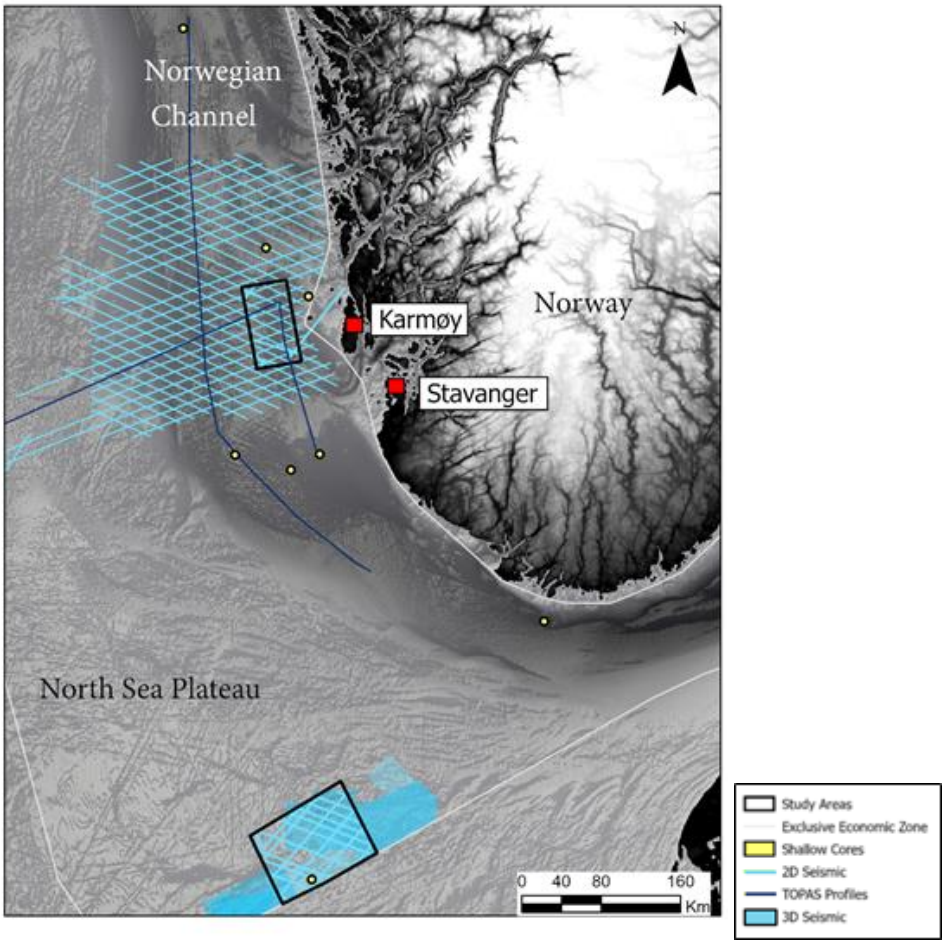


Coating of nanofibers with a Nano Crystalline Diamonds (NCD) layer. Left: SEM images of seeded with a concentration of 0.3% diamond content. Right: Carbon fibers coated with NCD after 1hour of deposition. (Note the scales given at the pictures).

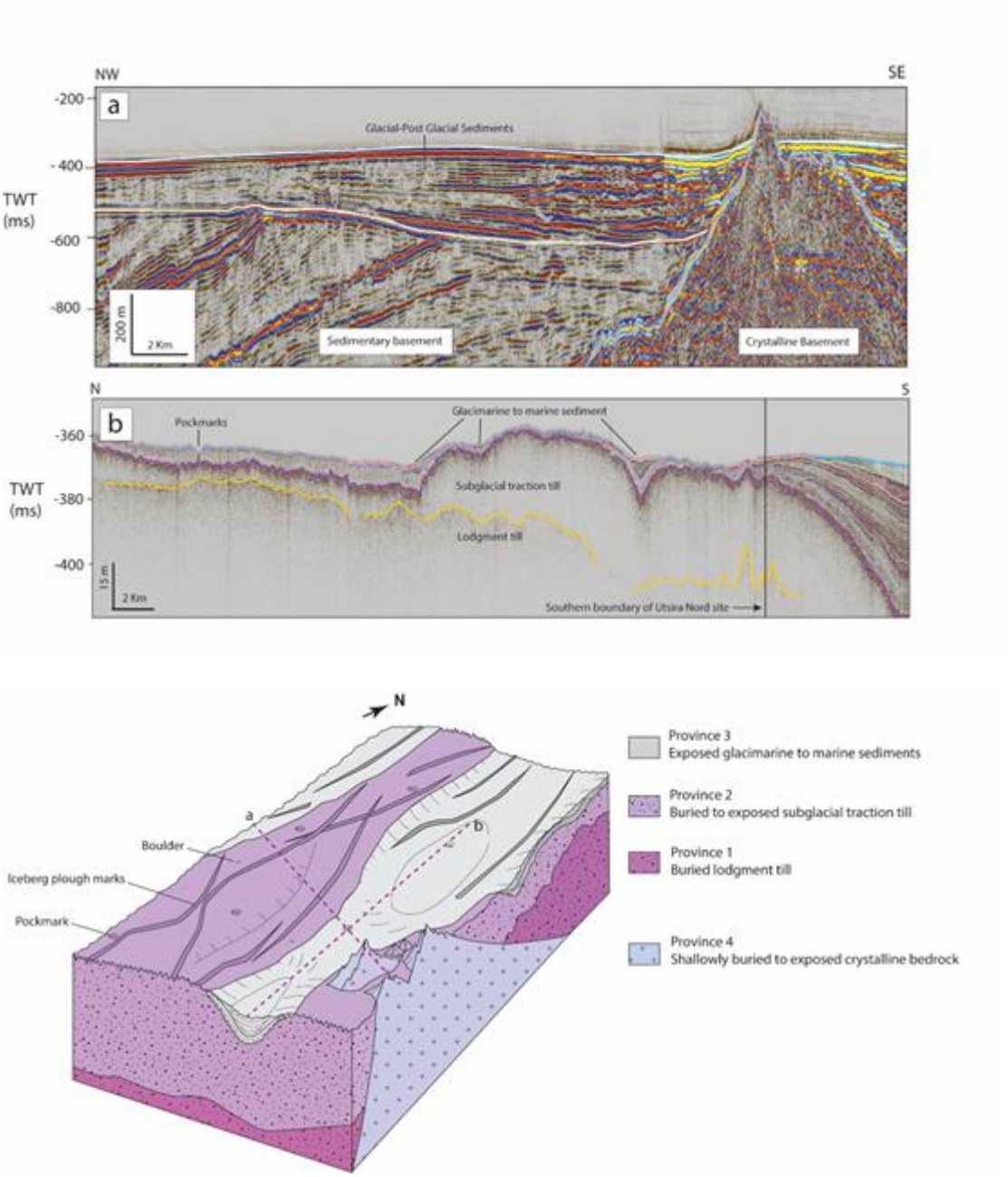
An integrated geological characterization of marine ground conditions for offshore wind foundations in the North Sea.

BOW responsible: Professor Haflidi Haflidison, Department of Geoscience.
Haflidi.Haflidason@uib.no

The increasing size of offshore wind sites represents a significant challenge with regards to characterizing geological heterogeneity, particularly within the Late Quaternary glacial-marine deposits of the North Sea. This study investigates the two recently opened offshore wind sites in the Norwegian sector of the North Sea; Utsira Nord and Sørlige Nordsjø II. The main aims of this study are to 1) Investigate how the geological conditions at and below the seabed influence the location and design of offshore wind foundations and anchors, 2) Acquire high-resolution acoustic data and cores to investigate the key geotechnical risks to offshore wind developments and provide recommendations for the scope of site surveys in geologically heterogeneous areas and 3) Investigate the potential for integrated geological-geotechnical modelling to predict geotechnical risks across geologically heterogeneous sites to facilitate safe and lower-cost foundation design.



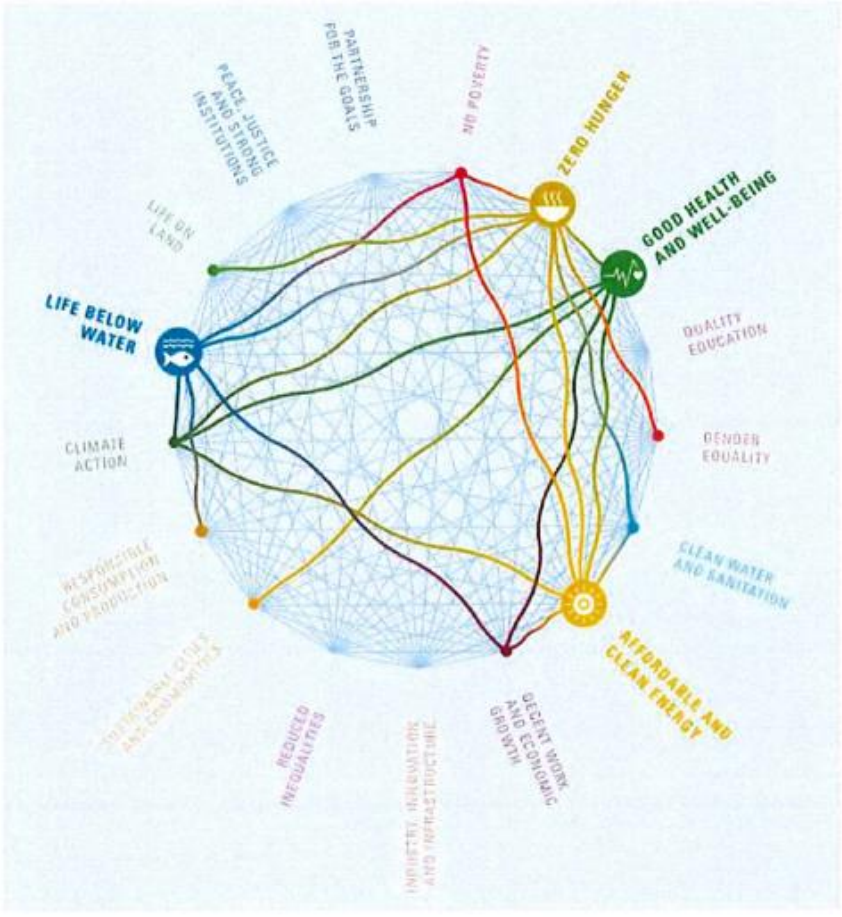
Geophysical and core data overview map for the two Norwegian offshore wind sites (Utsira Nord, north and Sørlige Nordsjø II, south). Bathymetry from GEBCO (2020).



Conceptual geological model for the Utsira Nord offshore wind site, based on geophysical and core data in the area.

DeWindSea (Designing a Refined Legal Framework for Legitimate Offshore Wind in the North Sea Basin). PI: Professor Sigrid Eskeland Schutz, Faculty of Law. Sigrid.Schytz@uib.no

This project consists of three working packages including WP1 legal aspects, WP2 social sciences aspects and WP3 aligning offshore wind sciences in law and social sciences. Professor Sigrid Eskeland Schütz is the project manager and responsible for WP1 where PhD candidate Eirik Finserås takes part, whilst Professor Michaël Tatham undertakes WP2, and Schütz and prof Finn Gunnar Nielsen WP 3. DeWindSea is funded by Akademiaavtalen and is due to conclude in 2024. The legal aspect seeks to understand how licensing procedures can be optimized to increase the deployment of offshore windfarms by mitigating uncertainties and ambiguities in the regulation. This is achieved by drawing on regulatory experience from the UK and Denmark in a comparative context. The participants have commenced preliminary research thus far and has additionally spent time getting to know the scientific environment in the respective fields.



Figurer DeWindSea

Illustrating interactions between SDG 2, SDG 3, SDG 7, SDG 14, analyzed by the International Science Council, A guide to SDG Interactions; From Science to Implementation, 2017 p. 159.

Educational and committee activities

TRAIN2WIND BOW responsible: Professor Joachim Reuder
Geophysical Institute. joachim.reuder@uib.no

The project is an International Training Network (ITN) funded by the Horizon 2020 scheme MSCA-ITN under grant agreement no. 861291. TRAIN2WIND is a PhD TRAINing school analysing enTRAINment in offshore WIND farms with computer models and experiments. By its very nature, a wind turbine extracts energy from the wind, which is replenished from the wind field on the sides and above due to the ambient turbulence. However, offshore the turbulence is lower, and wind farms are typically larger than onshore, therefore the wind can only be replenished from above in a process called entrainment. TRAIN2WIND will investigate the entrainment process using advanced high-resolution computer modelling and wind tunnel models together with measurements of the wind field above, within and downstream of large wind farms, using lidars, radars, satellite measurements and Unmanned Aerial Systems.

The project is initiated and led by DTU Wind Energy in Danmark, with the University of Copenhagen, EPFL in Lousanne, the University of Tübingen and the University of Bergen as academic partners. The project consortium is complemented by the industrial partners Vattenfall, Equinor, Innogy and SeaTwirl. The contribution of UiB/BOW is one PhD project (Mauro Ghirardelli) working on the development and test of a drone-based turbulence measurement system, and a second PhD project (position to be filled in July 2021) dedicated to ship-based wind lidar measurements. Both PhD projects are supported by a research assistant position with a duration of 18 and 12 months, respectively.

LIKE (Lidar Knowledge for Europe). BOW responsible: Professor Joachim Reuder, Geophysical Institute. joachim.reuder@uib.no

The LIKE project, as the TRAIN2WIND, is funded by Marie Sklodowska-Curie Actions (MASC-ITN) in Horizon2020. LIKE aims to foster training and education of young researchers on emerging laser-based wind measurement technologies and their translation into industrial applications. BOW /GFI will be the host institution of two of the 15 PhD projects. The LIKE project is headed by Professor Charlotte Hasager at DTU and BOW, securing a close connection to BOW and secondment of PhD students to UiB.

The first PhD project at UiB/GFI (Jan Markus Diezel) is related to the characterization of the atmospheric boundary layer for the airborne wind energy device Kitemill, a tethered unmanned aircraft that will drive a generator on the ground. For this project we started a lidar measurement campaign in collaboration with DTU Wind Energy in Denmark at Lista airport. Continuous wind profile measurements started in October 2020 and will be continued until at least September 2021. A potential extension is in discussion. In parallel with the lidar wind profiler we have also installed a passive microwave temperature and humidity profiler from the OBLO infrastructure. The combination of both instruments will provide a unique data set for the characterization of the Atmospheric Boundary Layer with respect to Airborne Wind Energy Applications. In addition, it will allow for a proper evaluation of the recently released NORA3 hindcast data set provided by MET.no.

The second PhD project (Sai Wang) investigates turbulence in complex terrain and its implications for air traffic safety at exposed airports by model simulations and lidar measurements. Although not directly related to offshore wind energy, both the modelling and measuring activities in the PhD project will directly influence future offshore wind related research. A measurement campaign at Værnes airport in Trondheim is under preparation. The main activities in 2020 were, however, related to Large Eddy Simulations with PALM for a new planned airport at Lofoten.

IEA. Professor Joachim Reuder is heading and coordinating the Norwegian engagement in IEA Wind Task 32 Wind Lidar Systems for Wind Energy Deployment. Professors Bodil Holst, Joachim Reuder and Charlotte Bay Hasager are all active in the newly established IEA Wind TCP Task 46 Erosion of wind turbine blades. Hasager as Co-operating Agent and Holst as co-leader of WP5: Erosion Mechanics and material properties. Reuder, together with Stephan Kral are active members in WP2 on the meteorological conditions for erosion.

EU offshore energy strategy – natural sciences and law. A team of representatives from BOW worked together with Energiomstilling Vest (EOV) to provide input to the EU strategy on offshore energy. This document "Offshore wind. Grasping the opportunities and solving the challenges" was handed over to the commission in July 2020", see more here

Additionally, Assoc. Professor Herrera Anchustegui along with Lecturer Daria Shapovalova and Lecturer Eddy Wifa from the University of Aberdeen, submitted a Response to the EU Offshore Energy Strategy highlighting key legal issues to be addressed in the future for wind energy to take off.

EERA. BOW has been represented on workshops and conferences, EERA Deep Wind, by presentations and posters. Kristin Guldbrandsen Frøysa represents UiB in EERA JP Wind Steering Committee.

High Level Panel for a Sustainable Ocean Economy. As a follow-up of the 2019 report "The Ocean as a Solution to Climate Change: Five Opportunities for Action", Prof. Nielsen contributed as author to a Bluepaper: "What role for Ocean-Based Renewable Energy and Deep-Seabed Minerals in a Sustainable Future?". Here the opportunities using ocean-based energy sources, in particular offshore wind are addressed. The electrification of the energy sector implies increased use of several special minerals, which are found at the bottom

of the deep oceans. Utilization of these minerals implies opportunities but also severe environmental concerns as well as legal challenges.

Since 2020 Professor Charlotte Bay Hasager is co-organizer of an annual **International Symposium on Leading Edge Erosion of Wind Turbine Blades**. She is planning for a mini symposium on leading edge erosion at the WESC 2021 conference.

The NorRen Summer school, 2020 was organised by UiB, NTNU and UiO. The interdisciplinary PhD course took place at Os south of Bergen and the Summer School invited PhD-students from a wide spectre of disciplines working within the fields of energy. Eirik Finserås had a presentation on the legal framework of offshore wind.

NorRen Summer School visiting Midtfjellet Wind Farm on Stord. © Gry E. Parker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