RAVE

RESEARCH AT ALPHA VENTUS

Eine Forschungsinitiative des Bundesumweltministeriums

The Research Initiative at the

First German Offshore Wind Farm


AV
9
JB 114

Preface

"alpha ventus" Marks the Beginning of Offshore Wind Energy Deployment in Germany

The German Federal Government has set the political objective and chosen the technological path into an age of renewable energie. The energy sector has to be developed step by step towards this goal. A very important step for Germany along this path is the recent commissioning of the offshore test site alpha ventus.

Germany has made a pledge to the European Union to produce 18 % of its overall energy requirements from renewable sources by 2020. Today the share is 10 %. For the electrical energy sector, where the share is 16 % at present, the goal is even more ambitious: 30 % by 2020. Electricity from wind energy has in the medium term the greatest potential among renewable energies in Germany for meeting this goal. An important share of electricity from wind has to be produced in the future by offshore wind farms.

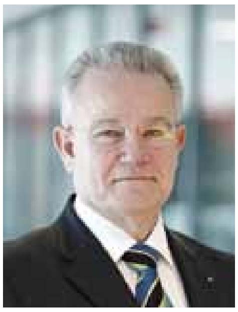
Alpha ventus, planned from the beginning as a test site for the modern 5 MW turbine class under harsh marine conditions, is initiating the age of offshore expansion of the German wind energy sector. The technological challenges of German offshore wind energy farms far from the coast are high. However, the advantages of an eco-friendly and reliable future energy supply are considerable. Cities along the coast with former shipbuilding and marine industries have already recognized these opportunities and have oriented themselves towards the offshore wind industry. Investors are creating new jobs at special harbors, at turbine and foundation manufacturers not far from the quay, at offshore service companies, as well as at research and development organizations.

In order to maximize the experience and knowledge from alpha ventus at a high scientific and technological level, the Federal Environmental Ministry launched the accompanying RAVE research initiative – Research at alpha ventus. Under the RAVE research initiative some 25 projects have so far been supported to the tune of 36 million euros. Industry, universities, and other research organizations are working closely together in a research network which has enhanced the cooperation amongst German wind energy researchers to a hitherto unknown level.

The results of RAVE will contribute considerably towards ensuring that future wind farms can be planned using this new scientific and technological knowledge base. These broad research activities covering aspects such as social acceptance surveys, environmental impact assessment, offshore wind physics, electrical grid integration, and turbine improvement are needed in order to progress on the path towards an offshore age of wind energy deployment. This will enable the German wind energy industry to repeat at sea the success story already achieved on land.

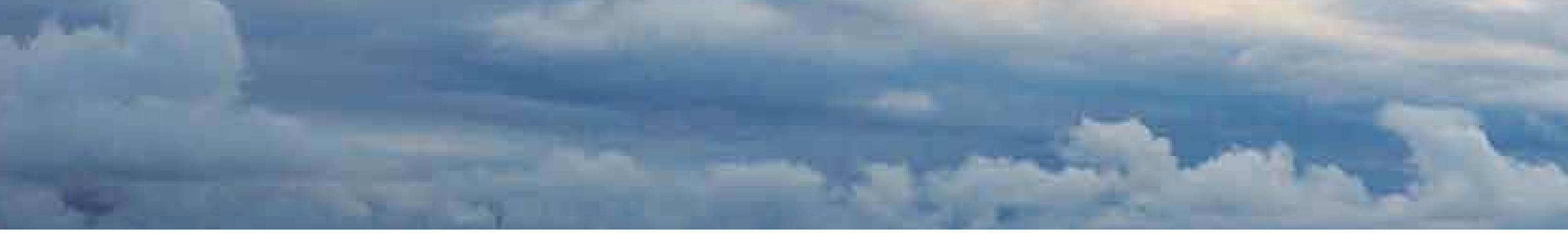
This brochure presents the current RAVE research topics and projects. It will also give readers an indication of the wealth of information being gained by RAVE researchers which will provide a unique basis for answering scientific questions and meeting the technological challenges of offshore wind energy utilization in the future.

We are confident that the alpha ventus test site and the RAVE research initiative will provide a new impetus for the expansion of offshore wind energy.



Prof. Dr. Hans-Jörg Bullinger
President Fraunhofer-Gesellschaft

Prof. Dr. Jürgen Schmid
Director Fraunhofer IWES



RAVE Chronology

2002 German government's strategy on offshore wind energy deployment

2006 Common declaration for the implementation of an offshore test field by federal and state governments, administration, industry and other promoters

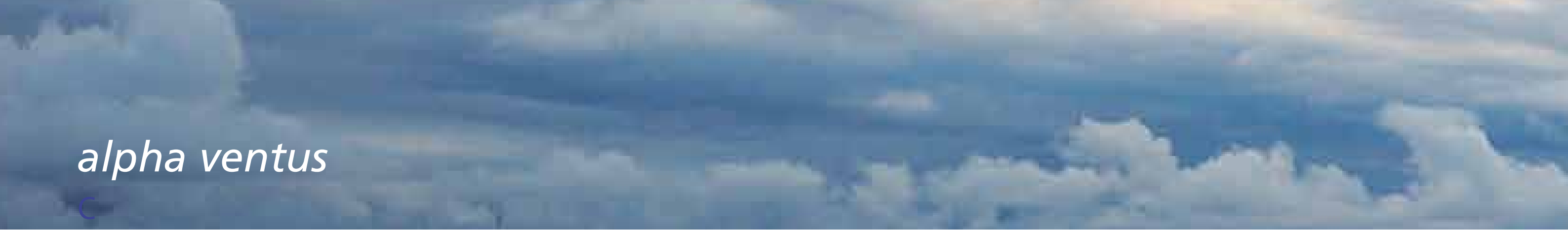
2007 The Ministry for the Environment starts the offshore research initiative RAVE – Research at alpha ventus
First RAVE projects start their work

2008 Official Kick-off event of the RAVE initiative in Berlin
Further projects join the RAVE initiative
Planning and installation of measurements for RAVE projects start
Offshore grid connection established
Offshore substation build and commissioned

2009 All 12 offshore wind turbines installed on site
RAVE instrumentation system for Multibrid turbines in operation

2010 The RAVE-initiative incorporates 15 joint projects and more than 40 partners from science and industry
Official inauguration ceremony for alpha ventus

CONTENT

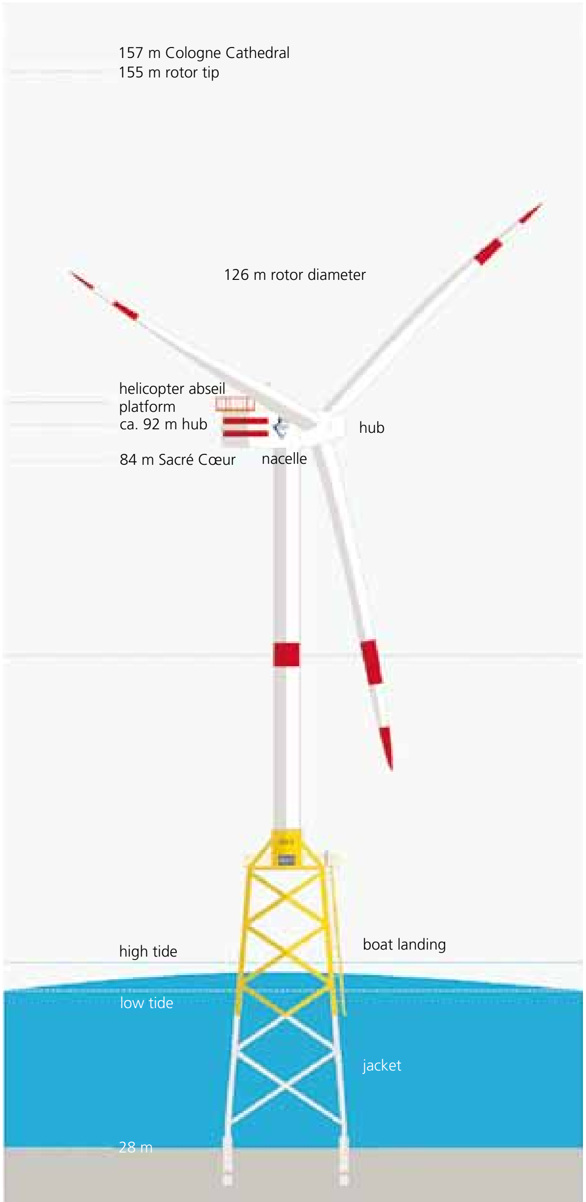


The first German offshore test site

The alpha ventus offshore wind farm is a pioneering project being undertaken jointly by EWE AG, E.ON Climate & Renewables, and Vattenfall Europe Wind Power. An extremely ambitious and successful undertaking: Situated some 45 kilometers north of the island of Borkum in water 30 meters deep, the twelve wind turbines of the first German wind farm at sea were built in 2009 under genuine offshore conditions.

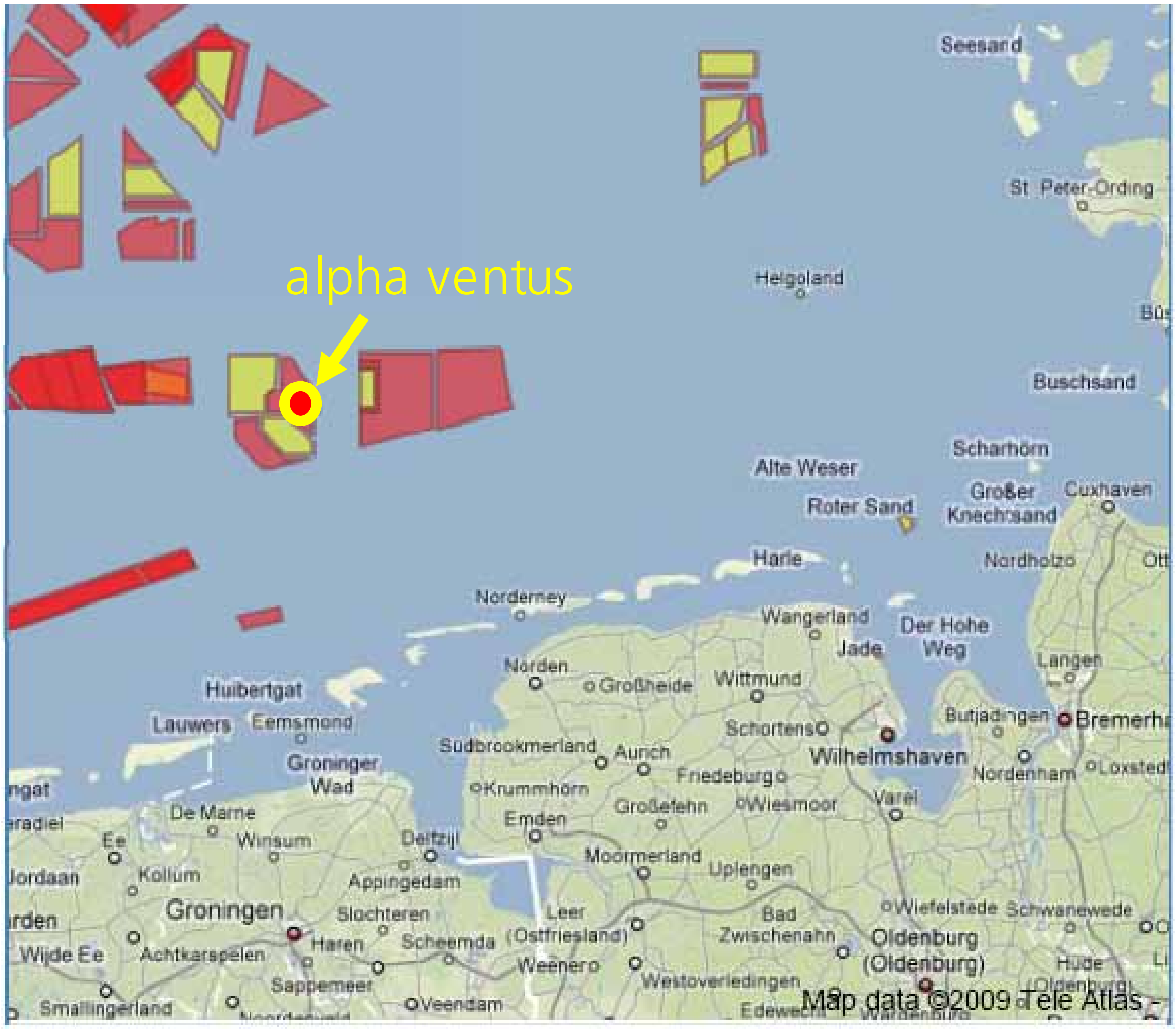
The twelve wind turbines were placed in a grid-like formation with gaps of approximately 800 meters between each turbine. Four rows form a rectangle having a total surface area of four square kilometers – about the size of 500 football pitches.

With the installation of an offshore transformer at the south-eastern most point of the wind farm, the first important construction phase for alpha ventus was com-



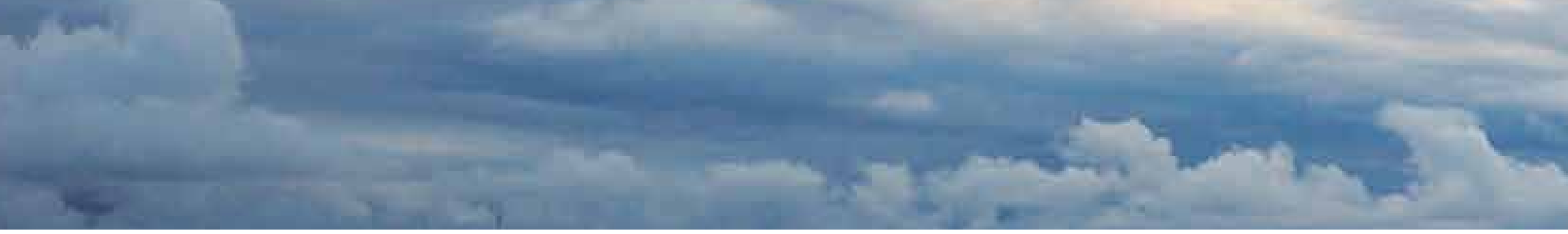
REpower 5M

AREVA Multibrid M5000



pleted in autumn 2008. After that, the entire offshore construction of all twelve wind turbines took seven months, from April until November 2009. Currently, alpha ventus is the first offshore wind farm to operate a dozen, 5 megawatt class wind energy turbines. With its total capacity of 60 MW, a yearly energy yield of approximately 220 gigawatt hours is expected: equivalent to the power consumption of around 50,000 households. Since August 2009 the wind turbines have been continuously undergoing trial operations. Up until summer 2010 all the wind turbines will be in normal operation. The alpha ventus wind farm will thus provide further fundamental experience with a view to future commercial use of offshore wind power in Germany.

RAVE is of high importance for gathering and distributing objective data on alpha ventus and for ensuring not only an environmental benefit but also a scientific benefit of the wind farm. Close cooperation with DOTI and the suppliers of turbines and foundations during the early planning states was essential as the technical equipment had to be assembled, installed, and tested on land. Since early 2010 the scientific installations have been collecting live and continuous data from the turbines.



REpower 5M specifications
Rated power: 5 MW
Hub height above sea level: 92 m
Rotor diameter: 126 m
Type of foundation: jacket
Length sea level rotor tip: 155 m

AREVA Multibrid M5000 specifications
Rated power: 5 MW
Hub height above sea level: 90 m
Rotor diameter: 116 m
Type of foundation: tripod
Length sea level rotor tip: 148 m

Partners / Contacts:

DOTI – Deutsche Offshore-Testfeld- und
Infrastruktur-GmbH & Co. KG
c/o Vattenfall Europe Windkraft GmbH
Lutz Wiese (press officer)
+49(0)40 63 96 22 63
kontakt@alpha-ventus.de
Karin Kloske
karin.kloske@vattenfall.de

www.alpha-ventus.de

Joint research and development for a major goal

Alpha ventus, the first German offshore wind farm testing and demonstration project, has started utilizing the wind energy in the German North Sea. The associated German research initiative RAVE – Research at alpha ventus – involves the carrying out of various measurements and investigations to further promote Germany as a leader in wind energy technology.

Main focus: Profitable, cost effective, and durable

The main focuses are the reduction of costs, increased efficiency, advancing the availability of wind turbines, improving the technology for developing offshore wind energy, ecologically responsible application as well as technological optimization of turbines with regard to their environmental impact. To start the large-scale utilization of offshore wind in German waters, the German Federal Ministry for the Environment (BMU) has allocated 50 million euros for research and further development of wind energy utilization at sea.

Synergies for a variety of projects

The RAVE research initiative consists of a variety of projects in connection with the installation and operation of alpha ventus. In order to provide all participating research projects with detailed data, the test site will be equipped with extensive measurement instrumentation.

As part of the RAVE initiative, the participating institutes and companies have so far set up projects on the following topics:

- Realization of joint measurements and data management
- Analysis of loads, modeling, and further development of the different components of offshore wind turbines
- Loads on offshore foundations and structures
- Further development of LIDAR wind measuring techniques
- Grid integration of offshore wind energy
- Monitoring of offshore wind energy utilization in Germany
- Measurement of operating noise and modeling of sound propagation between the tower and water
- Ecological and oceanographic research, and social acceptance

Contact

RAVE – Research at alpha ventus
www.rave-offshore.de

RAVE-Coordination
www.iwes.fraunhofer.de

Funding body

BMU – German Federal Ministry for the Environment
www.bmu.de
www.erneuerbare-energien.de

RAVE Supervisor on behalf of BMU:
PtJ – Project Management Jülich
Dr. Joachim Kutscher

Partners

DOTI – German Offshore Test Site and Infrastructure Company
www.alpha-ventus.de

German Offshore Wind Energy Foundation
The German foundation for the promotion of a sustainable and environmentally friendly energy supply by increased use of offshore wind energy.
www.offshore-stiftung.de

Organizing of the research collaboration at alpha ventus

On behalf of the Federal Ministry for the Environment (BMU), the RAVE research initiative is being supervised by PtJ and coordinated by the Fraunhofer IWES.

The objective of the RAVE coordination project is to co-ordinate the whole RAVE initiative, to network all the single RAVE projects, and to represent them. The overall objective is to provide the structure for an effective joint program for the relevant projects. In order to use synergies and improve the quality of the results, a balanced concept was developed for collaboration between the different projects in the test field.

RAVE steering committee

The organizational coordination is achieved by the RAVE steering committee, including the coordinators of all the individual RAVE projects, by internal RAVE services as well as by mediation within the RAVE initiative and representation of interests externally.

Scientific coordination

The scientific coordination provides the frame for the organization of scientific conferences and special topic workshops related to RAVE projects. Another task is the information of the national and international scientific community on RAVE results. Moreover, the international cooperation is supported through RAVE delegates in the Technology Platform Wind Energy (TP Wind) at the European Commission and through cooperation within the IEA Wind Implementing Agreement – Tasks 23 and 25.

Information for the public

Last but not least, the RAVE coordination project informs the public, politicians, administrations and companies about the research taking place at the offshore test site alpha ventus, e.g. on the RAVE homepage and with summarising reports and publications.

Figure 1: RAVE steering committee meeting

Coordination

Fraunhofer Institute for Wind Energy and
Energy System Technology IWES
Dr. Bernhard Lange, Michael Durstewitz
info@rave-offshore.de

Measurement concept
DEWI GmbH – German Wind Energy Institute
Dr. Thomas Neumann
t.neumann@dewi.de

RAVE Measurement project
BSH – Federal Maritime and Hydrographic Agency
Kai Herklotz
kai.herklotz@bsh.de

Partners

Uni Duisburg
RWTH Aachen
Hochschule Magdeburg
Deutsches Meeresmuseum Kiel
Fh Kiel
IZP
MENCK GmbH
THALES GmbH
BioConSult SH
Hydrotechnik Lübeck GmbH
PROKON Nord GmbH
Karl Wrede Stahl- u. Maschinenbau GmbH

Central realization of measurements within the framework of RAVE research projects

Main goals:

- Coordination of the RAVE research measurements
- Implementation of the measurement concept
- Installation and technical realization of measurements
- Operation, maintenance and inspection of gauges
- Logistics
- Data management, data preparation and provision for the integrated database

Motivation

The RAVE research initiative accompanies the setting up and operation of the alpha ventus test site in order to acquire a broad knowledge and experience base. Comprehensive measurement data are indispensable for this research. The goal of the measurement project is to carry out measurements and to coordinate the measurement requirements of the individual sub-projects. This project therefore provides a necessary service for all the individual RAVE projects and all the institutes, authorities, and companies involved.

Monitoring program

Load conditions, operational noise, noise during the wind turbine set-up phase, and oceanographic and geological parameters are the main measurement data. The BSH-Federal Maritime and Hydrographic Agency coordinates the measurement set-up and operational activities and installs oceanographic sensors for operation under extreme offshore conditions.

Figure 1: Project engineers and scientists are installing measurement sensors and cables on the wind turbine carrying tripod structure

Figure 2: Video and radar for observation of waves

Figure 3: Regular maintenance ensures smooth offshore data aquisition

Figure 4: Transfer by tender boats

Figure 5: Sensor installation

Coordinator:

BSH – Federal Maritime and Hydrographic Agency
Kai Herklotz
Bernhard-Nocht-Str. 78
20359 Hamburg
www.bsh.de

Cooperation partners:

DEWI – German Wind Energy Institute
Dr. Thomas Neumann
Ebertstr. 96
26382 Wilhelmshaven

Germanischer Lloyd Garrad Hassan
Hans-Peter Link
Sommerdeich 14 b
25709 Kaiser-Wilhelm-Koog

Germanischer Lloyd Industrial Services GmbH
GL-Wind
Wilhelm Heckmann
Geschäftsbereich Windenergie
Steinhöft 9
20459 Hamburg

Holistic design concept for offshore wind turbine support structures

Main research issues:

- How can offshore wind turbine support structures be improved in order to become an economic, mass-produced product?
- What are the real and individual load on an offshore wind turbine and how can they be measured and observed?
- How can the life time of offshore structures be extended?
- Which changes in the sea bed are expected from driven piles?

During the design process for offshore wind turbines, one of the biggest cost factors compared to onshore wind turbines is the support structure. This particular aspect becomes even more important due to the fact that thousands of offshore WTs are being planned for the North Sea and Baltic Sea.

Since 2001 the research group GIGAWIND has been engaged in optimizing support structures for planned offshore wind turbines. The research project GIGAWIND alpha ventus ties in with its parent projects GIGAWIND and GIGAWINDplus. The methods created and validated on offshore structures such as the FINO1 research platform will now be transferred to real offshore wind turbines. One focus is the integration of these methods into one modular simulation and design package.

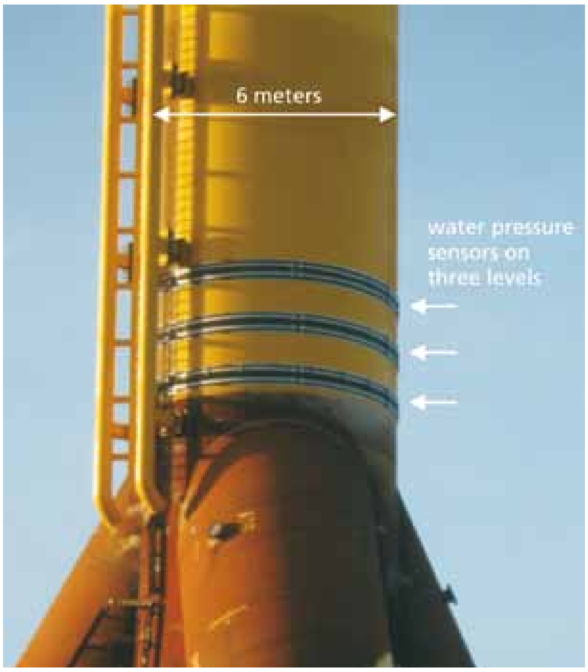


Figure 2: Tripod with three water pressure measurement belts

Project objectives and project description

The main objective of this project is cost reduction for offshore wind turbine support structures, which include towers, different types of substructures and foundations. This can be divided into the design on the one hand (material cost) and the optimization of the design process on the other hand (personnel cost).
This objective is reflected in several work packages of the project:

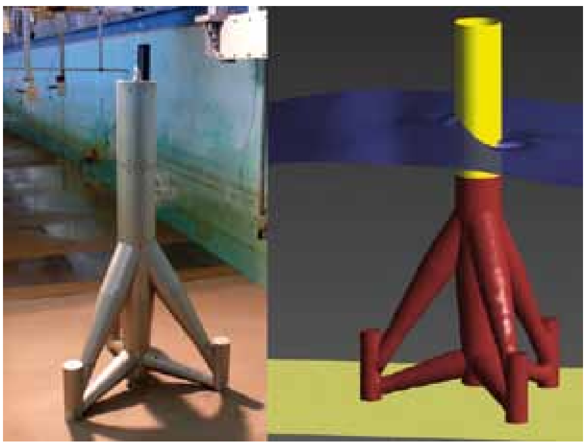
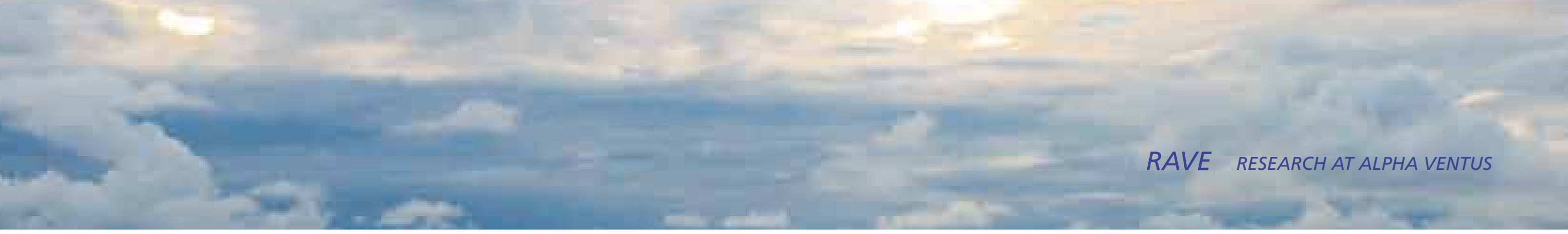


Figure 1: Model of the alpha ventus tripod (scale 1:40) in the wave flume (left) and CFD-model (right) for the simulation of breaking waves

Figure 3: Breaking wave on a cylindrical model in the wave flume



Load modeling for waves and its correlation effects to wind

Load cases for non-breaking waves are validated and optimized especially for the offshore wind turbines at the test site alpha ventus (model of a tripod see Figure 1).

Additionally, load cases for breaking waves are under research and will be validated both with measurements from experiments and real measurement data from the test site (Figure 3). For this purpose three water pressure measurement belts were installed during the manufacturing of the tripod (Figure 2).

Fatigue analysis and joining techniques

Relevant design specifications for support structures for offshore wind turbines imply a unique structure, which means that effects of series manufacturing are disregarded.

The objective of this work package is to identify positive manufacturing effects on fatigue limits and to integrate them into existing design methods. Selected details of the support structures have been recorded during the manufacturing process with different optical methods (see Figure 4). These measurements will be compared to the reference geometries in order to evaluate the differences.

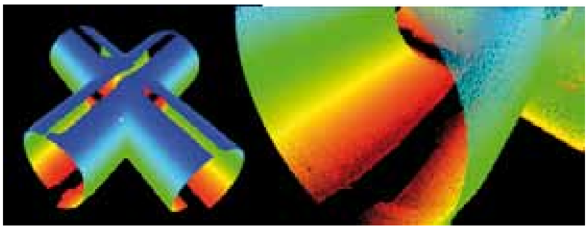


Figure 4: Measurements of the actual node geometry with a terrestrial laser scanner

Corrosion protection for offshore steel structures

Corrosion protection systems for steel structures are particularly important for offshore applications. Within the scope of this project, one mineral and various other corrosion protection systems for offshore use will be tested, evaluated and optimized.

Corrosion processes will be examined by using special sensors at the test site alpha ventus in order to demonstrate that early detection of damage is possible (see Figure 5).

Figure 5: Test coupons installed on the jacket for monitoring of corrosion processes

Load monitoring systems

During the design process for an offshore wind turbine support structure numerous assumptions are made, whose exact influence on the load bearing behavior is unknown. Realistic loads on structural and single construction elements have to be measured and the residual bearing strength has to be determined. To do this, online monitoring systems are qualified and additional structural health monitoring systems are tested and compared.

First results on onshore wind turbines show that damage detection and localization is possible (see Figure 6).

Figure 6: Diagnostics of predetermined damage on a guyed tower of an onshore wind turbine. The tension in cable 1 has been reduced by 13 %. The diagnostic methods show a reduction by 17 %.

Scour monitoring and scour protection
To identify scour phenomena on offshore wind turbine foundations several scaled (1:40 and 1:12) physical experiments in the wave flume have been carried out. In this context natural measurement data from scour monitoring recorded by the Federal Maritime and Hydrographic Agency (BSH) will be evaluated and numerical simulations of scour genesis will be undertaken.

To protect the foundation from scour, which could compromise the stability, an innovative scour protection system has been developed. It consists of textile scour protection chains, which are placed around the structure. Due to interlocking and laminar effects these chains provide an effective protection function, and this is shown in Figure 7.

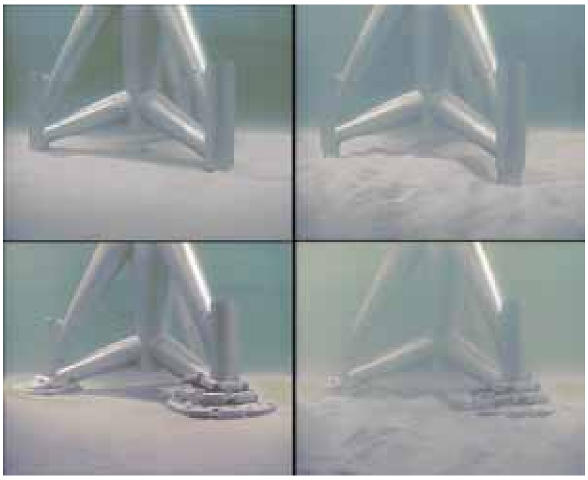


Figure 7: Model of a downscaled tripod (1:40) with (bottom) and without (top) scour protection chains before (left) and after (right) applying 1000 waves

Modeling of the load-bearing behavior of driven offshore piles
Loads acting on offshore wind turbine support structures are transferred to the ground. Most substructures planned for the German North Sea are founded on piles. In this work package existing methods will be further developed for application to combined as well as cyclic loads.

Cyclic triaxial experiments applied to seabed samples from the German North Sea have been run in order to evaluate testing methods for their usability.

Automated validation of structural models
Precise simulation and optimization of the design of a support structure for offshore wind turbines requires a well adjusted, realistic structural model. In this work package numerical methods for an automated validation will be further developed and optimized. This will significantly improve the validation process.

Holistic design concept
The results of the hydrodynamics, wave loads, lifetime analysis, corrosion protection, load monitoring, scour protection, sediment modeling, and model validation work packages are interfaced in order to develop a modular holistic design concept for support structures for offshore wind turbines (see Figure 8).

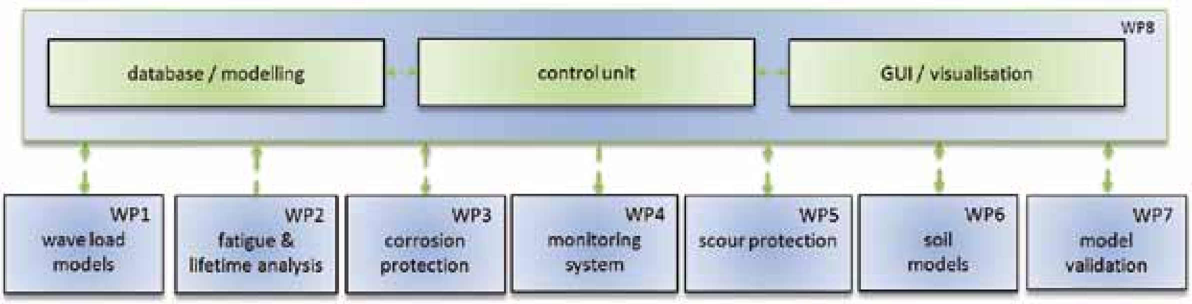


Figure 8: Modular concept of the design and simulation package and its interfaces to other work packages in GIGAWIND alpha ventus

Figure 9: Optimized design as the result of an iterative optimization with the help of the simulation and design package

Literature:
Rolfes, R.; Huhn, H.; Schaumann, P.; Schlurmann, T.; Lohaus, L.; Achmus, M.; Haake, G.: Support Structures for Offshore Wind Turbines - A Holistic Design Concept, Proceedings DEWEK 2008, Bremen, 26.-27.11.2008
Haake, G.; Rolfes, R.; Schaumann, P.; Huhn, H.; Schlurmann, T.; Lohaus, L.; Achmus, M.: Research on Support Structures in the German Offshore Wind Farm alpha ventus, Proceedings EWEC 2009, Marseille, 16.-19.03.2009
Rolfes, R.; Schaumann, P.; Huhn, H.; Schlurmann,T.; Lohaus, L.; Achmus, M., et al.: Ganzheitliches Dimensionierungskonzept für OWEA-Tragstrukturen anhand von Messungen im Testfeld alpha ventus, GIGAWIND alpha ventus Jahresbericht 2008, Hannover, April 2009

The integration of software and the results into an easily operable simulation and design package will enable the costs of the design process to be optimized (see Figure 9). Hence, the support structure for an offshore wind turbine can be designed and optimized, while personnel and material costs are kept at a minimum.

Partners / Contacts:

www.gigawind.de

Leibniz Universität Hannover
Institute of Structural Analysis
(project coordinator)
Prof. R. Rolfes
Appelstraße 9a
30167 Hannover
Phone: +49 511-762 3867
www.isd.uni-hannover.de

Institute of Steel Construction
Prof. P. Schaumann (vice coordinator)
www.stahlbau.uni-hannover.de

Franzius-Institute of Hydraulic, Waterways and Coastal Engineering
Prof. T. Schlurmann
www.fi.uni-hannover.de

Institute of Building Materials
Prof. L. Lohaus
www.institut-fuer-baustoffe.de

Institute of Soil Mechanics, Foundation Engineering and Waterpower Engineering
Prof. M. Achmus
www.igbe.uni-hannover.de

Fraunhofer IWES
Institute for Wind Energy and Energy System Technology
Dr. H. Huhn
Am Seedeich 45
27572 Bremerhaven
Phone: +49 471-902629 21
www.iwes.fraunhofer.de

REpower Systems AG
www.repower.de

AREVA Multibrid GmbH
www.multibrid.com

A practical design and monitoring procedure for foundations of offshore wind turbines under cyclic loads

Main research issues:

- How accurate are predictions about the long-term behavior of the turbine's foundation?
- What is the influence of the pore water pressure on the pile's resistance?
- How is the pile affected by the combination of cyclic lateral and vertical loads?

The foundation plays a key role in the safety of the whole turbine. Excessive deformation of the bedding or progressive changes in the sediment's stiffness can affect the turbine's serviceability or even lead to the collapse of the whole construction.

For given pile dimensions for different foundation types and sediment characteristics, the effect of cyclic, dynamic loads on the behavior of the foundation is still unclear.

This project aims to produce analysis criteria for selection of a foundation system (monopile, tripod, jacket, etc.) for offshore wind turbines and calculation methods and models for the design.

Model tests (scale 1:20 and 1:100) will provide information about the evolution of significant parameters of the embedment (sediment stiffness, pore water pressure, axial load transfer, etc) during the cyclic load. Additionally, a numerical model including a high quality constitutive model calibrated with laboratory tests will be developed to investigate the influence of the pore water pressure on the system's behavior. The results of the model tests, the numerical model, and the present state of the art will lead to practical design proposals for the engineer.

The validation of the models and procedures will be carried out with measurements from a tripod foundation at alpha ventus. One aspect of the project will be the installation of encased strain gauges on the pile, capable of resisting the pile-driving and the offshore environment. They will indirectly provide information about the interaction between axial load transfer (skin friction and tip resistance) and lateral bedding of the systems under regular loads and extreme events.

The results of this project will improve the safety and availability of offshore wind turbines, whilst at the same time lowering the financial cost of inspection and maintenance tasks

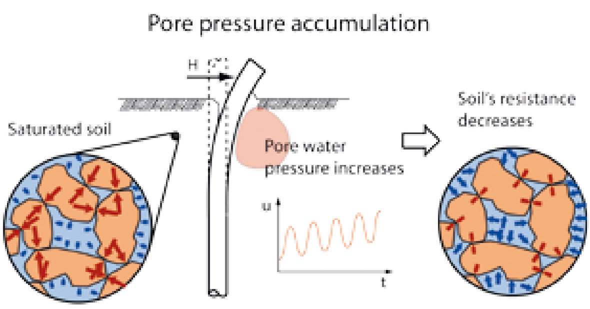


Figure 1a: Effect of pore water pressure on pile behaviour

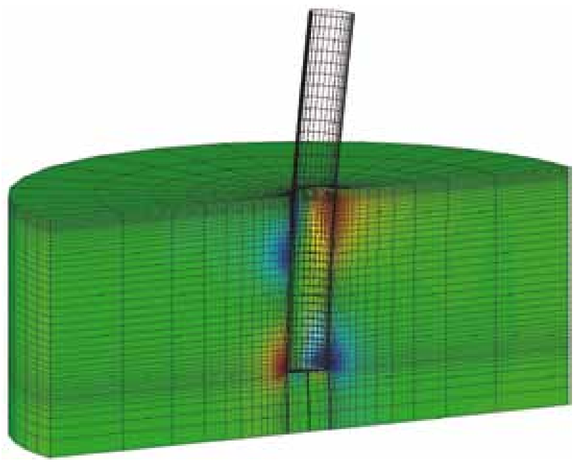


Figure 1b: Numerical prognosis of excess pore pressure around an offshore pile under extreme lateral loading during a storm.

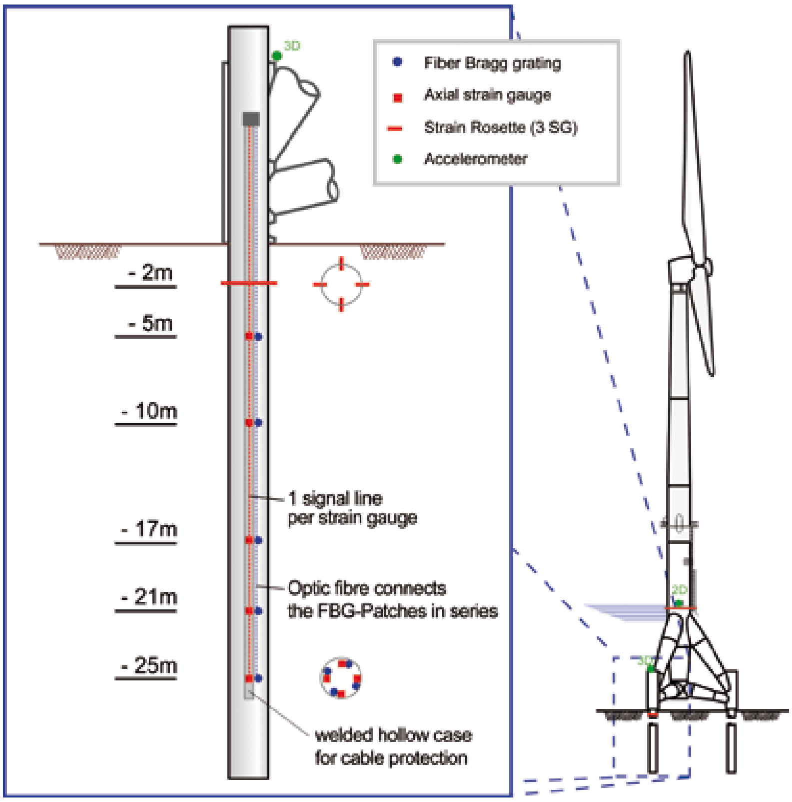


Figure 2: Instrumentation of the tripod pile

Figure 3a: Tripod Pile

Figure 3b: Tripod Pile

LITERATURE:

Rücker, W. (2007): Offshore wind energy plants: Problems and possible solutions. Proc. EVACES 2007 conference in Porto, Portugal.

Cuéllar, P., Baessler, M., and Rücker, W. (2009). "Ratcheting Convective Cells of Sand Grains around Offshore Piles under Cyclic Lateral Loads." Granular Matter, 11(6), 379-390.

Rohrmann, R. G.; Rücker, W.; Thöns, S. (2007): Integrated Monitoring Systems for Offshore Wind Turbines. Proc. 6th International Workshop on Structural Health Monitoring, 11-13 Sep-tember, 2007, Stanford, USA

Tasan, H.E.; Rackwitz, F.; Savidis, S.A. (2007): Modellversuche in der Geotechnischen Ver-suchsgrube zur Untersuchung des Tragverhaltens von Offshore-Monopilegründungen. Veröf-fentlichungen des Grundbauinstitutes der Technischen Universität Berlin, Heft 41, S.197-213.

Partners / Contacts:

BAM – Federal Institute for Materials Research and Testing, Division VII.2, Buildings and Structures (project coordinator)
Prof. Werner Rücker
werner.ruecker@bam.de
Dr. Matthias Baeßler
Matthias.baessler@bam.de
www.bam.de

TUB – Technical University of Berlin
www.grundbau.tu-berlin.de

Areva Multibrid GmbH
www.multibrid.com

REpower Systems AG
www.repower.de

Further development of offshore wind turbine components with respect to costs, longevity, and servicing convenience

Main research issues:

- Can modern offshore turbines fulfill future grid requirements that are comparable with conventional power plants?
- Can new control methods reduce mechanical loads on the turbine resulting in lower material input without cutting down the energy yield?
- Attainment of a high level of transparency for offshore wind power plants by means of a new generation SCADA system?

The individual mechanical and electrical systems always affect the system "wind energy plant" together, so that backlashes occur in all directions. Due to the variety of interactions, the system always has to be looked at and optimized as a whole. This holistic approach is also followed at the organizational level because close collaboration between universities, non-university research organizations, and industry players represents the central implementation method.

The project is composed of several work packages that relate to the different WEC components and contribute to the overall outcome. They include (1) gearbox, (2) grid, (3) advanced controls, (4) SCADA, and (5) logistics. The selection of measures to deploy is driven by the pool of experience from operating the REpower 5M as well as by the excellent opportunities that the offshore test site offers.

Figure 1: REpower 5M abseil training

Figure 2: REpower 5M wind turbines in alpha ventus

The project aims to optimize the wind energy converter (WEC) REpower 5M with regards to costs, longevity, and ease of servicing. The advancements are based on experiences gained with first prototype versions of this type. The innovative approaches used are seen as a logical step in the further development, taking into account the particular requirements of an offshore environment. Especially in view of current developments and perspectives in this area, the work will ensure that important steps towards the further development of WEC technology are taken in good time.

The results that REpower expects to get from the project will significantly contribute to cost reduction, earnings increase and an improved availability rate for the offshore wind turbine.

Eventually, improved performance of offshore wind turbines with respect to actual power plant behavior will also lower the risks for the German electricity grid as well as decrease the demands put on conventional power plants and thereby lead to further costs reductions.

Partners / Contacts:

REpower Systems AG
(project coordinator)
Peter Quell
Marcus Reiner
TechCenter
Albert-Betz-Strasse 1
24783 Osterrönfeld
Phone: +49-4331-1 31 39-121

RWTH Aachen
Templergraben 55
52056 Aachen
Phone: +49-241-80-1

University of Duisburg
Forsthausweg 2
47057 Duisburg
Phone: +49-203379-0

Development of an innovative, performance-optimized, and cost-efficient rotor blade for offshore wind turbines

Main research issues:

- How can higher aerodynamic efficiency be achieved?
- Can the planned innovations increase the economic efficiency?
- Will advanced production technology contribute to such improved results?

In the German part of the North Sea and Baltic Sea, offshore wind farms with a total installed capacity of more than 5,000 megawatts are already approved. A large part of the planned farms is based on the REpower 5M 5 megawatt turbine. REpower has delivered six wind turbines for the first offshore wind farm in Germany's North Sea territories. Higher electricity yields from wind energy and significantly lower costs for electricity generation over the lifetime of a wind turbine make projects at sea more attractive and promote offshore wind energy as a whole. The planned technical innovations for the turbine component "rotor blade" aim to contribute to this.

The project deals with the development of an innovative, yield-optimized, and cost-efficient rotor blade for offshore wind turbines. It is designed to improve the REpower 5M wind turbine with its installed capacity of 5 megawatts with respect to costs, durability, and convenient maintenance. Based on expertise gathered from prototype turbines, the further development will respect the specific challenges of offshore sites. Even though the experiences have been positive overall, it was shown that there is a need for targeted technological development of the rotor blade towards the required operating efficiency.

Figure 1: Transportation of blades for offshore installation

Figure 2: Loading of REpower 5M components

Using the expertise and support of research institutions and companies, the project will analyze technical innovations in aerodynamics, structural form, manufacturing technology, and structure monitoring.

The implementation of the advancements will as far as possible be implemented at the offshore test site. The project has two major themes, (1) the improvement of aerodynamics and (2) cost reduction, both of which have 3 sub-goals. At the operational level 8 work packages are defined to ensure that all the sub-goals and the overall project aim are achieved. Due to the interconnection of the R&D activities executed by industry and research organizations, broad, practically-oriented scientific progress is made in the relevant areas.

Partners / Contacts:

REpower Systems AG
(project coordinator)
Peter Quell
Dr. Martin Knops
TechCenter
Albert-Betz-Strasse 1
4783 Osterrönfeld
Phone: +49-4331-1 31 39-121

Leibniz Universität Hannover
Institute of Structural Analysis
Appelstr. 9A
30167 Hannover
Phone: +49-511-762-3867

RWTH Aachen
Institute of Plastics Processing
Pontstraße 49
52062 Aachen
Phone: +49-241-80 93 806

Development, construction, and testing of the M5000 wind turbine under offshore conditions

Main research issues:

- The technical behavior of the Multibrid M5000 in an offshore environment will be monitored. The main question is whether any necessary adjustments must be made.
- Is it possible for the complete remote control system and the analysis of data to be carried out via a new SCADA system?
- Can the planned innovations increase the economic efficiency?

The offshore test site alpha ventus illustrates how reliable the technology installed by the German wind industry is. By carrying out research work at the test site, manufacturers can improve new technologies and answer key questions.

In 2009, six Multibrid M5000 turbines were installed for the first time in the North Sea at the first German offshore test site alpha ventus. The M5000 is a 5 MW wind turbine which was especially designed for harsh offshore conditions.

The M5000 wind turbines are installed on tripod foundations. Up to now, four Multibrid M5000 turbines have been erected onshore in Bremerhaven and six turbines offshore in the North Sea. The onshore and the offshore Multibrid M5000 turbines have shown exceptional results.

Figure 1: Installation offshore

Figure 2: Multibrid M5000 offshore service

Figure 3: Multibrid M5000 wind turbines in alpha ventus

The research project involving several technical topics is being carried out within the framework of the alpha ventus test site project, in order to verify the offshore capability of the Multibrid M5000 under real conditions and to improve the turbine. The test site offers excellent conditions for monitoring the first M5000 wind turbines offshore.

The AREVA Multibrid research project comprises:

1. blade connection
2. appliances for installation of the turbine
3. converter and transformers
4. cooling system
5. several concepts of erection and start of operation (implementation), maintenance
6. data exchange interface
7. strong wind cut-off.

Within the framework of the test site project, there are new developments in the above-mentioned areas. The results of the work packages will contribute, for example, to new installation methods for wind turbines offshore and ascertainment of whether it is possible to implement the complete remote control system and analysis of data via a new SCADA system. Aspects to bear in mind during the further development and construction phase of the M5000 are the longevity of components and a high availability of the Multibrid M5000. The results of the offshore monitoring and testing phase can be used to further adapt the 5MW wind turbine.

Partners / Contacts:

AREVA Multibrid GmbH
Dr. Annette Hofmann
annette.hofmann@areva.com
Björn Siegmeier
bjoern.siegmeier@areva.com
Am Lunedeich 156
27572 Bremerhaven
Phone: + 49-471-8004-0
www.multibrid.com

Development of LIDAR wind measuring techniques

Main research issues:

- What are the possible applications of LIDAR technology in the offshore wind energy industry?
- How does power curve assessment with ground and nacelle based LIDAR systems compare to standardized measurements with cup anemometers?
- What is the behavior of wind turbine wakes in an offshore environment and how can the wake wind field be measured with LIDAR technologies?
- Which loading reduction can be achieved with LIDAR supported control based on inflow wind field measurements?

Wind measurement with LIDAR technology is gaining in importance due to the higher costs of "met" masts and the increasing demand for wind field measurements with high spatial and temporal resolution. The LIDAR remote sensing technique offers great advantages, especially for offshore development. The joint project aims to develop LIDAR technologies to support other research at alpha ventus. The measurement techniques developed onshore at the Multibrid M5000 prototype test site have direct applications in the ground-based and nacelle-based measurement of power curve and nacelle-based inflow/wake wind fields. Moreover, research is undertaken with regards to wake loading simulation and measurements. Loading control strategies and power curve determination are based on inflow measurements. Consequently, the construction and operation of wind turbines can be optimized and their lifetime increased.

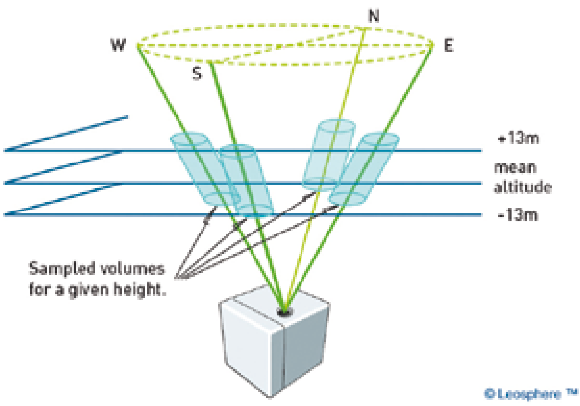


Figure 1: Principle of ground-based measurement (© Leosphere)

Figure 3: Onshore test site with the prototype and the meteorological mast (© SWE)

Figure 2: LIDAR –system including scanner-device on the Multibrid M5000 (© SWE)

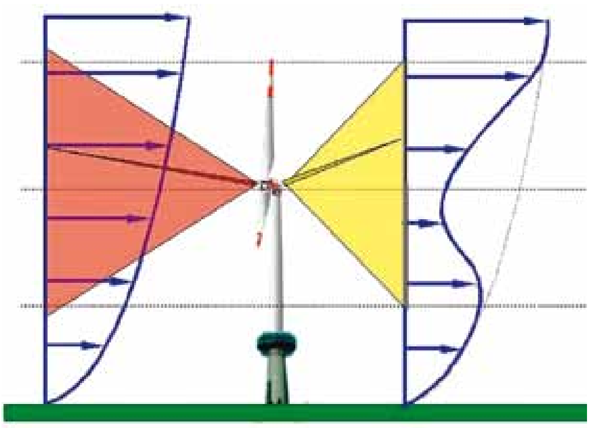
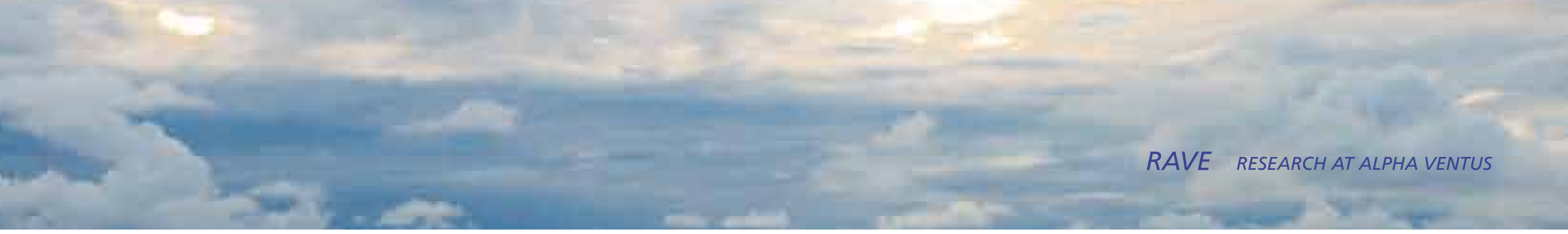


Figure 4: Sketch of nacelle-based measurements (© SWE)



The project is organized into four work packages. The first of these,"LIDAR technology" deals with the specification, acquisition, and calibration of a commercial LIDAR system for the measurement campaigns. Furthermore, a scanner system for nacelle-based measurements was developed and deployed. This additional system has been conceived with a certain flexibility to allow different trajectories and to scan the flow field in front of and behind wind turbines. The design and construction of the device was supported by self-developed software for wind turbine LIDAR simulation. The experiences acquired with this system will be used for future measurements at alpha ventus and for the pre-evaluation of a robust LIDAR system. [SWE, ForWind, DEWI, DLR]

The "power curve measurement" work package is dedicated to power curve assessment with ground-based and nacelle-based LIDAR using standard statistical methods. Additionally, it deals with the development of new methods for the measurement of non-steady, short-term power curves. The system has also been tested at theresearch platform FINO I regarding its suitability for offshore deployment. [SWE, ForWind, DEWI]

One aim of the work package "wind field measurement and simulation" is to develop simulation models for wind turbine loading in wake. Simulations are to be compared with measurements performed in the near and far wake of the Multibrid M5000 using a DLR long-range LIDAR system. Furthermore, inflow measurements were carried out with various scan patterns. These are studied for application in predictive control for load reduction based on knowledge of the incoming wind. [SWE, DLR]

Finally, dissemination of results to the wind energy industry takes place in work package 4 – "technology transfer". [SWE, FGW]

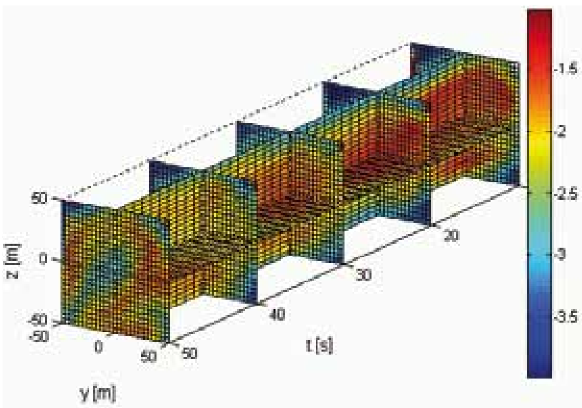


Figure 5: Results of two dimensional wake measurements (© SWE)

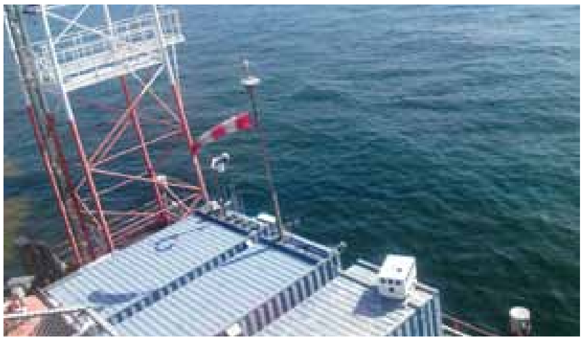


Figure 6: Measurement under real offshore conditions at FINO research platform (© DEWI)

The LIDAR technology offers great opportunities for wind energy applications. Therefore, the SWE and ForWind will continue their work in this field of study. In a follow-up project, LIDAR II, the SWE will develop further their strategies for nacelle-based power curve determination and predictive control algorithms for offshore use. ForWind will focus their work on the development of a robust LIDAR device and concentrate their efforts on dynamic power curve determination under wind farm conditions, too.

Partners / Contacts:

University of Stuttgart (project coordinator)
SWE – Endowed Chair of Wind Energy
Andreas Rettenmeier
rettenmeier@ifb.uni-stuttgart.de
www.ifb.uni-stuttgart.de/LIDARSWE

ForWind – Center for Wind Energy Research
www.forwind.de

DEWI – German Wind Energy Institute
www.dewi.de

Deutsches Zentrum für Luft- und Raumfahrt e.V.
www.dlr.de/ipa

FGW – Federation of German Windpower
www.wind-fgw.de

AREVA Multibrid GmbH
www.multibrid.com

Verification of offshore wind turbines

Main research issues:

- What is the effect of specific atmospheric conditions in offshore environments on the power curve of wind turbines? Can power curves be measured offshore with sufficient accuracy using LIDAR technology?
- How do airflows in wind farms behave and interact? How does operation in the wake of other turbines affect a wind turbine's loading in an environment with very low ambient turbulence?
- Are state of the art simulation models and tools appropriate for predicting wind turbine behavior and loading for offshore applications? How much can the results be improved by integrated analysis if complex foundations are involved?
- How should an efficient, robust, and durable load monitoring system for offshore wind turbines appear and how can it help to improve wind turbine performance?
- How can turbulence parameterization in numerical regional weather models for entire coastal regions like the southern North Sea be improved?

Figure 1: One REpower 5M on a jacket support structur, two Multibrid M5000s based on tripod structures within the wind farm alpha ventus

In the OWEA project, essential aspects of offshore wind turbines (WTs) (i.e. the rotor-nacelle assemly and supporting structure) are investigated in five work packages (WPs). The OWEA-consortium wants to achieve the following goals:

1. An increased accuracy of wind energy yield predictions for single WTs and wind farms (WP 1 and 5);

2. A reduction in investment and operational costs for wind energy converters (WECs) by improving the prediction of loads and of life expectancy (WP 2, 3 and 4);

3. A more precise description of loads caused by wind, waves and wind farm layout and their interaction with the WT (WP 2, 3 and 5);

4. Enhanced technical safety of offshore WECs (WP 2, 3 and 4);

5. The development of tools for operation and load monitoring as a supplement to condition monitoring tools (WP 4).

WP 1, Offshore Power Curves, is led by the DEWI (Deutsches Windenergie-Institut). The main task is to reduce the risks in the energy yield forecast of single WECs as well as of complete wind farms. Thus, the impact of atmospheric factors (temperature, stratification, humidity, etc.) on the energy yield of offshore wind WECs will be analyzed.

For the development of appropriate forecasting models, measurements of meteorological parameters and of the energy output of WECs will be carried out. Most of these measurements are made at the research platform FINO-1, which is situated in close proximity to the offshore test site.

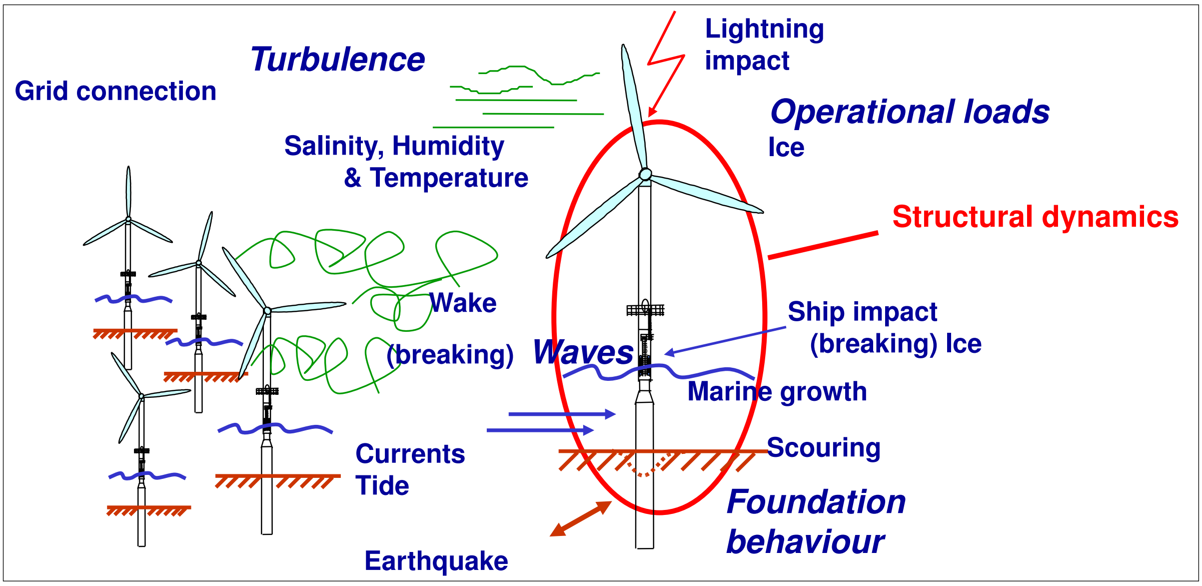


Figure 2: Environmental impacts on an offshore wind farm

This offers the unique opportunity to estimate the energy yield of offshore WECs by determining the power curve using state-of-the art techniques. As erecting masts for wind velocity measurements at offshore sites is cost-intensive, an alternative new measurement method will be tested at "alpha ventus". In this so-called LIDAR (Light Detection And Ranging) method that utilizes the Doppler effect, the wind velocity is determined with a laser beam that is scattered by airborne dust particles. Measurements with a LIDAR mounted on a nacelle will begin in the summer of 2010.

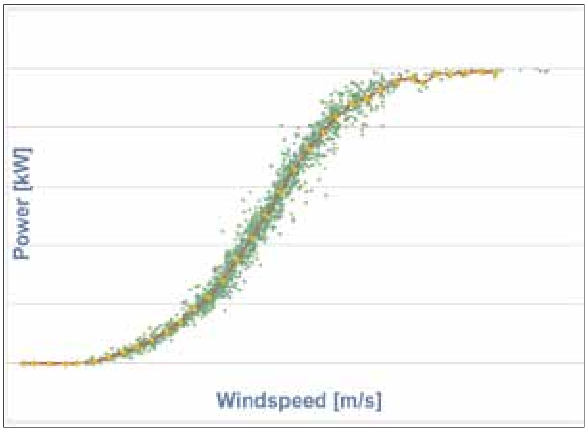


Figure 3: Power curve from a wind turbine. Dots represent single measurements (10 minutes mean) and the regression curve is plotted as a line

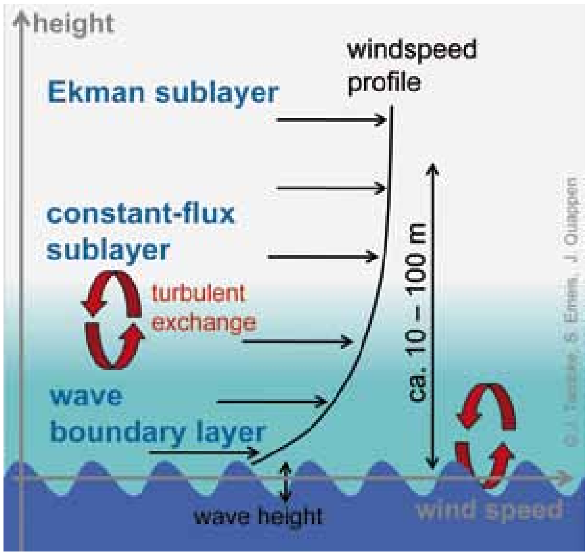


Figure 4: Schematic diagram of processes influencing the wind speed profile in the marine boundary layer

ForWind – the Center for Wind Energy Research at the Carl von Ossietzky University Oldenburg – is the leader of work package 2: Verification of Flow Conditions and Wake Loads in Offshore Wind Farms. Due to the lower ambient turbulent intensity, it is even more crucial to consider wind farm effects such as wake deficits when offshore wind farms are planned. The measurements at FINO-1 and the offshore test site will for the first time allow for a verification of engineering models that estimate energy yield and loads for offshore wind farms with WTs of the 5MW class. Based on FINO-1 and LIDAR measurements, a high frequency wind field model will be developed. Wind fields generated by this model will be used to determine inflow conditions for CFD calculations (URANS) of the near wake flow behind a WT. The results of these simulations will then be used to parameterize the near wake flow in CFD calculations (LES) of the far wake. These far wake simulations coupled with aerodynamic and aeroelastic simulations will provide information on the interaction between different WTs. Results of this model chain will be verified with data from the measurements at the test site. The validated numerical results will then be used in order to further develop less cost intensive engineering models. Finally, even the turbulent flow within and behind complete wind farms will be simulated with CFD models. Results of these simulations will then be used for the derivation of wind farm parameterizations in meso-scale and weather forecast models.

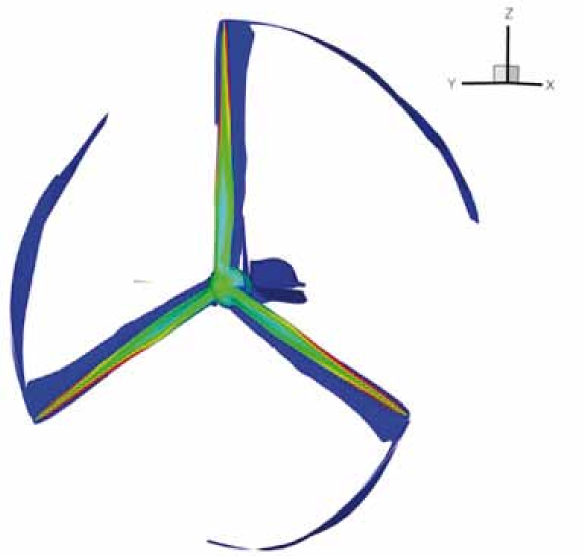


Figure 6: Air flow around a rotating rotor, CFD calculations carried out by IAG, University of Stuttgart

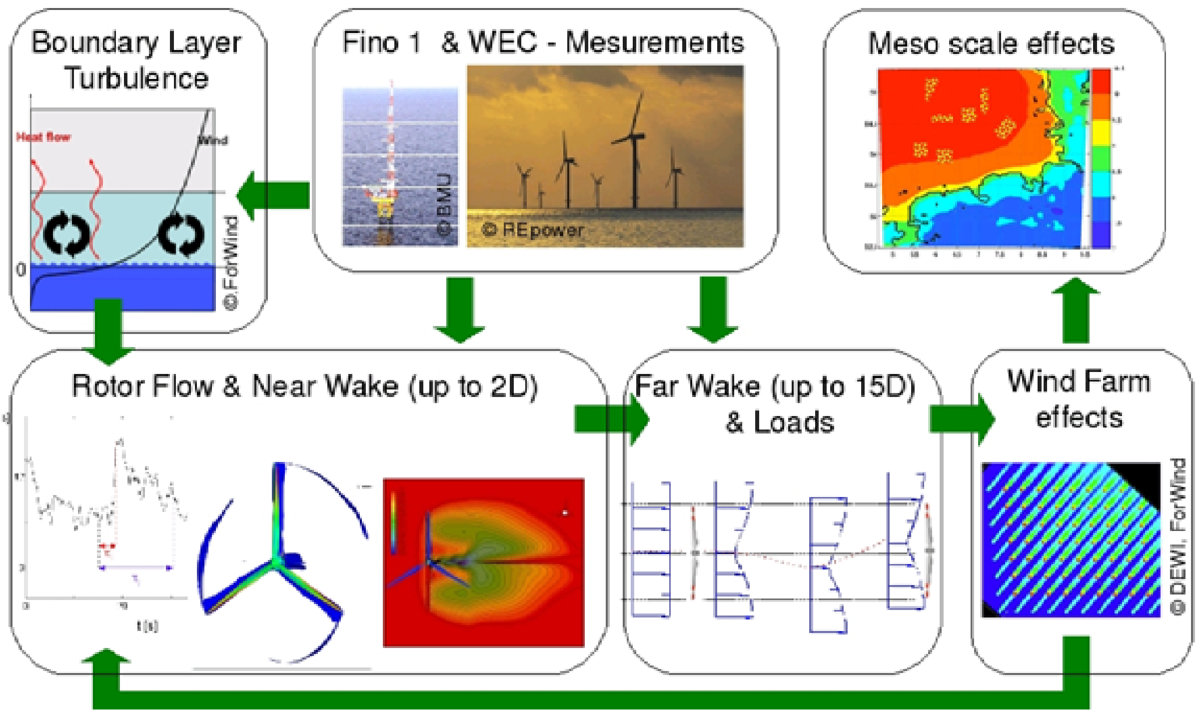
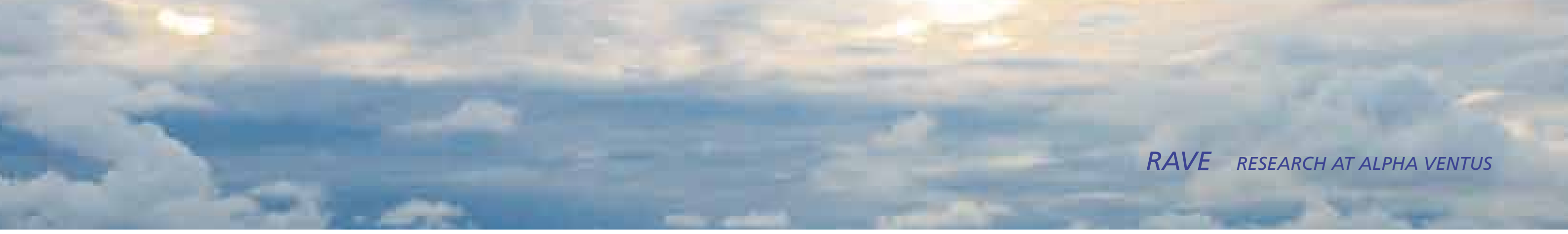


Figure 5: Process chain of the different activities on flow conditions and wake-induced loads



Work package 3 focuses on the Verification of Wind Turbine Dynamics and Loads and is led by the Endowed Chair of Wind Energy (SWE) at the University of Stuttgart. In particular, the project focuses on the verification of load simulation models. Acceleration sensors as well as strain sensors have been installed in the rotor blades, nacelle, tower and foundations of a number of WTs within the RAVE measurement project. Data from these sensors allow a determination of the effective loads and vibrations. Measured and simulated loads are compared, and the computer models enhanced. Ultimately, the prediction of energy yield, vibration characteristics and loads will be improved. Furthermore, existing simulation methods will be modified, aiming at a better representation of offshore WT foundations.

Work package 4 is also led by the SWE. It addresses the problem of Online Load Monitoring. Offshore WECs are operated in especially rough environmental conditions. Here, two fundamentally different concepts for an efficient and reliable load monitoring are analyzed. One approach involves measuring the loads on single components directly by means of additionally installed measurement equipment. In contrast, the second method provides load estimations based on standard signals taken from the Safety Control and Data Acquisition System (SCADA-System) of each WT. Utilizing proper training data for a neuronal network setup eventually allows the derivation of loads on components, such as the tower and blades. The information gained is of high value, allowing conclusions about the residual lifetime of single components and about the operating state of the WT (e.g. early detection of component failures and technical management shortcomings).

Research in work package 5, Verification of Turbulence Parameterization and Description of the Vertical Structure of the Marine Atmospheric Boundary Layer in Numerical Simulation Models for Wind Analysis and Forecasting, is done by the Institute for Meteorology and Climate Research – Atmospheric Environmental Research (IMK-IFU) at Karlsruhe Institute of Technology. This work package focuses on the analysis and the improvement of the description of turbulence in regional numerical simulation models for offshore areas with a size of several 10000 km^2. Turbulence and wind speeds for typical weather conditions in the southern part of the North Sea will be simulated using an existing wind field model (WRF) and compared with measured data. The main objective is to specify the influence of peculiarities of the ocean surface on turbulence. This will result in improved simulation models for wind and weather forecasts in the North Sea region.

Partners:
ForWind – Center for Wind Energy Research
www.forwind.de
Carl von Ossietzky University of Oldenburg, Institute of Physics
Prof. Martin Kühn, (project coordinator), kuehn@uni-oldenburg.de
Prof. Joachim Peinke, peinke@uni-oldenburg.de
Leibniz Universität Hannover, Institute of Steel Construction, Prof. Peter Schaumann
schaumann@stahl.uni-hannover.de
www.stahlbau.uni-hannover.de

University of Stuttgart
Endowed Chair of Wind Energy
Jan Quappen, quappen@ifb.uni-stuttgart.de
www.uni-stuttgart.de/Windenergie
Institute of Aerodynamics and Gasdynamics
Dr. Thorsten Lutz, lutz@iag.uni-stuttgart.de
www.iag.uni-stuttgart.de

DEWI GmbH – German Wind Energy Institute
Dr. Tom Neumann, t.neumann@dewi.de
www.dewi.de

Karlsruhe Institute of Technology
Institute for Meteorology and Climate Research
Atmospheric Environmental Research (IMK-IFU)
Prof. Stefan Emeis, stefan.emeis@kit.de
http://imk-ifu.fzk.de

REpower Systems AG, Marcus Reiner,
marcus.reiner@repower.de, www.repower.de

AREVA Multibrid GmbH, Dr. A. Hofmann
annette.hofmann@areva.com, www.multibrid.com

DEWI-OCC Offshore and Certification Centre GmbH, Jürgen Kröning, j.kroening@dewi-occ.de
www.dewi-occ.de

FGW – Federation of German Windpower
Jens Rauch, rauch@wind-fgw.de, www.wind-fgw.de

Germanischer Lloyd
Björn Schmidt, bjoern.schmidt@gl-group.com
www.gl-group.com

Fraunhofer IWES
Dr. Bernhard Lange
bernhard.lange@iwes.fraunhofer.de
www.iwes.fraunhofer.de

Monitoring of offshore wind energy utilization

Main research issues:

- What energy yield can be achieved and what does offshore wind energy cost?
- What is the effect of specific offshore conditions on equipment and on the operation and performance of wind turbines and what are the main differences to onshore systems?
- What are the fluctuations of feed-in caused by the variation of wind speeds and how is availability affected by extreme wind conditions?
- What are the advantages and/or disadvantages of different system concepts, different concepts of installation, maintenance strategies, and different grid-connection concepts?

The objective of Offshore WMEP is to generate a data pool in close collaboration with operators, manufactures, suppliers, and scientists that enables topic-specific evaluations for all participants and a general monitoring for political decision-making processes as well as for the public.

The common data pool enables future operators of offshore wind farms to make statistically reliable predictions concerning the success of operational and system concepts. As a result of a common database, weak points can be identified, components can be qualified in cooperation with manufactures and suppliers, and statements can be made about the probability of failure behavior. Using these findings, maintenance work can be reduced, whilst reliability and availability is improved.

The Offshore WMEP project also provides general monitoring, which serves as basic information for politicians. In addition, general results and trends will be depicted for the public. In order to get a large statistical database for evaluations, and therefore get results with strong validity, as many German wind farms as possible need to be included.

For common data acquisition, the information has to be stored in a standardized form by all participants. In the current concept phase, the Offshore WMEP project establishes the basis for this standardization. On the one hand the concept clarifies which data need to be collected by whom and how they will be transferred, and on the other hand who will get access to what findings and information. To protect all participants' interests, a confidentiality concept has jointly been developed. Before the Offshore WMEP project moves on from its current concept phase to the operating phase, stipulations have to be made to guarantee the confidentiality of data, which is confidentially held by IWES. The major task for the near future is to put the concept into practice, in collaboration with all the participants. IWES is in close contact with relevant companies and in advanced discussions.

Figure 1: REpower 5M
© DOTI 2009

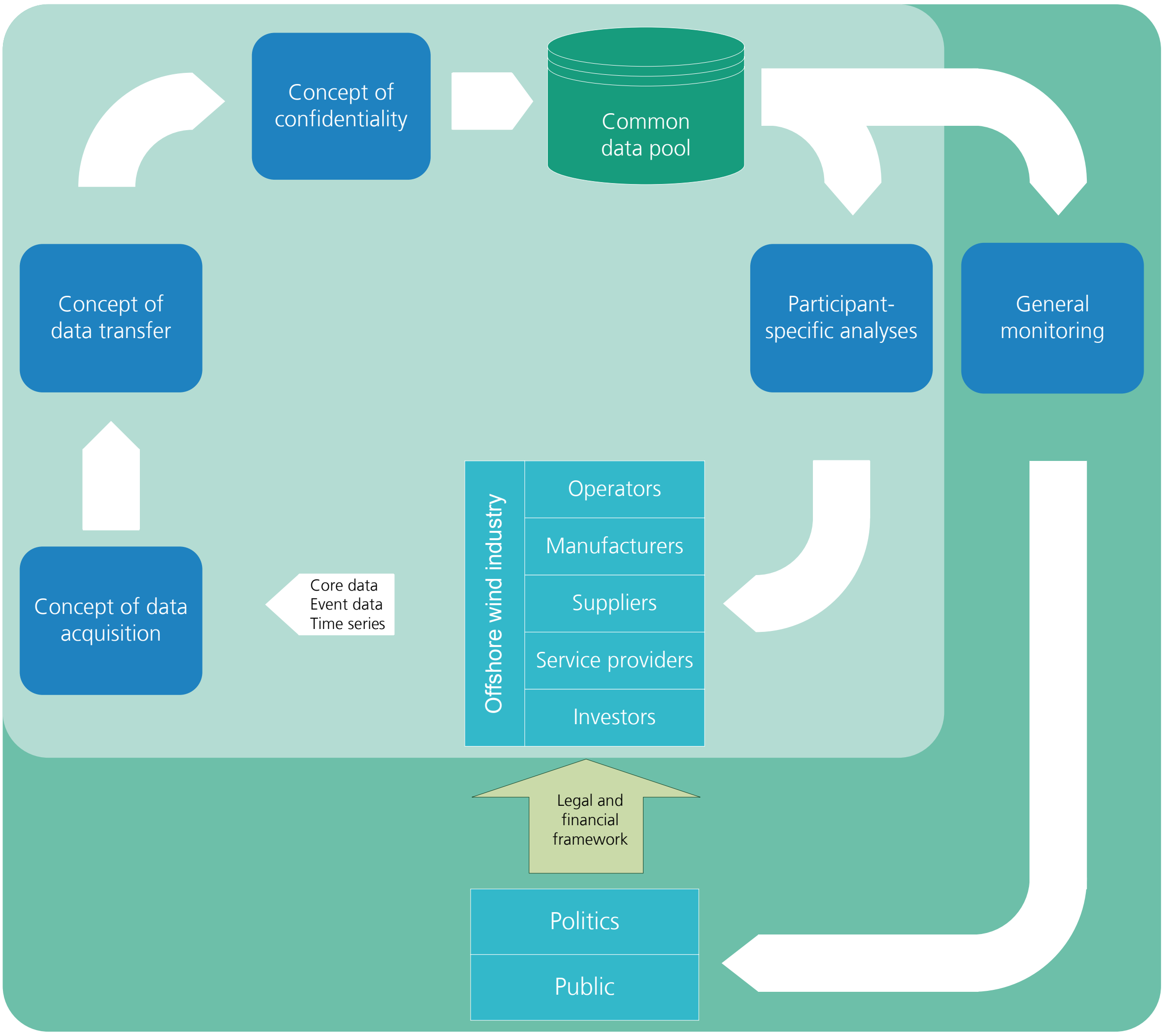


Figure 2: Offshore~WMEP Concept

Partners / Contacts:

Fraunhofer IWES
Philipp Lyding, philipp.lyding@iwes.fraunhofer.de
www.offshore-wmep.de

FGW – Federation of German Windpower
Mesut Gezen, gezen@wind-fgw.de

IZP – Ingenieurgesellschaft für Zuverlässigkeit und Prozessmodellierung Dresden
Dr. Harald Jung, h.jung@izp.de

Grid integration of offshore wind farms

Main research issues:

- How to model fluctuating wind power?
- Which wind power forecast models are needed for offshore wind farms?
- Which Numerical Weather Prediction Models will be used to achieve the best wind power forecasts?
- How can offshore wind farms be operated almost as conventional power plants?

The development of strategies and tools to integrate offshore wind power into the electricity supply system is a crucial prerequisite for the future expansion of offshore wind energy in Germany. The research project Grid integration of offshore wind farms will develop strategies and tools for the effective integration of offshore wind farms into the German power system.

The project focuses on reducing the need for balancing energy and reserve power with an advanced wind power forecasting system that ensures effective grid integration of offshore wind farms. A new set of wind power forecasting models will be developed that provide the best available information to wind farm operators and transmission system operators.

In a further step, a prototype for operational control of offshore wind farms using the Wind Farm Cluster Management System (WCMS) will be developed and implemented at IWES. In this context, control strategies are being developed which offer the possibility of running alpha ventus almost like a conventional power plant. An additional pooling of several wind farms can later be used to increase the share of guaranteed wind power.

Power output measurement from the wind farm alpha ventus will be analyzed together with meteorological data. The results will be used to extrapolate the findings on fluctuating wind power to an offshore wind power scenario that is envisaged by the German government to meet CO2 emission reduction targets. Smoothing effects of wind power will be studied to characterize the length of weak and high wind power penetration with respect to effective grid integration.

Figure 1: Offshore Platform Fino 1 (© Germanischer Lloyd Industrial Service GmbH)

Figure 2: Offshore substation at alpha ventus (© DOTI)

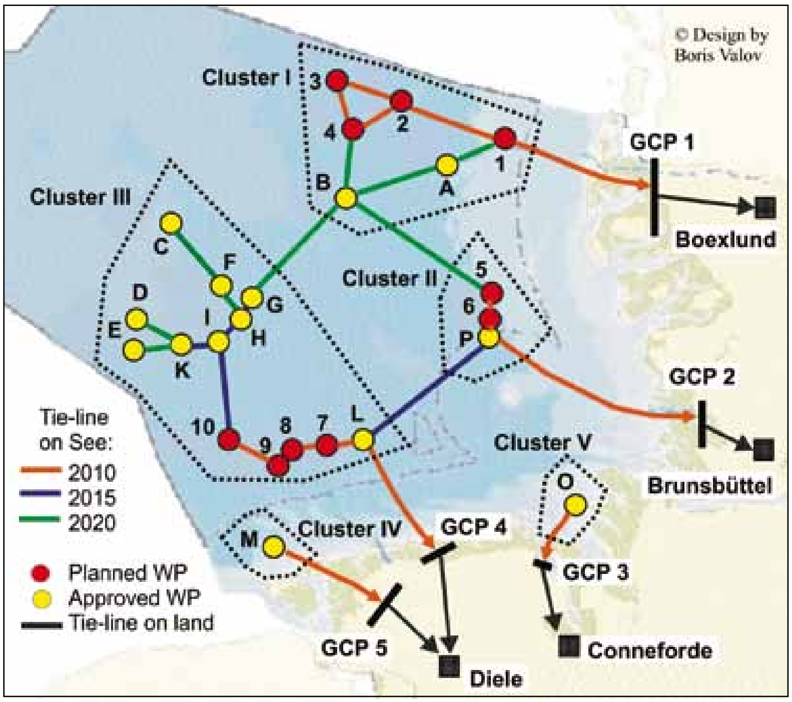


Figure 3 (left): Example of clustering of future offshore wind farms in the German Bight

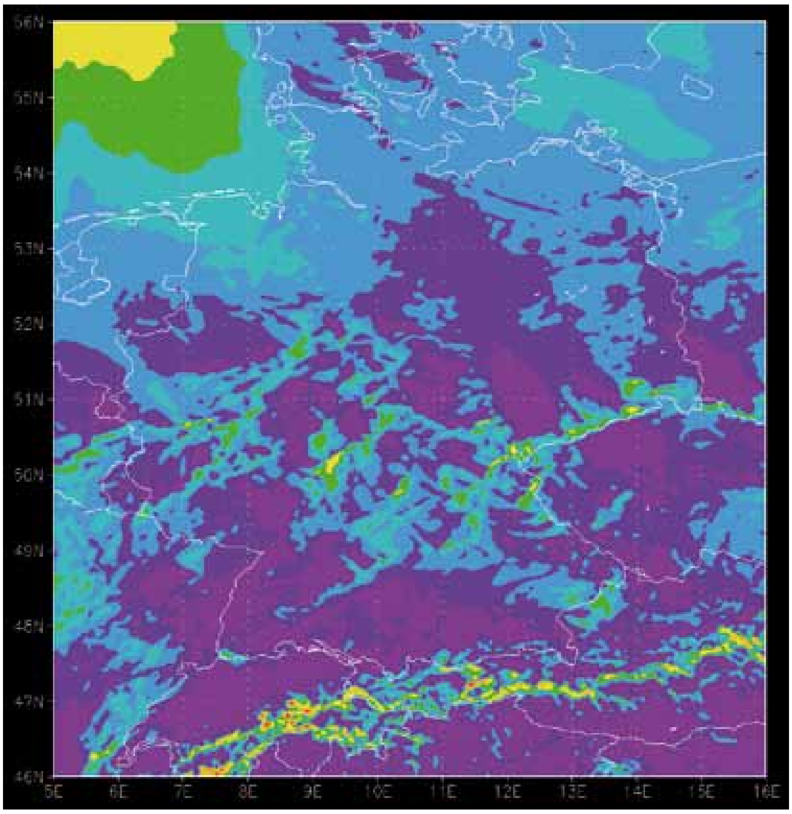


Figure 4 (lower left): Wind speed forecast at a height of 30 m from the German Weather Service

Partners / Contacts:

Fraunhofer IWES (project coordinator)
Dr. Bernhard Lange
bernhard.lange@iwes.fraunhofer.de
Dr. Arne Wessel
arne.wessel@iwes.fraunhofer.de
www.iwes.fraunhofer.de

University of Kassel
www.uni-kassel.de

Otto-von-Guericke University Magdeburg
www.uni-magdeburg.de

ForWind – Center for Wind Energy Research
Carl von Ossietzky University Oldenburg
www.forwind.de

Hochschule Magdeburg
www.hs-magdeburg.de

REpower Systems AG
www.repower.de

Deutscher Wetterdienst
www.dwd.de

AREVA Multibrid GmbH
www.multibrid.com

WEPROG – Weather & Wind Energy PROGnosis
www.weprog.com

Ecological research to evaluate BSH's standards for environmental impact assessments (StUKplus)

Main research issues:

- Will marine mammals and passage migrant birds continue using the wind farm area as habitat?
- What impacts will noisy construction work and the operational phase have on marine mammals and fish?
- What changes in the habitats of benthic organisms and fish species are to be expected close to the foundations? How far does the influence of the artificial hard substrate extend?
- How do migratory birds react to the rotating, lighted turbines? Will there be collisions and evasive movements?

The Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency) is the co-ordinator of a project on ecologic research conducted at the alpha ventus offshore test site. The StUKplus research project supplements the mandatory ecological monitoring carried out by wind farm operators according to the BSH's Standards for Environmental Impact Assessments (StUK3). Its purpose is to gain better knowledge about the ecological impact of offshore wind farms and to evaluate the StUK3 standards.

The purpose of ecological research is to identify environmental risks at the earliest stage possible and to avoid them. To that end, a before/after comparison study was carried out. Comprehensive preliminary studies of benthic organisms, fish, passage migrants, migratory birds, and marine mammals were conducted at the test site as early as 2008. These studies have been supplemented by underwater noise measurements. A large database has

Figure 1: Underwater structure of FINO1 (next to test site alpha ventus) with blue mussels and plumose anemone in about 5 m depth
© Sebastian Fuhrmann

Figure 2: View of camera systems from transformer platform to the nearby turbine, © Reinhold Hill, Avitec Research

been compiled, which will be used later in assessing the likely impact of the construction and operational phases. To obtain reliable data about how animals react to a wind farm in their habitat, long-term studies over several years will be necessary. The BSH's large marine environmental database will be combined with the research data and jointly evaluated.

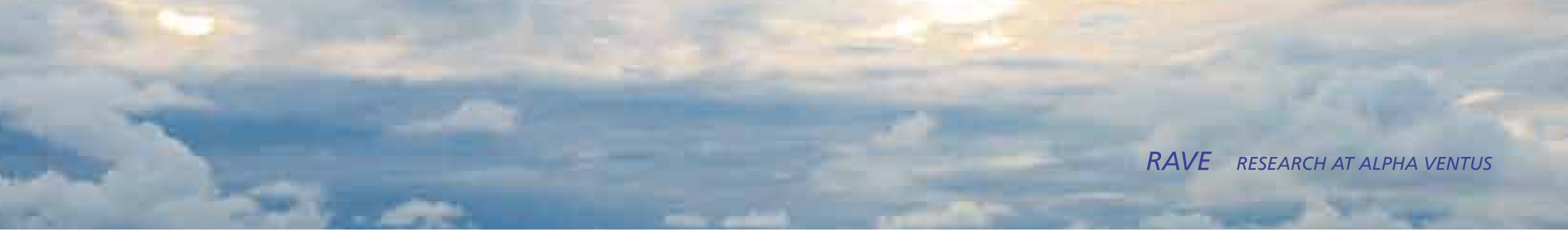
Investigations into the impact of wind turbine construction work on harbor porpoises began in 2009 (Figure 3). Surveys of harbor porpoises before, during, and after pile-driving operations were carried out by means of aerial counts, boat counts, and underwater microphones. The findings will allow conclusions as to the spatial and temporal impact of pile-driving noise on harbor porpoises. As these marine mammals are highly sensitive to noise, they were dispelled from the area before starting the pile-driving operations in order to protect them from the hammering noise. The underwater noise produced by these activities was detectable at distances of up to 20 km, providing evidence of its wide propagation.

Novel video cameras, heat imaging cameras, and radar systems have been developed to monitor bird collisions with turbine rotor blades and evasive movements of birds. It is the first application of this novel equipment, which has been installed on the transformer station, turbines, and the nearby research platform FINO 1.

Within just a short period of time, the foundation structure of the research platform FINO 1 has developed into an artificial reef colonized by blue mussels and plumose anemones (Figure 1). The first "reef" species such as edible and velvet crabs have been observed on the fine sands close to the installations, which is evidence of a changing habitat.

Some of the research partners of StUKplus have spent several years studying the ecological impact of offshore wind farms. Their know-how and experience will now be applied to a real-life project: the alpha ventus offshore test site.

Figure 3: Harbor porpoise ***(Phocoena phocoena)*** as the most common marine mammal species in the southern North Sea
© Klaus Lucke, Research and Technology Center Westcoast (FTZ) / Fjord & Belt Centre, Kerteminde, Denmark



Part projects / contacts:

Alfred- Wegener-Institut für Polar- und Meeresforschung (AWI)
Dr. Alexander Schroeder, Dr. Lars Gutow

- Investigation of the impacts of wind turbines on fish and vagile megafauna in the alpha ventus test site;
- joint evaluation of research data, data from monitoring programmes, and environmental impact studies as a holistic approach to ecological effects monitoring in the alpha ventus test site;
- completion of time series during the operational phase and assessment of benthic changes in extended site-specific effect monitoring.

Avitec Research GbR
Reinhold Hill, Katrin Hill

- Test site research on bird migration in the area of the alpha ventus pilot project;
- evaluation of 2008 and 2009 bird migration data recorded continuously at FINO 1.

Forschungs- und Technologiezentrum Westküste (FTZ)
Dr. Klaus Lucke (marine mammals),
Dr. Stefan Garthe (passage migrants)

- Supplementary studies on the impacts of the offshore test site alpha ventus, both in the construction and operational phases, on marine mammals;
- joint evaluation of seabird and marine mammal data for ecological effect monitoring in the alpha ventus test site;
- studies on possible habitat losses and behavioural changes of seabirds in the offshore wind energy test site (TESTBIRD)

Institut für Angewandte Ökologie (IfAÖ)
Dr. Axel Schulz, Dr. Christoph Kulemeyer

- Monitoring of evasive movements of migratory birds using Bird Scan method (Fixed Pencil Beam Radar);
- assessment of collision risk of migratory birds using VARS camera system

Institut für technische und angewandte Physik (itap)
Rainer Matuschek, Dr. Klaus Betke

- Measurement of pile driving and operational noise at larger distances from the alpha ventus test site, and model-based processing.

Figure 4: Foraging fulmars ***(Fulmarus glacialis)***
© Stefan Garthe, Research and Technology Center Westcoast (FTZ)

Figure 5: Underwater noise measurements with a hydrophone during construction works at the alpha ventus site © itap GmbH

Partners / Contacts:

BSH – Federal Maritime and Hydrographic Agency
Kristin Blasche, Christian Dahlke
Bernhard-Nocht-Str. 78
20359 Hamburg
www.bsh.de

Project homepage: www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/StUKplus/stukplustext.jsp

Measurement of operational underwater noise emission of wind turbines at the alpha ventus offshore wind farm

Main research issues:

- How loud are single 5 MW offshore wind energy converters in the water?
- What amount of underwater noise does the alpha ventus wind farm produce?
- How do weather and tide conditions influence underwater noise production and propagation?
- What is the shape of the transfer-function between tower vibration and underwater noise?

The goal of this research project is to measure the operational underwater sound emission of different types of 5 MW offshore wind turbines under varying boundary conditions. The reason for undertaking this project is to learn about the exposure of marine animals to noise, especially marine mammals, in the vicinity of offshore wind farms.

The noise production of offshore wind turbines and underwater sound propagation are influenced to a greater or lesser extent by many parameters (boundary conditions) such as the wind velocity, wind direction, sea state, water height, water flow profiles, water temperature, water temperature profiles, salinity, etc.

The following issues are being investigated:
- Measurement of underwater noise production by different types of offshore wind turbines under various boundary conditions;
- Determination of the transfer function between tower vibration (structure-borne sound) and emitted underwater noise for different types of offshore wind turbines;
- The influence of different boundary conditions on sound propagation;
- Measurement of the total underwater noise emission by the alpha ventus wind farm under all possible boundary conditions.

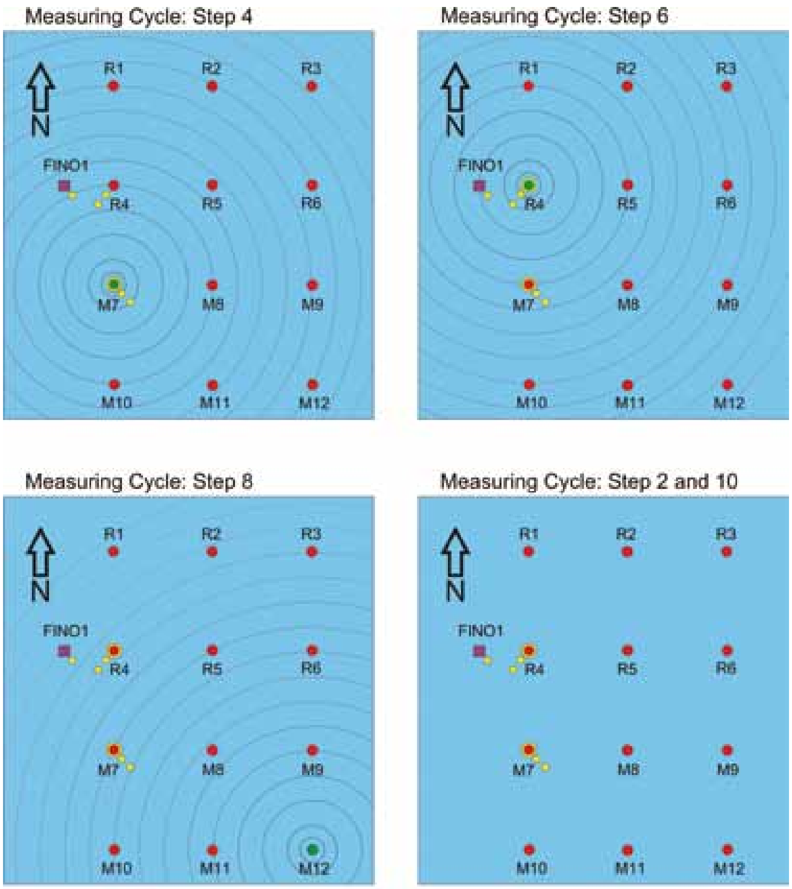
On the one hand we are measuring the noise emission of single wind turbines. This means that all other wind turbines on the wind farm have to be switched off during the measuring cycle (see Table 1 and Figure 1) and means that the wind farm produces no electrical power. For this reason, only a limited number of measurements can be performed in different weather conditions.

On the other hand we are measuring the overall noise emission of the wind farm, when all wind turbines are operating. In this case, the measuring time is only limited by the local data storage capacity and the data transmission bandwidth.

A total of 5 hydrophones are positioned about 3 meters above the seabed near 2 wind turbines and near the research platform FINO. In addition, acceleration sensors are mounted on the underwater and above-water sections of the wind turbine towers. Measuring computers that are installed in both wind turbines and on FINO1 digitize the signals of the acceleration sensors and hydrophones. The time series of the sensor signals are stored locally and afterwards transmitted onshore. The measuring system can be remotely controlled from onshore so that measurements can be performed in all weather conditions. From the time series, all sound pressure levels and sound power spectra can be calculated in the laboratory. In addition, using the time series we are able to identify background noise from other sources such as passing ships.

Step	Action
1	Shut down all wind turbines
2	Background measurement
3	Switch on M7
4	Measurement of the sound emission of M7
5	Shut down M7, switch on R4
6	Measurement of the sound emission of R4
7	Shut down R4, switch on M12
8	Measurement of the sound emission of M12*
9	Shut down M12
10	Background measurement
11	Switch on all wind turbines

Table 1: Definition of the measuring cycle for measurement of the sound emission from single wind turbines.
* Auxiliary measurement for the determination of the local underwater sound attenuation.



- Hydrophones
- OWEC with measuring equipment, OWEC switched on
- OWEC with measuring equipment, OWEC switched off
- OWEC switched on
- OWEC switched off
- Research platform FINO1

Figure 1: Measuring cycle: individual wind turbines are sequently switched on and off

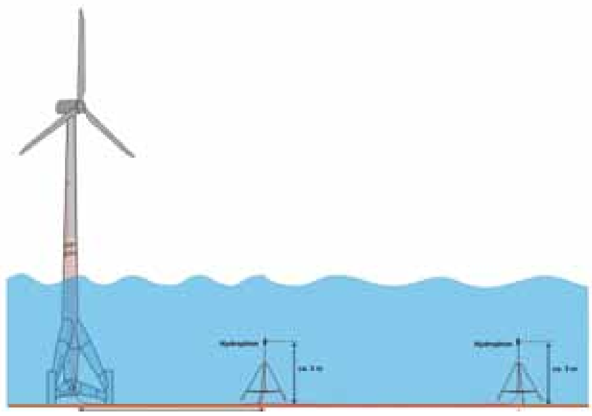


Figure 2: Measuring set-up at Multibrid M7

Literature:
CRI, DEWI, ITAP (2004): Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore-Windenergieanlagen. Abschlussbericht zum BMU-Projekt (FKZ 0327528A), Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin
Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006). Effects of offshore wind farm noise on marine mammals and fish, biola, Hamburg, Germany on behalf of COWRIE Ltd.
Elmer, K. H., Bethke, K., Neumann, T., Gabriel, J., (2007): Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore-Windenergieanlagen. Abschlussbericht zum BMU-Projekt (FKZ 0329947), Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin

Partners / Contacts:

Flensburg University of Applied Sciences
Kanzleistraße 91-93
24943 Flensburg / Germany
www.rave-schall.fh-flensburg.de
Dr. Hermann van Radecke
+49 (0) 461 805 1386
hermann.vanradecke@fh-flensburg.de
Dr. Michael Benesch
+49 (0) 461 805 1271
michael.benesch@fh-flensburg.de

University of Applied Sciences Kiel,
Prof. L. Dannenberg, Lothar.Dannenberg@FH-Kiel.de
Dr. Klaus Lucke, FTZ, Research and Technology Centre Westcoast, lucke@ftz-west.uni-kiel.de

DEWI GmbH – German Windenergy Institute Wilhelmshaven
Dr. Thomas Neumann, t.neumann@dewi.de

Research and testing of a "Layered Bubble Curtain (LBC)" at the offshore test site alpha ventus

Main research issues:

- Concept design and development of a layered bubble curtain close to the foundation of an offshore wind turbine of type Multibrid;
- Testing and subsequent evaluation of the operation of the layered bubble curtain under offshore conditions and meeting the requirements of pile-driving procedures, which are necessary to install the foundations;
- Assessment of the tide's influence on the noise mitigation efficiency of the bubble curtain;
- Investigation of the influence of the ram energy level on the noise mitigation efficiency of the bubble curtain.

Background

The measurement results for hydro-sound levels as a consequence of pile-driving activities in the North Sea and the Baltic Sea show that the recommended values defined by the German Umweltbundesamt (UBA) are seriously exceeded. It is therefore necessary to use effective sound reduction techniques in order to reduce the impact on the marine environment as far as possible. However, the application of noise mitigation measures has to be cost-effective and must not significantly disturb the installation procedures for the offshore wind turbines' foundations.

Within the framework of the workshops arranged by the Stiftung Offshore-Windenergie it was decided in December 2008 to test a layered bubble curtain close to the foundation. The design and construction of the concept was undertaken by MENCK GmbH in collaboration with Hydrotechnik Lübeck.

By the end of May 2009 the required hydro-sound measurements during the installation of a wind turbine of type Multibrid were carried out under the coordination of ISD together with the research partners DEWI and ITAP. During the measurements the bubble curtain was mounted at two of the pile sleeves of AV09.

Noise mitigation concept: bubble curtain

The name "bubble curtain" comprises the whole concept, consisting of the tube system and the actual bubble curtain, which arises, when the air bubbles escape from the nozzles of the tubes at status "filled with compressed air". As the bubbles raise to the surface they form a dense curtain.

Figure 1: Lower preinstalled system mounted at the pile sleeve of AV09, Eemshaven, the Netherlands (Source: Hydrotechnik Lübeck, GmbH)

Figure 2: Upper mobile system at transport frame including lifting bodies, Eemshaven, the Netherlands (Source: Hydrotechnik Lübeck, GmbH)

Gas bubbles change the acoustic properties of the medium water. Due to the different impedances of the two media, acoustical scattering occurs at the boundary.

In addition to this effect, the single bubble reacts like an acoustical resonator when insonified by an incident wave close to its resonance frequency. The result is a very high ratio of effective acoustical to geometrical cross section at resonance. Overall the two effects lead to a significant reduction of the hydro- sound eimmission "behind" the bubble and at greater distances, which is the main reason for the efficiency of the system.

Since the bubble curtain is not a rigid construction, but consists of freely moving air bubbles, it is vulnerable to sea currents and waves. A further challenge is posed by the immediate vicinity ofto the piling activities. To minimize any disturbance caused by the installation procedure the bubble curtain was split into in an upper part (Figure 2) and a lower part (Figure 1). The lower parts were mounted at two pile sleeves in Eemshaven.

When the AV09 was being installed offshore, the lower bubble curtains were put into operation as planned. The upper mobile systems, however, could not be applied due to bad weather and the risk of delay to the installation process.

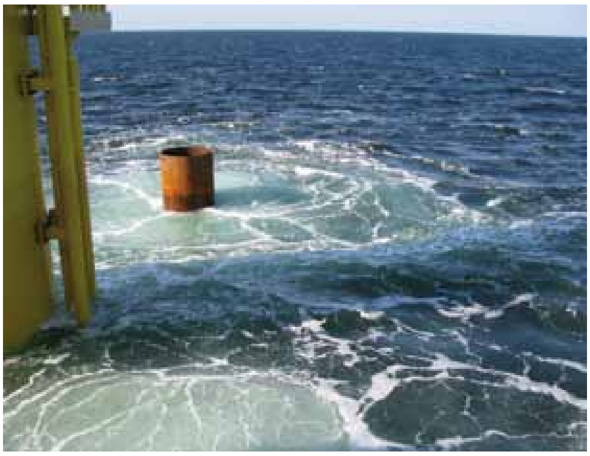


Figure 3: Emersion of bubble curtain at water surface at turn of tide, north-east pile of AV09, May 31th, 2009 (Source: ISD)

Literature:

[1] Medwin, H.; Clay, C. (1998): "Fundamentals of Acoustical Oceanography", Academic Press, San Diego
[2] Medwin, H. (2005): "Sounds in the Sea", Cambridge University Press, Cambridge

Partners / Contacts:

Leibniz Universität Hannover
Prof. Raimund Rolfes (head of project)
Institute of Structural Analysis
Appelstr. 9A
30167 Hannover
www.isd.uni-hannover.de

MENCK GmbH (associated partner)
Industrial Area Moorkaten, Am Springmoor 5a
24568 Kaltenkirchen
www.menck.com

DEWI GmbH – German Windenergy Institute
Ebertstr. 96
26382 Wilhelmshaven
www.dewi.de

ITAP – Institute for technical and applied physics
Marie-Curie-Str. 8
26129 Oldenburg
www.itap.de

Hydrotechnik Lübeck GmbH
Grootkoppel 33
23566 Lübeck
www.hydrotechnik-luebeck.de

PROKON Nord Energiesysteme GmbH
/Prokon Nord
Offshore Installations GmbH
Gustav-Elster-Str. 1
26789 Leer
www.prokonnord.de

Karl Wrede Stahl- und Maschinenbau GmbH
Süderbehmhusen 2
25715 Eddelak
Bode & Wrede
Fraunhoferstraße 3
25524 Itzehoe
www.bode-wrede.de

Investigation of sonar transponders for offshore wind parks and technical integration into an overall concept

Main research issues:

Besides the need for dimensioning the electro acoustic transducer and the control unit to meet the requirements of the German Navy, the following issues are of particular importance:

- Which mounting position is most suitable for the sonar transponder? To answer this question, the topology of both the foundation and the whole wind park have to be taken into account.
- How can hydro-sound propagation of the far field be calculated taking into consideration the topology of the foundation, water depth, bathymetry, and entry of air bubbles?
- What diffraction and interference effects are possible when one or more transponders are activated?
- How can the impact on marine mammals be minimized?

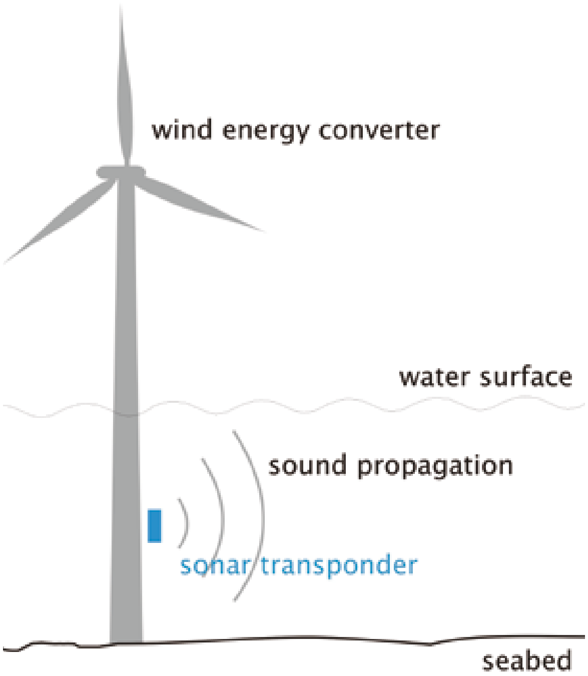


Figure 1: Position of sonar transponder at offshore wind turbine - schematic view (Source: THALES Instruments GmbH)

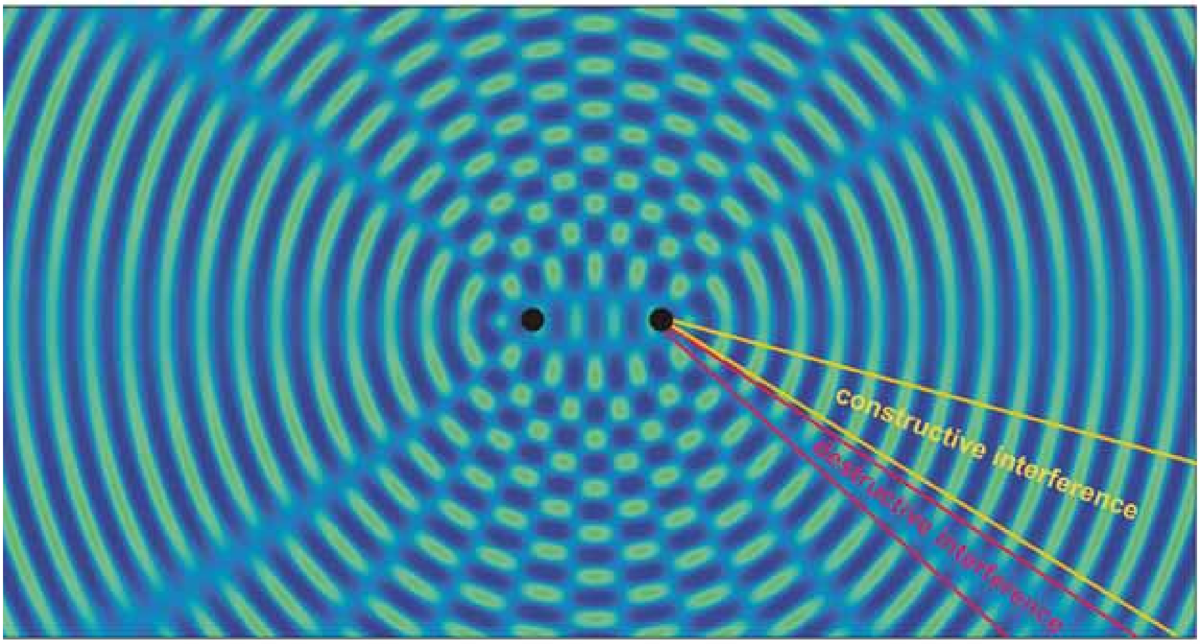


Figure 2: Example of the interference patterns of two monofrequeny signals (yellow: constructive interference, red: destructive interference)
Source: ISD

Figure 3: Sonar transponder (Source: THALES Instruments GmbH)

Background
Since offshore wind turbines pose a potential danger for submarines, the installation and operation of sonar transponder units is required in order to give an acoustic warning. The exact specification of this kind of warning is being evaluated by the German Navy in collaboration with the Research Branch of Waterborne Sound and Geophysics (FWG) in Kiel. Provision is made for a combination of an electro-acoustic transducer and a control unit, which can be activated by a monofrequency signal emitted by a submarine in an emergency. In this case, the sonar transponder responds by also sending a monofrequency signal, so allowing the submarine to locate the offshore wind turbine.

Due to their spatial expansion, offshore wind farms need several sonar transponders placed at their corners. A fundamental safety requirement is to ensure there is an adequate signal-to-noise ratio at a certain operational distance, even under bad weather conditions. To achieve this goal the transmission level has to be sufficiently high. On the other hand, the impact on marine animals has to be taken into account and so the transmission level has to be kept as low as possible, both in the near field and the far field.

Moreover, underwater sound propagation depends on several factors, meaning its spatial and temporal distribution is subjected to large fluctuations.

Hydro-sound propagation model
One key task of the project is to develop a numerical simulation model which is capable of describing hydro-sound propagation induced by monofrequency signals both in the near field and the far field of the acoustic source. The vicinity of the source to the wind turbine's foundation is characterized in particular by reflection and diffraction effects, whereas at greater distances refraction, reflection, and absorption are dominant. To meet the different physical requirements of the near field and the far field, a hybrid method seems to be most suitable. For the noisy near field the Boundary Elements Method (BEM) is appropriate for modeling diffraction and reflection effects caused by the foundation, but avoiding reflections from the system boundary into the domain.

For the far field a ray based procedure is suitable, because a BEM model would be inapplicable due to model complexity and calculation complexity.

This modular approach based on decoupling the sound generation and sound propagation provides the necessary basis for easily transferring calculations to different foundation types and to different boundary conditions in the far field.

Literature
[1] Nissen, I. (2004): "Akustische Kenntlichmachung von künstlichen Unterwassergefahrenquellen - Modellierung und Leistungsdaten –", Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik, Kiel, Kurzbericht KB 2004-1

Partners / Contacts:

Leibniz Universität Hannover
Institute of Structural Analysis
Prof. Raimund Rolfes (head of project),
Appelstr. 9A
30167 Hannover
www.isd.uni-hannover.de

THALES Instruments GmbH (associated partner)
Werftweg 15
26135 Oldenburg
www.thales-instruments.de

DEWI GmbH – German Windenergy Institute
Ebertstr. 96
26382 Wilhelmshaven
www.dewi.de

ITAP – Institute for technical and applied physics
Marie-Curie-Str. 8
26129 Oldenburg
www.itap.de

BioConsult SH GmbH & Co.KG
Brinckmannstr. 31
25813 Husum
www.BioConsult-SH.de

Acceptance of offshore wind power utilization

Main research issues:

- How distinct is the acceptance of offshore wind power, and what factors influence this?
- What effects have offshore wind farms on tourism and the local economy?
- What measures can be employed to solve or avoid conflicts between residents, operators, and public authorities?

To increase the share of renewable energy in the electricity supply mix, an increase of offshore wind power up to 7,000 – 10,000 MW is planned. To reach this goal, public support is a must. In order to learn of expectancies and experiences before and after building offshore wind farms, the German Federal Ministry for the Environment, Nature, Conservation and Nuclear Safety is funding the interdisciplinary project `Acceptance of offshore wind power utilization´. The consortium consists of experts from the areas of environmental/social psychology, marketing/tourism, and architecture and landscape planning.

To assess offshore wind acceptance, surveys are being conducted in four coastal regions on the North Sea and Baltic Sea. In each case two regions with and without offshore parks are being investigated. Residents, tourists, and local experts are being interviewed using standardized questionnaires. The first survey started in July 2009, and the second is planned in June 2011.

Figure 1: Example of the abstract of the landscape. Layout concepts for offshore wind parks in a topview. © lareg

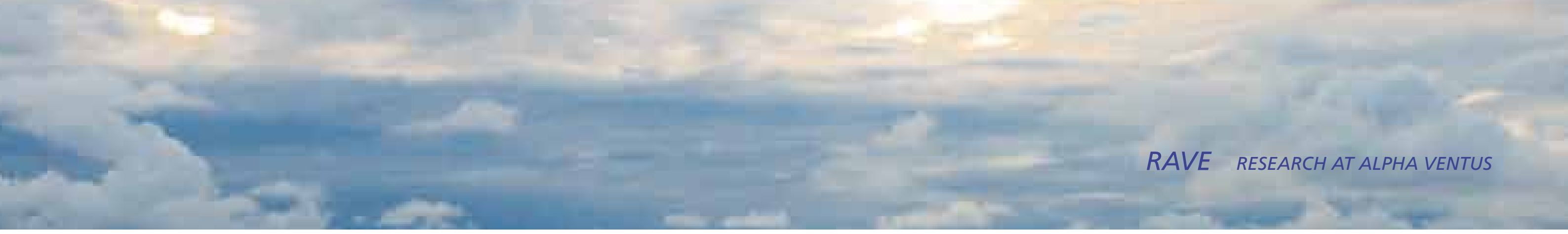


Figure 2: Zero emission © Risø Institute

For example, it is of interest whether offshore wind power affects tourism, what the public believe to be the effects on the marine environment, and whether this plays a key role in the acceptance of offshore wind farms. Wind farms modify the landscape. To answer the question as to whether wind farms created according to design principles and connected with the unique landscapes are evaluated more positively, six specific concepts, including the real planning, were developed for the North Sea and Baltic Sea. Residents and tourists rated the most preferred design solutions. Furthermore, attitudes and expectancies concerning sea cable trays are being taken into account.

The project results will provide recommendations for decision-makers on how to implement offshore wind farms in as untroubled a way as possible.

Partners / Contacts:

Martin-Luther-Universität Halle-Wittenberg
Institut für Psychologie
PD Dr. Gundula Hübner (project manager)
gundula.huebner@psych.uni-halle.de
Dr. Johannes Pohl
06099 Halle (Saale)

Technische Universität Berlin
Institut für Landschaftsarchitektur und Umweltplanung
Prof. Elke Bruns
elke.bruns@tu-berlin.de
10623 Berlin

Technische Universität München
Fachgebiet für Landschaftsarchitektur regionaler Freiräume
Prof. Sören Schöbel-Rutschmann
lareg@wzw.tum.de
85350 Freising

Hochschule Bremerhaven
University of Applied Sciences
Institut für Maritimen Tourismus
Prof. Michael Vogel
mvogel@hs-bremerhaven.de
27568 Bremerhaven

Analysing impacts of offshore wind turbines to the marine environment

Main research issues:

- Determination of scour depths and scouring dynamics
- Influence of offshore wind turbines on the overall sediment dynamics at an offshore wind farm
- Characterisation of impacts of sediment dynamical processes on geotechnical properties and benthic organisms of the upper seabed
- Continuous oceanographic observations
- Provision of oceanographic measurement data for all RAVE-projects
- Analysis of interactions between offshore structures and the marine environment

Geology

The sedimentological characteristics of the seabed and hydrodynamic processes fundamentally affect both the ecological function of the seabed as a marine habitat as well as its soil mechanical properties with regard to the scouring behaviour of offshore wind turbines. The geological research program is therefore focused on the acquisition of data and the evaluation of sediment dynamical processes caused by offshore wind turbines that may produce alterations in the layer formation and the sediment composition of the upper seabed.

To survey the scour depths, up to 24 echo sounders have been installed for each of the two different foundation types applied at the offshore test site. Periodic hydroacoustic surveys allow evaluation of the impact of changes in sediment dynamics on layer formation and sediment composition of the upper seabed. Penetration

Figure 1: Image of a side scan sonar. The sketches on the right are showing targets from a side scan sonar survey recorded at the test site.

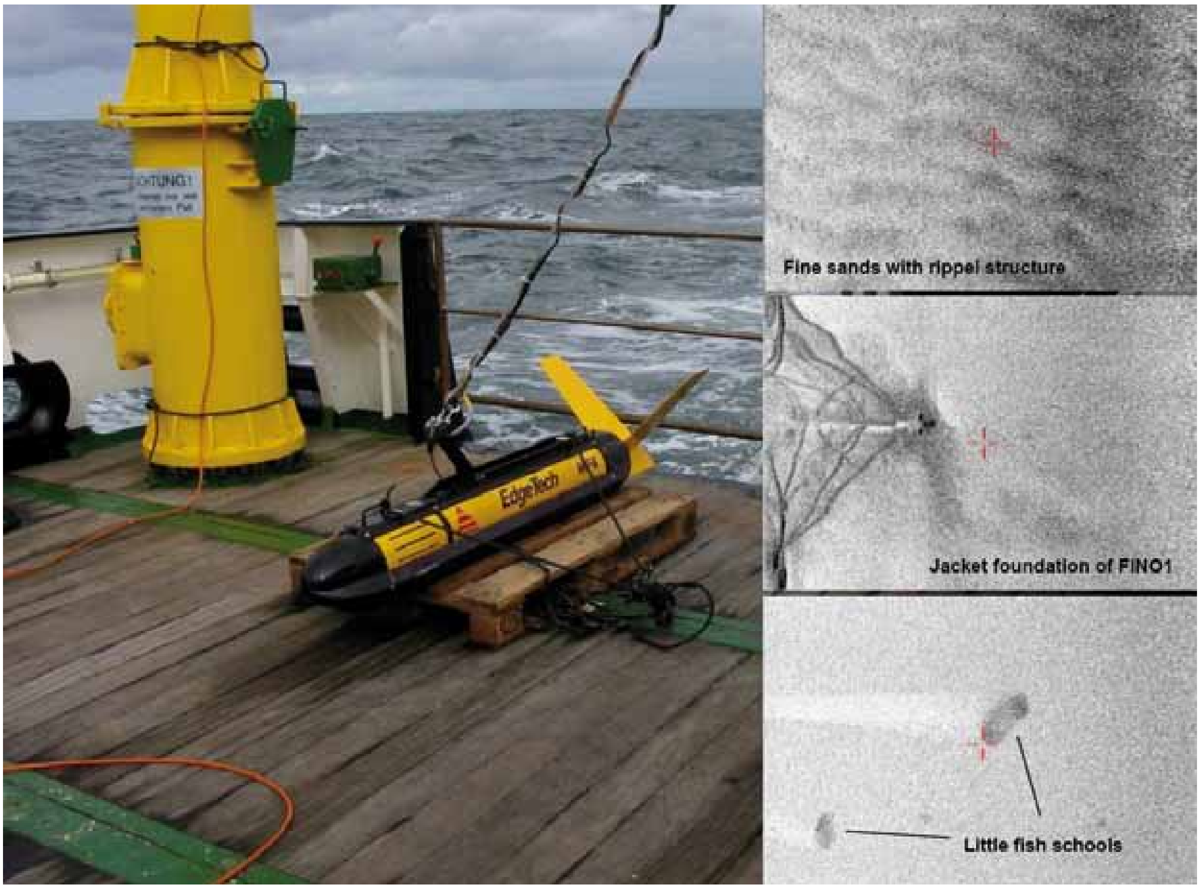


Figure 2: Jack-up platform at the wind turbine AV 5. The inserted side scan sonar target is showing the jacket foundation of the AV 5 and next to it the footprints left by the platform poles.

Figure 3: Installation of the echosounders at the tripod foundation of the wind turbine AV 7. The echosounders are continuously scanning the scour depths around the foundation.

tests with dynamic penetrometers and geotechnical laboratory studies provide information about the mechanical properties of the sediment and changes that occur.

Oceanography

Marine environmental conditions have a major impact on the operational management of offshore structures and facilities, e.g. offshore wind farms. This is especially noticeable in the strong tidal current systems as well as the sea surface dynamics. In order to build and operate an offshore wind farm in this rugged marine climate, detailed knowledge of the predominating oceanographic conditions is absolutely vital.

The core of the oceanographic project is a measurement program consisting of sea state and sea current observations. Usual oceanographic parameters (temperature, salinity and oxygen) are measured in the initial phase of wind farm operation using an autarkical mooring. Temperature measurements are carried out continuously at two different offshore wind turbines and foundations structures of alpha ventus.

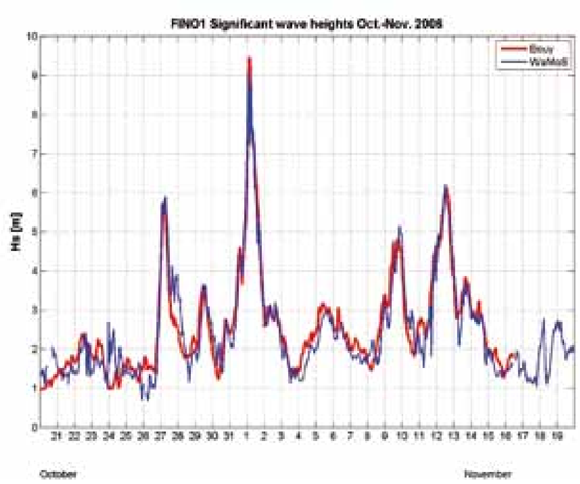


Figure 4: Results of wave measurements close to alpha ventus

Figure 5: Retrieving of a wave measuring buoy

Figure 6: Acoustic Doppler Current Profiler (ADCP) in its base frame

Contact:

BSH – Federal Maritime and Hydrographic Agency
Kai Herklotz, Manfred Zeiler,
Maria Lambers-Huesmann
Bernhard-Nocht-Str. 78
20359 Hamburg
www.bsh.de

Partner:

MARUM – Center for Marine Environmental Sciences
Marine Geotechnics
Prof. Achim Kopf
Leobener Straße
28359 Bremen
www.marum.de

Published by
Fraunhofer Institute for Wind Energy and Energy System Technology IWES
Königstor 59
34119 Kassel / Germany
www.iwes.fraunhofer.de

Editors
Michael Durstewitz, Uwe Krengel, Bernhard Lange
Fraunhofer IWES
July 2010

Layout
Renate Rothkegel
Fraunhofer IWES

www.rave-offshore.de

The RAVE Initiative is

funded on the base of an act of the German Parliament by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

supervised by

PtJ Projektträger Jülich Forschungszentrum Jülich

coordinated by

Fraunhofer IWES