IRPWind

Integrated Research Programme
on Wind Energy

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1. Executive Summary

1.1 Status on the EERA Joint Programme on Wind Energy and the Integrated Research Programme on Wind Energy (IRPWIND)

IRPWIND is an integrated research programme that combines strategic research projects and support activities within the field of wind energy. The concept behind this programme is built on the successes of existing initiatives supporting the SET Plan Agenda such as the European Energy Research Alliance Joint Programme on Wind Energy, whose organizational structure and participation is mirrored in this consortium. Openness of the programme is achieved through the implementation of 2 pilot funding schemes: one promoting mobility of experienced researchers and another accommodating shared use of infrastructures to carry out experiments at multiple facilities all over Europe.

Several technical and collaborative gaps, currently hampering the next generation of wind energy technologies, have been identified. It is these gaps that IRPWIND now proposes to bridge with a team that gathers 24 partners and the critical mass of research performers within wind energy across Europe bringing the EERA joint programme on wind energy to a new level of coordination, alignment and integration.

The present Strategic Action Plan for JP Wind and IRPWIND outlines among others the plans to progress this work for the period 2014-2017 for each EERA JP WIND sub-programme. With this first Yearly Reporting, we are giving a status on the research themes and milestones, mentioned in the first Strategic Action Plan for IRPWIND.

The reporting will also be done within national and other European projects contributing to the IRPWIND and EERA JP Wind. The yearly reports include a country-by-country status on national projects, through which we try to ensure the best national involvement in the IRPWIND.
One of the key missions in EERA JP Wind is to develop new projects building on the combined use of national and EU funding. This is a challenging exercise for both member states and EERA JP Wind members, but work is ongoing to realise this potential. All Full Participants in the EERA JP Wind have been given the task of ensuring that the Associate Participants they represent in the SC are able to make a coherent contribution to the yearly reporting.

In the yearly reports most sub-programme coordinators are also reflecting on international collaboration and research publications published in 2014. From year 2 of IRPWIND, the yearly reporting will additionally reflect on the landscape of wind energy R&D in various European countries with respect to industrial and public stakeholders, national priorities and strategies.

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Aerodynamics

A sub-programme within the
Joint Research Programme on Wind Energy

Yearly reporting for 2014

2. Sub-programme on Aerodynamics

2.1 Reporting on Research Themes

RT1: Inflow wind field modelling

EERA vision
Improved engineering inflow wind field modelling including vertical and directional shear, coherence, extremes, consistency with conservation laws, to be used as input for aerodynamic design and aero-elastic simulations.

To investigate the impact of atmospheric inflow conditions on the load spectra of wind turbines numerical time-resolved simulations are performed at USTUTT-IAG and the simulation tools are enhanced. Unsteady anisotropic flow fields are fed in the CFD simulation domain and one focus of the 2014 activities was to study the evolution and potential decay of turbulence caused by numerical effects. Different synthetic turbulence generators are examined and the impact of the numerical scheme and the discretization has been investigated. The simulations have been expanded to the consideration of complex terrain effects and wake impacts of interacting turbines.

In the context of RT1, Metuwind has an on-going nationally funded research project funded by The Scientific and Technological Research Council of Turkey (TUBITAK). The project aims to couple mesoscale weather prediction models with an in-house CFD solver that is based on finite volume Navier Stokes solver for the purpose of high resolution wind prediction capability on complex terrain. Other open source solvers such as OpenFoam and SU2 are also being tried for coupling with the mesoscale solver WRF within the context of the project. Coupling of high resolution unsteady CFD with mesoscale solvers brings in the capability of better wind farm design and optimization as well as better wind potential prediction capability for existing wind farms.

RT2: Aerodynamic design models

EERA vision
Understanding the underlying physics and determining the underlying parameters of aerodynamic design models. For this purpose detailed measurements and CFD techniques are used. The long-term research will lead to the development of new advanced aerodynamics models. To better model the acoustic emission of wind turbines, computational aero-acoustics (CAA) is further developed.

The development of aerodynamic design models is performed in the European project AVATAR, the development of innovative aerodynamic features are developed in the European project Innwind. The validation of the aerodynamic modelling is largely supported by the largest aerodynamic wind tunnel experiment of the last ten years: **New-MEXICO** experiment.

In June/July 2014 the New Mexico experiment was carried out. In this experiment pressure distributions and the underlying flow field were measured on a 4.5 meter rotor diameter placed in the Large (9.5x9.5 m2) Low Speed Facility of the German Dutch Wind Tunnel DNW. The experiment was very successful and led to the explanation of several puzzling phenomena which were found in the former Mexico experiment. A detailed analysis of New Mexico data will be carried out in the third phase of IEA Task 29 Mexnext (Mexnext-III) which was approved by the IEA Executive Committee and which will run from January 1st 2015 until December 31st 2018. The research group is collaborating with EERA. This third phase is a follow-up of Mexnext-II which was finished by the end of 2014. In Mexnext-II the New Mexico experiment was prepared but in addition aerodynamic model validations were carried out on basis of other detailed aerodynamic measurements (e.g. measurements on the NREL Phase VI (NASA-AMES) turbine at high induction factors which until now remained unexplored).

Aerodynamics of large (10MW+) wind turbines is investigated in the EU FP7 project AVATAR. Comparisons of model results from a large number of participants at conditions representative for such large turbines showed a surprisingly large scatter and it was found that current state of the art boundary layer transition models do not always perform well for 10MW+ scale!

In order to improve aerodynamic models in this aspect, air foil measurements were carried out in the pressurized tunnel of DNW-HDG where the pressurization leads to Reynolds numbers which are representative for large wind turbines but which on normal wind tunnel scale cannot be reached under atmospheric circumstances. Pressure distributions and drag data from a wake rig up to a Reynolds number of 15 M will be brought into a blind test which will be announced in spring 2015 and which is open to third parties too. The outcome of the blind test will be presented on a side event of EWEA 2015 in November 2015 in Paris. The blind test will also include pressure distributions and flow field data taken in the wind tunnel from National Technical University of Athens on an air foil with vortex generators and measurements on an air foil with dynamic trailing edge flaps taken in the wind tunnel from TUDelft.

In November 2013 a consortium of 13 partners, including two main industries (LM Wind Power and GE Wind Energy) started the EU FP7 project AVATAR. The consortium is coordinated by ECN. The main aim of the project is to develop the most advanced aerodynamic models for the next generation of large wind turbines, up to 20MW. In the first half of 2014 the industrial partners defined and reported the specifications for a 10 MW wind turbine which will be used by the consortium as a starting point to design a reference turbine. This reference turbine will be based on a new design philosophy which is aerodynamically very challenging and which potentially can reduce the cost of energy and loads.

A website has been created www.eera-avatar.eu.

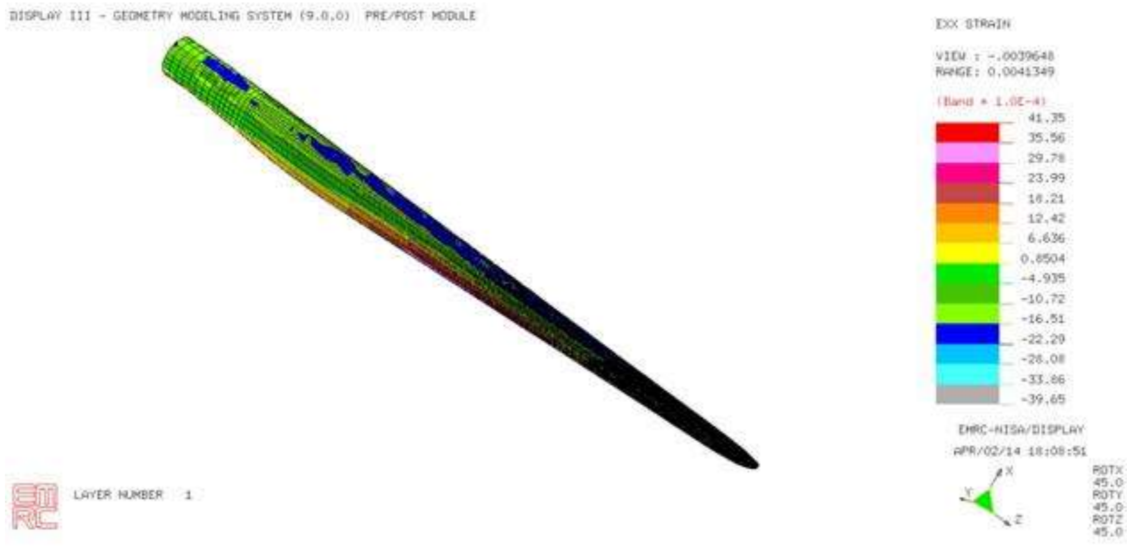

Figure: Blade design of the AVATAR reference wind turbine

NTUA: A hybrid CFD-Vortex simulation tool HoPFlow has been concluded and validated. HoPFlow is targeted to provide insight in the turbulent wind – wind turbine interaction by including the turbulent inflow in the form of vortex particles. Similarly it is expected to model loading in half wake conditions.

CRES: Advanced CFD models for very high Reynolds numbers and compressible flow are being developed in the context of the AVATAR project. Initial results have shown that there are still discrepancies between computational methods in these conditions that need to be addressed.

At USTUTT-IAG CFD-based noise prediction models are being enhanced with regard to better consideration of turbulence anisotropy effects and weak flow separation from the blade. The enhanced methods are applied to verify aeroacoustics air foil designs performed at the institute, to calculate the aeroacoustics characteristics of rotor blades and to design active noise reduction concepts.

Metuwind completed a joint project with Aerotim, Ltd., which is an SME that has specialization on rotary wing aerodynamics. The project was funded by The Scientific and Technological Research Council of Turkey (TUBITAK). The project involved the development of a very fast GPU-based free wake solver, which is capable of producing wake and load predictions similar to the CPU-based code and in a substantially reduced amount of time. Also, Metuwind has an on-going project related to wind turbine flow induced noise predictions. This is a research project funded by The Scientific and Technological Research Council of Turkey (TUBITAK). The noise calculation of the wind turbines is a complex problem and needs cost effective numerical solutions. This project aims to develop software based on 2D and 3D Navier Stokes solvers for noise calculations.

DTU: MIRAS is a computational model for predicting the aerodynamic behaviour of wind turbine rotors. The core solver is based on an unsteady free wake three-dimensional panel method which avoids restrictive computational costs, making its use more attractive during the design stage of a wind turbine. The design of a wind turbine requires access to fast and accurate computing tools for predicting the aerodynamic behaviour of rotor blades. Today, design of wind turbines is carried out employing the so-called BEM (Blade-Element Momentum) technique, which is a simplified approach that is extensively used by the industry. The BEM technique is based on one-dimensional momentum theory and requires a considerable amount of engineering add-ons to take into account complex flow conditions, such as yaw or wind shear. MIRAS is based on a viscous-inviscid interactive approach, which makes it possible to take into account such conditions as an intrinsic part of the flow solver, hence reducing the amount of engineering approximations during the design phase of a wind turbine. Due to the increase in computer capacity, MIRAS has the potential to become an alternative between the fast, but simple, BEM method and heavy, but more accurate, Navier-Stokes solvers. During the last seven years a strong effort has been made at DTU-FLU to develop a wide variety of viscous-inviscid interaction methods. Originally, the work concerned two-dimensional flow solvers for air foil calculations, including steady, unsteady and deep stall simulations. Moreover, in the last three years, the three-dimensional solver MIRAS has been developed, now making possible the simulation of flows around a wind turbine using the panel approach. Opposed to most of the computer tools based on the panel method technique, MIRAS, has been conceived to take into account friction effects inherent to the near wall region, or boundary layer, which plays a crucial role in the aerodynamic behaviour of the rotor blades. This is accomplished using a viscous-inviscid coupling, through the transpiration velocity concept, which is capable of mimicking the effect of the boundary layer into the outer potential flow.

RT3: Wake modelling

EERA vision
Understanding wake formation (near wake), wake breakdown (vortex roll-up and breakdown) and expansion (turbulence creation, interaction with atmospheric turbulence and ground/ wave/complex terrain effects). The wake modelling partly overlaps with the offshore sub-program, the key issue here is wake modelling to accurately describe the inflow conditions at the next rotor. Accurate and detailed wake models are developed, and for integration in wind farm design codes, engineering wake models are developed.

At USTUTT-IAG wakes are simulated in CFD either using the actuator line method, or directly within a turbine simulation where the relevant turbine components are fully meshed. The focus is on the near wake, where interaction of atmospheric turbulence and tip and root vortices take place. To adequately take into account of these interactions, eddy resoling hybrid RANS/LES methods are applied in combination with high order WENO reconstruction schemes.

Metuwind has experimentally investigated loads on two interacting wind turbines in an open-jet wind tunnel facility. The effects of tip injection and Mie vanes applied on an upstream rotor on the loads of a downstream rotor are experimentally investigated.

RT4: Aero-hydro-elastic modelling

EERA vision
A key challenge in the development of accurate design tools for large wind turbines is to understand and model aero-elastic phenomena. The integrated design tools are extended by adding the effects of hydrodynamic loading of the turbine and adding low-frequency cyclic motion. Damping mechanisms are investigated. The models are able to model the integral

wind turbine, including aero-elastics, control, foundation (also floating), etc. so that the cost of energy can be estimated. The activities are coordinated with the sub-program offshore wind energy.

NTUA: A non-linear wave modeling has been developed and added to the hydroGAST coupled tool. The tool has been validated against experimental data for free floating surface piercing platforms. Currently verification for off-shore wind turbines is carried out.

At USTUTT-IAG a CFD-based aeroelastic code has been improved by implementation of a new mesh deformator enabling consideration of arbitrary blade deformations as well as active trailing and leading edge flaps. This code is used to predict rotor load spectra under atmospheric inflow conditions in flat and complex terrain. Further, the tool is applied in different projects to verify BEM based aeroelastic blade analyses for onshore and (floating) offshore wind turbines.

Metuwind completed a study on the comparisons of quasi-static and transient aeroelastic analysis. Applicability of the quasi-steady aeroelastic analysis of wind turbine blade is investigated in terms of how accurately the quasi-steady aeroelastic analysis predicts the deformed state of the blade at certain azimuthal positions. For this purpose, comparative study of transient and quasi-steady aeroelastic analysis of a composite wind turbine blade in steady wind conditions is conducted.

RT5: Development and evaluation of innovative concepts and features

EERA vision
New air foils, new planforms, optimization routines including costs, downwind, two bladed, high-speed rotors, vertical axis, variable geometries, etc. This RT is carried out in coordination with the sub-program on offshore wind energy.

Innovative features are investigated in the European Innwind and AVATAR projects – where dedicated efforts are made to develop cost-effective large slender blades.

The CFD-based process chain available at USTUTT-IAG has been used to examine the characteristics of different novel passive and active load alleviation concepts and to assess their effectiveness. Besides active trailing-edge flaps, a (passive) adaptive camber concept and a further passive concept based on elastic connection of the rotor head to the nacelle are studied.

NTUA: Within the INNWIND project variable chord concepts are currently evaluated by means of wind tunnel experiments. The data will become available mid-2015.

CRES: In the framework of the innovative rotor aerodynamic designs of INNWIND.EU CRES has proposed and investigated the concept of Low Induction Rotors (LIRs). The concept shifts the design logic for rotor optimization from power coefficient maximization to power capture maximization under constrained maximum blade loading. The result is a larger rotor operating with lower maximum thrust but at the same time with a better energy yield. Due to its reduced thrust a LIR is highly suitable for operating in large offshore clusters, reducing wake losses. In parallel, CRES is developing within INNWIND.EU a new family of low design lift profiles which maximize the benefits of LIR operation. Thanks to the increased Reynolds numbers on multi-

MW rotors these profiles experience high performance at relatively low lift (Cl = 0.7-0.9) even at profile thickness that exceed 20%. In the framework of the INNWIND.EU project a new concept of multi-rotor wind turbines for very large sizes was evaluated (concept proposed by Univ. Strathclyde, structural and dynamic evaluation performed by CRES and NTUA).

Metuwind has an on-going nationally funded research project funded by The Scientific and Technological Research Council of Turkey (TUBITAK). This project experimentally investigates the effects of tip injection on loads and wake structure of a model wind turbine. The method proposed and investigated in the project has not been applied before to HAWTs. Determination of the effects of tip injection on rotor loads and wakes is the main contribution of this project to the literature.

2.2 Reporting on Milestones

EERA Aerodynamic workshops will be organised twice a year

Year	Meeting
2014	*last Thursday and Friday of September 2014 in connection to EERA JPWind Conference (Amsterdam)*
2015	*the Friday after EWEA 2015*
2015	*last Thursday and Friday of September 2015 in connection to EERA JPWind Conference (Amsterdam)*
2016	*the Friday after EWEA 2016*
2016	*last Thursday and Friday of September 2016 in connection to EERA JPWind Conference (Amsterdam)*

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	Explantion of symbols in Tables in the report
√	Goal has been reached (and maybe even exceeded).
	Ongoing activity / prior to deadline
X	Goal has not been reached

Ad hoc workshops are organised in relation to

- Calls in Horizon2020
- IEA Annex Mexnext workshops

Mile-stone	Objective	Date	Partners involved	Person months	Comments / Project	Status – end 2014
2.1	**Inflow field experiments** The EERA participants make an inventory of - inflow field experiments - inflow field models	12-2014	All	-	Own funding	In IEA Mexnext a report was made
2.1d	Initiatives to better characterise and model inflow field conditions - Sharing analysis on existing datasets with emphasis on large heights	06-2015			Own funding	√
2.2	**AVATAR** **Reference Wind Turbine and Reference Blade** Dissemination of AVATAR RWT to EERA sub programme Aerodynamics.	10-2014	ECN ForWind IWES	10 13	AVATAR	√
2.3	**INNWIND** **MEXICO experiment** Dissemination of preliminary results of the Mexico experiment in the DNW wind tunnel	12-2014	ECN	12	INNWIND	√
2.4	Report on definition of Aerodynamics	12-	DTU ECN	1	Own funding	√

	Experiment	2013				
2.5	During 2011/2012, the **IEA Annex Mexnext** ended. Extension of the operation within IEA Annex Mexnext and with collaboration within EERA. IEA/EERA workshop Mexnext	09-2013	All	24	IEA Mexnext	√
2.6	Evaluation of the **AVATAR RWT** and cross-comparison with the **INNWIND.EU RWT**	05-2015	All	24	AVATAR	√
2.7	Definition of a Aerodynamics EERA project on in H2020 in 2015	12-2015	All	2	Own funding	●
2.8	Aero-hydro-elastic modelling EERA Publication on influence of aerodynamic modelling on mechanical loads in wind turbines	12-2015	All	2	Own funding	●

2.3 International collaboration in 2014

The partners in EERA-Aerodynamics are involved a.o. in the European collaborative projects AVATAR, InnWind and ESWIRP and are all active members in the IEA Annex MexNext. Besides basic research activities in the field of aerodynamics and aeroacoustics the partners cooperate with different national and international wind turbine manufacturers.
Several partners are consortium member of the New European Wind Atlas (NEWA) – FP7 ERANET+ Project Proposal.
Several partners are consortium member of the BOWMORE Project. Best practice in the integration of Offshore Wind Modelling and Observations for Resource Evaluation.

INNWIND	
INNWIND.EU	**Participants** DTU, AALBORG UNIVERSITET, CRES, TECHNISCHE UNIVERSITEIT DELFT, NTUA, SINTEF, POLITECNICO DI MILANO, GOTTFRIED WILHELM LEIBNIZ UNIVERSITAET HANNOVER, FORWIND-OL, UNIVERSITY OF PATRAS, UNIVERSITY OF SHEFFIELD, UNIVERSITY OF STRATHCLYDE, UNIVERSITAET, WMC, CENER, UNIVERSITY OF BRISTOL UBRISTOL, DHI, RAMBOLL, Siemens Wind Power
www.innwind.eu	**General Description** The overall objectives of the INNWIND.EU project are the high performance innovative design of a beyond-state-of-the-art 10-20MW offshore wind turbine and hardware demonstrators of some of the critical components. These ambitious primary objectives lead to a set of secondary objectives, which are the specific innovations, new concepts, new technologies and proof of concepts at the sub system and turbine level.

Contribution in Aerodynamic R&D

A specific work package focuses on innovative solutions in aerodynamics. The design of a new family of air foils is addressed, including compressibility effects and thick flat back solutions. These studies should be coupled together with new innovative rotor concepts to reduce the cost of energy of future 10-20MW offshore turbines. In addition, a specific task is dedicated to active and passive technologies for flow control.

Within INNWIND, POLIMI has collaborated with USTUTT and CENER on the development and testing of a scaled floating offshore wind turbine, successfully tested in the wave tank in Nantes.

AVATAR	
	Participants ECN, CENER, CRES, DTU Wind, ForWind, Fraunhofer IWES, GE Global Research, GE Wind Power, LM Wind Power, NTUA, POLIMI, TU Delft, University of Liverpool, University Stuttgart
www.eera.avatar.eu	**General Description** AVATAR is a project initiated by the European Energy Research Alliance (EERA), carried out under the FP7 program of the European Union. Its main goal is the development and validation of advanced aerodynamic models, to be used in integral design codes for the next generation of large scale wind turbines (up to 20MW).
Contribution in Aerodynamic R&D Its main goal is the development and validation of advanced aerodynamic models, to be used in integral design codes for the next generation of large scale wind turbines (up to 20MW).	

IEA Mexnext	
	Participants CWEA , DTU Wind Energy,Vestas, University of Stuttgart (IAG), University of Applied Sciences, Kiel, Forwind and Fraunhofer IWES, WindNovationTechnion, Mie University, KIER, Kari, ECN, TUDelft, Suzlon Blade Technology, University of Twente, IFE/NTNU, CENER, INTA; KTH/HGO, NREL
http://www.mexnext.org/	**General Description** The objective of IEA Wind Task MEXNEX(T) is a thorough investigation of various aerodynamic measurements. In Phase I the attention is focussed on the measurements which have been carried out in the EU sponsored Mexico project where Phase II investigates a wide variety of (Field and wind tunnel) experiments, including a 'New Mexico' experiment. Special attention is paid to yawed flow, instationary aerodynamics, 3D effects, tip effects, non-uniformity of flow between the blades, near wake aerodynamics, turbulent wake, standstill, tunnel effects etc. These effects are analysed by means of different categories of models (CFD, free wake methods, engineering methods etc.). As such the Task provided insight on the accuracy of different types of models and (descriptions for) improved wind turbine models.
Contribution in Aerodynamic R&D Unique database for code comparison and evaluation is set up supporting code development as well as giving the opportunity to have comparison data for one turbine regarding pressure distributions, loads and flow field. This kind of data is not available for other turbines and makes it possible to make a wide spread evaluation of different characteristics and their interaction.	

EERA DTOC	

	Participants DTU Wind Energy, EWEA, Fraunhofer, CENER, ECN, SINTEF, ForWind OL, CRES, CIEMAT, UPORTO, University of Strathclyde, IU, CLS, Statkraft, Iberdrola, Statoil, Overspeed, BARD, HEXICON, Carbon Trust, EON, Sweden, RES
www.eera-dtoc.eu/	**General Description** The European Energy Research Alliance (EERA) together with some high-impact industry partners proposes an integrated and validated design tool combining the state-of-the-art wake, yield and electrical models currently available within the existing consortium, as a plug-in architecture with possibility for third party models.
Contribution in Aerodynamic R&D Develop an integrated tool for the design of wind farm by bringing together existing models from partners, which open interfaces between them and a shell around the tools. Fine-tune the wake models using dedicated measurements	

Cluster Design	
	Participants 3E , ECN, ForWind Old, RWEI, Senvion, Imperial College
www.cluster-design.eu/	**General Description** The consortium will develop a toolbox for integrated wind farm cluster design that shall later be applied by offshore wind turbine manufacturers and wind energy project developers. The toolbox is to consist of interfaces linking the various models and databases.
	Contribution in Aerodynamic R&D Wind farm aerodynamic modelling and benchmarking for Alfa Ventus wind farm

2.4 National projects

NTUA

REWIND: The project aims at developing best practice procedures for repairing wind turbine blades (2013-2015). With respect to EERA objectives, within REWIND wind tunnel measurements have been performed on wind models with/without VGs and with/without stall strips. The data with VGs will be part of the Blind Test carried within AVATAR

POSEIDON: The project aims at developing a multi-purpose floating platform for wind and wave energy exploitation (2013-2015). With respect to EERA objectives, POSEIDON has concluded:

- full hydro-aero-elastic modeling of off-shore wind-wave systems mounted on semi-submersible floaters with TLPs.
- Experiments on a scaled system in NTUA's wave tank facility. The data will become available by September 2015

WIND_FSI: The project aims at developing aeroelastic modeling tools based on CFD. With respect to EERA objectives, WIND_FSI has concluded:

- FSI tools have been concluded and they are currently tested against experimental data
- An aeroelastic wind tunnel test is in progress at NTUA's wind tunnel facility. The data will become available by end 2015

CRES

AVRA: Development of a National Exploitation Plan for the Wind Potential in the Aegean Sea
Participants: Centre of Renewable Energy Sources, Hellenic Centre for Marine Research, National Technical University of Athens, ELICA, ENTEKA, EXERGIA, C. ROKAS, TERNA, JASPER
This project aims at providing the necessary knowledge basis for exploiting the wind resource in the Aegean Sea. The consortium includes research institutes and companies that are active in the wind energy sector in Greece. The project objectives include: the characterization of the wind potential in the Aegean Sea, technical analysis of the necessary electrical connections, development of design tools for offshore application, environmental and techno-economic analysis of offshore wind applications. Within the part of software development, a coupled hydro-aero-elastic simulation tool has been developed for offshore wind turbines. Using this tool, the effect of the wave induced motions of the system on the wind turbine performance & the system structure is investigated in the cases of a spar and semi-submersible floaters.

USTUTT-IAG participates the German collaborative projects AssiSt (CFD simulations in complex terrain), DFG PAK 780 (numerical studies on the adaptive camber load control concept), INFLOW-Noise (numerical and experimental studies on inflow and trailing-edge noise), KonTest (assessment of complex terrain sites for research wind turbines), LARS (numerical studies on a novel passive load alleviation concept), LiDAR Complex (time-resolved flow simulations of wind turbines in complex terrain), OWEA Loads (simulation of interacting offshore wind turbines) and heads the ActiQuiet project (active noise reduction).

METUWIND

Experimental Investigation Of Active Tip Vortex Control Using Tip Injection In Horizontal Axis Wind Turbines, METU Center For Wind Energy, Principal Investigator: Assoc. Prof. Dr. Oğuz UZOL

Development of a Navier-Stokes Flow Solver on Topografic Unstructured Grids For Micro Site Selection of Wind Turbines, METU Center For Wind Energy, Principal Investigator: Prof. Dr. İsmail Hakkı Tuncer

Development Of 2-Dimensional And 3-Dimensional, High-Resolution Navier-Stokes Solvers For Flow Induced Wind Turbine Noise Predictions And Their Application, METU Center For Wind Energy, Principal Investigator: Prof. Dr. Yusuf Özyörük.

DTU

COMWIND

The project concerns the mutual interaction between wind turbine aerodynamics, turbine wakes, terrain affected flow and atmospheric turbulence, which is not accounted for in state of the art modelling. This will be achieved by combining and exploring the knowledge and methodologies of leading national and international research groups within the fields of aerodynamics, computational fluid mechanics, atmospheric physics and wind energy. The project is partitioned into five clearly defined tasks: Rotor aerodynamics, wakes and clusters, wind farms, siting in complex terrain and atmospheric boundary layers. In all of the tasks the focus is on creating the methodologies to handle the mutual interaction between the ambient turbulence and the wind turbine.

The physical outcome of the project is a set of reliable and verified simulation tools, capable of bridging the multi-scale flow phenomena connected with operating wind turbines in the atmospheric boundary layer, and the application of these in the further development of wind energy. The overall aim of the activity is to manifest Denmark as the world leading player within wind turbine aerodynamics and atmospheric turbulence, both with respect to research, technology and education

2.5 Publications in 2014

Forwind IWES

- Herraez, B. Stoevesand, J. Peinke - "Insight into Rotational Effects on a Wind Turbine Blade Using Navier–Stokes Computations"

NTUA

- M Manolesos, SG Voutsinas Study of a stall cell using stereo particle image velocimetry, Physiscs of Fluids, 26, 2014
- DI Manolas, VA Riziotis, SG Voutsinas, Assessing the Importance of Geometric Nonlinear Effects in the Prediction of Wind Turbine Blade Loads, 2014, ASME, J. Comput. Nonlinear Dynam.
- Zou, F., Riziotis, V.A., Voutsinas, S.G, Wang, J., (2014), ”Analysis of vortex and stall induced vibrations at standstill conditions using a free wake aerodynamic code,” Wind Energy
- L Shi, VA Riziotis, SG Voutsinas (2014) «Aerodynamic analysis of vertical axis wind turbines using a vortex type free wake model” EWEA 2014, Barcelona

- M Manolesos, G Papadakis, SG Voutsinas, Assessment of the CFD capabilities to predict aerodynamic flows in presence of VG arrays, TORQUE 2014, Journal of Physics: Conference Series 524 (2014)
- Prospathopoulos J, Papadakis G, Sieros G, Voutsinas S, Chaviaropoulos T, Diakakis K, Assessment of the aerodynamic characteristics of thick air foils in high Reynolds and moderate Ma numbers using CFD modelingTORQUE 2014, Journal of Physics: Conference Series 524 (2014)
- Chassapoyannis P, Prospathopoulos J, Voutsinas S, Chaviaropoulos T, Analysis of the aerodynamic performance of the multi-rotor concept, TORQUE 2014, Journal of Physics: Conference Series 524 (2014)
- G Papadakis, SG Voutsinas, In view of accelerating CFD computations through coupling with vortex particle approximations, TORQUE 2014, Journal of Physics: Conference Series 524 (2014)
- M Manolesos, G Papadakis, SG Voutsinas, Assessment of the CFD capabilities to predict aerodynamic flows in presence of VG arrays, EWEA'2014 Journal of Physics: Conference Series 524 (2014)
- T.P. Mazarakos, D.I. Manolas, T. Grapsas, S.A. Mavrakos, V.A. Riziotis & S.G. Voutsinas
- Conceptual design and advanced hydro-aero-elastic modeling of a TLP concept for floating wind turbine applications , 2014, 1st International Conference on Renewable Energies Offshore RENEW2014 24 - 26 November 2014, Lisbon, Portugal

CRES

- P. Chasapogiannis, J. M. Prospathopoulos, S. G. Voutsinas, and T. K. Chaviaropoulos, "Analysis of the aerodynamic performance of the multi-rotor concept," in *Journal of Physics: Conference Series*, 2014, vol. 524, p. 012084.
- P. K. Chaviaropoulos and G. Sieros, "Design of low induction rotors for use in large offshore wind farms," in *EWEA 2014*, 2014.
- J. M. Prospathopoulos, G. Sieros, and P. K. Chaviaropoulos, "Numerical Estimation of Power Deficit and Efficiency in Large Offshore Wind Farms," in *EWEA 2014*, 2014.
- J. M. Prospathopoulos, G. Papadakis, G. Sieros, S. G. Voutsinas, T. K. Chaviaropoulos, and K. Diakakis, "Assessment of the aerodynamic characteristics of thick air foils in high Reynolds and moderate Ma numbers using CFD modeling," in *Journal of Physics: Conference Series*, 2014, vol. 524, p. 012015.

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2.6 Contact Point for the sub-programme on Aerodynamics

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Wind Conditions

A sub-programme within the:
Joint Research Programme on Wind Energy

Yearly reporting - 2014

3. Sub-programme on Wind Conditions

The Sub Programme wind conditions is not directly involved in the IRPWind Core projects, however, is indirectly involved in the activities of the core projects i.e. Wind Integration. Overall, the Sub Programme activities have been going on along the active FP7 projects and

3.1 Report on Research Themes

There are five Research Themes (RT) in the SP Wind Conditions

RT1: Applicability of the models of wind conditions in the atmospheric boundary layer.
RT2: Establish an experimental basis for uncertainty assessment and evaluation of model uncertainties. (Experimental Matrix)
RT3: Numerical weather models for short- and medium-term forecasting
RT4: Future climate: resource trends, variability and predictability.
RT5: Innovative measurement techniques.

SP Wind Conditions workshop

The workshop was held as a parallel session at the first Annual Workshop for IRP Wind Energy in Amsterdam September 26th

The attendance was there was a large attendance and the SP coordinator Hans E. Jørgensen (DTU Wind Energy) introduced and explained the basis for:
- the roadmap for SP introducing Objective and Research priorities and
- The concept of the proposal of the New European Wind Atlas II submitted within the ERANET + Scheme.

He explained the process and pointed out that the important point is that if the project will be funded, then it might be the possibility for other group in other institution of joining the experiments with in-kind funding.

Anna Maria Sempreviva (DTU Wind Energy) introduced the concept of the upcoming Benchmarking exercise for meso-scale modelling approaches for the estimate of site wind conditions. She introduced the scope of Work, Inputs and Deliverables. It will be co-organized by DTU Wind Energy and EWEA. The call will be probably issued at the end of October.
The benchmarking exercise is a milestone in the medium- long- term Strategic Plan and in the Roadmap for European Energy Research Alliance (EERA) Joint Programme (JP) Wind Energy, Sub Programme (SP) Wind Conditions. In this frame, the aim of this exercise is evaluating the capabilities of mesoscale models used in wind energy to the estimate of site wind conditions, with a tailored benchmarking.
The objectives are:
• To highlight common issues on mesoscale modelling of wind conditions on sites with different characteristics i.e. Offshore, Coastal, Onshore, providing a common understanding on differences; and
• To identify gaps and strengths of models and understand the root conditions for further evaluating uncertainties.

Then there were three scientific invited presentations:
Kristin Guldbrandsen, who is the coordinator of Norcowe (NO), presented the highlight of the project.
Xiaoli Larsen from DTU Wind Energy presented a new method to estimate extreme winds using a spectral analysis of wind speed time series from both mesoscale models and observations.
Hans Jørgensen from DTU Wind Energy, presented highlights on the Wind Scanner infrastructure.

In the second part of the meeting has been interactive. Hans Jørgensen and Anna Maria Sempreviva organised two working groups discussing what are the most important gaps and challenges in the uncertainty for the AEP estimate. Overall, we can say that there was an overall agreement on the flow modelling and the most important issue are reported in the following table:

GROUP I	GROUP II
Flow modelling	Coupling of scales
Measurements	Complexity of the terrain
Long-term estimate	Thermal stability
Losses (Wake and model coupling	Input conditions (initial and boundary)
Surface description	

<u>NEW PROJECTS: The New European Wind Atlas (NEWA)</u>

NEWA includes the activity within RT1 and RT2. During the past year, the activity has focused on - writing the application in the framework of the ERANET + programme; on the contract negotiation phase after the approval of the project. The project has been approved and it has been a large effort to coordinate the different timing in the countries included in the partnership due to different National legislations. Contact Point: Jakob Mann and Hans Jørgensen.

<u>BENCHMARKING EXERCISE</u>

Concerning RT1, a benchmarking exercise has been launched, co-organized with EWEA This benchmarking exercise is a milestone in the medium- long- term Strategic Plan and in the Roadmap for European Energy Research Alliance (EERA) Joint Programme (JP) Wind Energy, Sub Programme (SP) Wind Conditions. http://www.ewea.org/events/workshops/resource-assessment-2015/mesoscale-benchmarking-exercise/
One of the specific objectives of the SP is “ To characterize the applicability of the models of wind conditions in the atmospheric boundary layer”
In this frame, the aim of this exercise is evaluating the capabilities of mesoscale models used in wind energy to the estimate of site wind conditions, with a tailored benchmarking.
There are two objectives:
• To highlight common issues on mesoscale modelling of wind conditions on sites with different characteristics i.e. Offshore, Coastal, Onshore, providing a common understanding on differences; and

• To identify gaps and strengths of models and understand the root conditions for further evaluating uncertainties.
The main question to be answered here is: what is the range of values of model outputs when simulating a time series at the same site? Contact point Anna Maria Sempreviva and Hans Jørgensen.

WIND SCANNER:WindScanner experiment: Laser show at Rödeserberg

A unique measurement campaign with a multi lidar system consisting of six long-range WindScanners coordinated by the master computer took place at Rödeserberg in vicinity of Kassel, Germany from the end of June until mid-August 2014. The results of the WindScanner campaign at Rödeserberg imply that the measurement system based on multiple long-range WindScanners can potentially become a valuable tool for atmospheric and wind energy research. The three main objectives of the campaign were to: Apply scanning lidar installation procedures Demonstrate the synchronization of multiple lidars over a mobile network and validate the system's wind velocity measurements against the mast in forested complex terrain. The experiment was organised in collaboration between DTU Wind Energy (Denmark), Fraunhofer IWES (Germany. A new prototype was field-tested of new designed test manufactured extended range (300+ m) short-range
WINDSCANNER
Contact point: Nikola Vasiljevic and Torben Mikkelsen, DTU.

EERA DTOC:
Final DTOC1 detailed design was completed
Contact point: Charlotte Bay Hasager and Gregor Giebel, DTU.

3.2 Report on milestones

Mile-stone	Objective	Date	Partners	Person months	Comments /project	Status – end 2014
M1	RT5 Final DTOC1 detailed design complete	April 2014 Month 4	EERA DTOC Consortium		EERA DTOC	Completed
M2	RT1/RT2 Proposal for the ERA net + NEWA	August 2014 Month 8	NEWA Consortium		Application in progress. 8 countries involved	Completed Project started 1st February 2015
M3	SP Wind Conditions meeting in connection to IRPWind General assembly	September 2014 Month 9	ALL			Completed, Minute in the text
M4	RT1 Launch of a call for a benchmark exercise for meso-scale models for wind energy atlases.	September 2014 Month 9	DTU		IRPWIND	Call presented at the meeting.

Mile-stone	Objective	Date	Partners	Person months	Comments /project	Status – end 2014
						Exercise lauched 1st December 2015
M5	RT5/RT2 Prototype field-test of new designed test manufactured extended range (300+ m) short-range WINDSCANNER	October 2014 Month10	INFRA Wind Scanner Consortium		INFRA Wind Scanner	Completed
M6	Validation of DTOC1 design tool	December 2014 Month 12	EERA DTOC Consortium		EERA DTOC	Completed
M7	RT5/RT2 1st Experiment with wind scanner, Kassel (GE)	January 2015 Month 13	INFRA Wind Scanner Consortium		INFRA Wind Scanner	
M8	RT1,RT2 Joint Workshop " EERA SP Wind Conditions and "Results of the benchmark exercise on meso-scale models for wind energy atlases"	February 2015 Month14	DTU all			Workshop postponed in the second year, likely September 2015
M9	RT2/RT3 DTOC 1.0 tools ready	April 2015 Month16	EERA DTOC Consortium		EERA DTOC	On track
M10	RT5/RT2 Innovative WINDSCANNER.eu short and long-range new scanner design and manufacturing plans.	April 2015 Month16	INFRA Wind Scanner Consortium		INFRA Wind Scanner	On track
M11	RT1 Vision2030 and Draft protocol for development of the Model Chain:	June 2015 Month18	ALL			On track
M12	RT1, RT2, RT3,RT4 Vision and draft for a web-based platform for data mining, for the integrated model/ measurements uncertainty analysis.	June 2015 18	ALL			On track

3.3 Contact Point for the sub-programme on Wind Conditions

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Structures & Materials

Yearly reporting for 2014

4. Sub-programme on Structures & Materials

The goals and ambitions of the sub-programme are reported, together with the structure and partners.

Knowledge gaps

The envisioned large deployment of both on- and off-shore wind energy encompassing future wind turbines of 10-20 MW sizes (or even larger) to achieve the target for 50% electricity production from renewable sources, notably wind energy, requires the optimized design of wind turbine structural components. In turn, this implies a full understanding of structural response and increased knowledge of material behaviour in order to develop the appropriate tools for designing such large structures undertaking very high fluctuating loads with increased reliability and reduced maintenance needs, while complying with all constraints of the wind turbine system. This combination of requirements is not encountered in any other structural sector (oil & gas, aeronautics, naval structures, civil works) and certainly presents a challenge for the engineering community.

Since the wind energy sector is rather young and in parallel the sizes of the structures fall well beyond sizes that were tested and used in fatigue load carrying structures up to now, research is required to fill the gaps in the structural engineering area. These include for example the response and strength of components (blade, tower, substructure) that should endure hundreds of millions of fatigue cycles before failure. Realistic sizes of components must be considered, as size effects are not avoided in structural response. The design standards are about to be exceeded mainly due to the non-anticipated size increase (e.g. thick laminates and relevant standards regarding bolts), the use of advanced composite materials (with no established fatigue design models) as well as new design solutions entering the field of application (as damage tolerance design concepts). To adapt them, experiments are needed to support theoretical assumptions.

Further to that, in order to allow the required development for larger sized turbines, verification of the design and the manufacturing cannot be done using full scale structures due to the high cost and the extensive time required to actually perform a single fatigue test for structures of this size. To accelerate development, missing knowledge has to be gained at appropriate structural levels (above coupon sizes used for material characterization).

In parallel, at these scales it would be more effective to incorporate the actual output of the currently used and newly suggested manufacturing methods, including studies on manufacturing tolerances, eventual defects, their effect on the structural response and strength and the probability of their detection. This knowledge is currently missing and therefore, the proper tuning of safety factors is impossible (regardless of increasing or decreasing them). Appropriately testing subcomponents having sizes relevant to the full scale component will enhance the databases describing structural behaviour, paving the way for safety factors optimization to achieve the required reliability level. Probabilistic design tools are required to assess the structural reliability that is really achieved when using certain safety factors.

Work in this area will also serve the development of both structural health monitoring (SHM) as well as repair techniques (especially for blades), which are necessary for the reduction of cost of wind energy notably in the offshore field. Detailed knowledge on damage propagation and damage assessment, that can be achieved through experiments on subcomponents of relevant scales is essential for both SHM and repair techniques. Progress in these subjects will further

allow for a life cycle approach to minimize the cost of energy, putting focus on the total expected costs including initial/manufacturing and operation & maintenance costs.
Finally, currently proposed ideas, for example on higher tip speeds and/or smart control of the blades are explored without addressing the effects on the structure. Higher tip speeds would put stress on the protective coatings of the blade, which do not only serve for improved aerodynamic performance but also actually protect the material from environmental effects which usually result in property aging and degradation endangering the useful life of the huge wind turbine component. Additions for smart control would have to be incorporated in the structure and could therefore affect the structure's reliability, yet research on this area is quite limited.

Key objectives and Research Themes

The overall objective of the subprogramme on Structures and Materials is to align pre-competitive research activities at the European Energy research institutes to lay a scientific foundation for the industrial development of more cost effective wind energy. The research aims to reduce the uncertainty in the design of structural load carrying components, such as the blades, the support structures, the hub and the nacelle mainframe, in order to increase cost efficiency and reliability and allow for optimization, innovations and upscaling of future wind turbines. The specific objectives of the subprogramme are:

- Develop more efficient blade structures (lighter, stronger, stiffer, more sustainable, economical) by improving and validating structural analysis models, developing design methodologies and virtual test beds for blade joints, introducing innovative features and investigating alternative structural solutions.
- Develop structural reliability methods that include uncertainties associated with inherent material and loading variability as well as model, statistical and manufacturing induced uncertainties and allow design of optimized structural components in combination with appropriate operation and maintenance strategies
- Develop new material models and life prediction methods for materials used in the wind turbine structural components that include environmental effects, material and manufacturing imperfections, multiaxial stresses, etc. that strongly influence the property degradation during the lifetime of the components.
- Improve the design process of wind turbines by developing new, improved structural models, concepts and tools for wind turbine components affecting the overall behaviour of the system, such as the tower and the substructure, the hub and the nacelle main frame.
- Develop and evaluate new concepts and features such as blade and steel (tower and substructure) coatings, material state monitoring and predictive maintenance methodologies (for blades, towers and substructures), as well as repair solutions for blades to increase wind turbine availability.

To reach the above objectives the research is structured around a) development of theory and models, b) data from experiments and c) validation. Five long term Research Themes (RTs) are addressed:

- RT1: Efficient blade structures
- RT2: Structural reliability methods
- RT3: New material models and life prediction methods
- RT4: Design process of wind turbine components
- RT5: New concepts and features, material state monitoring for structural components and repair solutions for blades

Each of the above five RTs (RT1-RT5) constitutes a building block necessary for an integrated wind turbine design, required to contribute to improve cost effectiveness of wind energy. Partners within the subgroup cooperate to address challenges faced in each thematic. Strong interaction with other sub-programmes within EERA JP-Wind is also exhibited, especially, with "Offshore wind energy", "Research Infrastructures" and "Aerodynamics and Aeroelastics".

4.1 Report on Research Themes

The partners in JP Wind sub-programme Structures and Materials collaborate in various platforms:

- European projects (InnWind, IRPWIND.EU, etc.)
- International working groups (IEA, IEC, etc.)
- Bi-national projects
- Exchange of researchers and PhD students

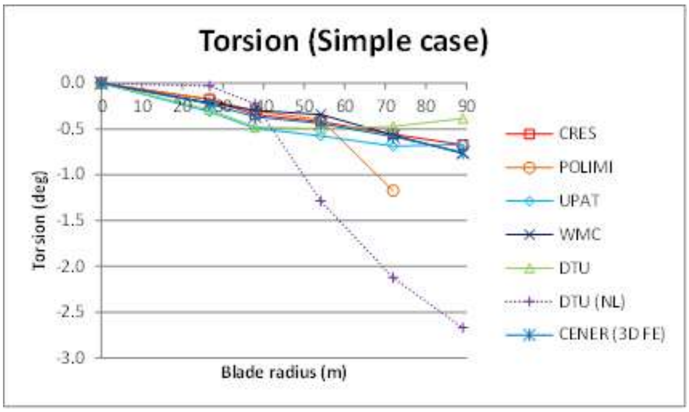
Below description of the developments in the R&D activities on Structures and Materials for wind energy is attempted, following the research lines in the roadmap for the sub-programme Structures and Materials. Then a short overview of the most relevant national and international projects is presented. Finally, a collection of papers, reports and articles produced in the area of Structures and Materials in 2014 is presented.

RT1: Efficient blade structures (RT Leader: CRES)

EERA vision
To develop the necessary tools and investigate on innovative features and structural solutions that will allow the design and manufacturing of efficient blade structures of 120m in terms of weight, strength, stiffness, sustainability and cost. The target is to enable the realistic full scale modeling of blades to accurately estimate the blade performance, predict the structural integrity under static and fatigue loads and ultimately allow for the structural optimization of blades and including the effect of thermo-mechanical loads, manufacturing and both global and local design constraints.

A key component of the wind energy system is the blade, which drives not only the production of energy (from wind to electrical), but also the loading on all other supporting components. Especially for offshore wind the economics of installations have led to requirements of blades of unprecedented sizes for a composite material structure. To comply with system requirements with respect to stiffness, strength, etc. using a lean design in terms of material usage to save weight and cost necessitates more advanced methods in structural analysis. Aspects of progressive failure, fatigue, material defects and manufacturing imperfections should be accounted for in the models, effectively and accurately. In this direction not only the improvement of structural analysis models is needed, but also their validation, so as state of the art methodologies are adapted faster by the industry.

In 2014 available numerical models have been collected and compared against each other in the frame of a benchmark exercise within the InnWind.Eu project. The benchmark study on structural analysis tools of wind turbine blades has been carried out with the participation of six organizations (CRES, CENER, DTU, PoliMi, WMC and University of Patras). Using the 10MW wind turbine blade of DTU (geometry, internal material layout and material properties) as a reference blade, comparisons were performed on all steps involved in a structural blade design. That is estimations on mass and stiffness properties, dynamic response, strength under extreme and cyclic loads, as well as strains, stresses and critical buckling loads were compared. Such an example is shown in the figure below. Variation of estimation of properties between the models were identified and linked with numerical simulation practices employed. Sensitivity of the results against specific assumptions in the model was noted and further experimental validation is required.



Prediction of torsional response to simple load case with various numerical models

In parallel, a review of the testing methodologies for the validation of modelling tools used in wind turbine blade structural analysis was performed in the frame of the IRPWIND programme. CRES, CENER, DTU, Fraunhofer IWES and WMC cooperated in order to prepare for the methodology to be applied for the verification of the numerical approach exercised in the design loop of the blade structure. The development of component testing techniques and the standardization is important to allow verification of design, as well as an unbiased assessment of manufacturing processes and proposed structural solutions. The report prepared within IRPWIND will therefore be an important asset in the process of the detailed evaluation of new proposed structural concepts.

Some of these alternative structural and manufacturing solutions which might allow a higher score on load carrying capacity were investigated this year within the InnWind.Eu project. During 2014 within the research project University of Patras examines the use of an internal space truss structure to replace the shear webs to reduce the overall blade weight, TUDelft investigates the use of grid reinforced panels for the shell structure of the blade to improve strength against buckling, while other solutions are scheduled to be scanned in the next year. In parallel structural solutions to support new aerodynamic concepts as well as aero elastically driven solutions are sought for. In this direction, CRES worked on supporting the newly introduced Low Induction Generator blade, while PoliMi optimized the reference blade for achieving passive load alleviation with Bend Twist Coupling (BTC) and/or Individual Blade pitch Control (IBC) utilizing PoliMi's multi-disciplinary design optimization code.

PoliMi worked also towards the experimental verification of the new structural concepts, such as the bending twisting passive load alleviation within the InnWind.Eu project, through testing of a scaled wind turbine in PoliMi's wind tunnel.

Within the Smart Blades project the Fraunhofer IWES investigated the structural behaviour of rotor blades implementing advanced technologies towards load mitigation. This includes multi-axial stress analysis caused by structural bend twist coupling and asymmetric stacking sequence as well as the determination of the blade performance regarding torsional stiffness and loading. Furthermore component and material tests are performed in the laboratories to validate the numerical simulations.

Fraunhofer IWES is coordinating BladeMaker a funded project from by the German Federal Ministry for Economic Affairs and Energy. It is a joint research project aiming at industrializing the production of wind turbine rotor blades. New materials, production processes and automation systems are being developed by 16 project partners from industry and research organizations. Among the processes are: direct tooling of blade molds, fibre placement processes, new foaming concepts for sandwich cores, handling and bonding of blade components as well as grinding of the blade surface. The production of the 40 m long BladeMaker blade will be demonstrated for a 20 m long segment in the BladeMaker demo centre which is equipped with a flexible, gantry-based rotor blade machine tool, blade molds, mixing units, handling jigs and a fabric cutter.

RT2: Structural reliability methods (RT Leader: AAU/DTU)

EERA vision
The development and validation of models for probabilistic assessment and reliability estimation of wind turbine structural components. These models are required for obtaining efficient wind turbines by designing the structural components at an optimal balance between material cost, maintenance cost and risk of failure.

Cost efficiency optimization of the wind turbine system requires knowledge of reliability of the individual components operating in unison under highly variable loading environment and requiring minimum maintenance for a period of 20 to 30 years. The requirement on minimum weight for the design and installation of the wind turbine components along with the multiparametric analysis required at all stages and connection points certainly present a challenge.

At the end of 2013 participants of the subprogramme (University of Aalborg, DTU, WMC, CRES, CENER) issued a white paper reviewing the state of the art for the probabilistic design of wind turbine blades and pinpointing near future research needs. Relevant to the improvement and validation of stochastic methodologies for the reliability assessment of strength and stability of wind turbine blades activities are included in IRPWIND. The kick-off of the IRPWIND programme within 2014 provides also a boost for activities focusing on the development of probabilistic methods for the reliability assessment of support structures. Specific actions to serve the needs of this long term research subject include collection of required input, development and/or improvement of models where necessary, assessment and validation of models for blades, but also support structures. Within IRPWIND CRES, DTU and AAU have started working on probabilistic aspects relevant to blade, while AAU works also on aspects relevant to the support structures.

At maturity, the advanced and improved methods are envisaged to provide part of the required input for the development of maintenance strategies.

RT3: New material models and life prediction methods (RT Leader: WMC)

EERA vision
A key challenge in the development of effective design tools as that for efficient blade structures in section **Error! Reference source not found.** is to understand and accurately model he material behavior of wind turbine structural components under the influence of extreme environmental conditions for both currently used materials and newly (or future) developed ones, and hence evaluate the effect of the degradation mechanisms including corrosion. Metallic and composite materials are addressed. For metals material models including extreme conditions (marine environment) are envisaged. These models should be representative of the different marine conditions (splash, tidal and submerged) and reflect the effect on the mechanical properties of the metallic materials. For composites, material models improved to

account for thick laminates, layer based fatigue models, micromechanical modelling, ageing, marine environment influence & extreme conditions, etc.

Work on PrePreg miniproject has continued within 2014. The project supported by national funding (own funding) from the participating partners relates to the mechanical characterization of pre-impregnated carbon/epoxy material including investigations on environmental effects. CENER provided the raw pre-preg material, which was close to end expiry, WMC and CENER prepared coupons, which were partly mechanically tested, respectively by WMC and CENER, while the rest of the laminate batch was send to CTC. CTC applied environmental aging on the specimens: in laboratory simulating tidal and/or splash zones, UV radiation with and without water spraying and outside weather conditions for 14 months. Mechanical tests on these specimens undergoing environmental aging are planned next in order to identify the environmental effect on the material properties.
The kick-off of IRPWIND commenced activities related to the review of available material databases and material models for blades and support structures. The result of this review will lead to the identification of needs for further testing, specifically designed to fill in the gaps of the databases, which are needed for the verification of the material models.
A workshop on "Metals in Wind Turbines - Challenges & Ideas" was performed at DTU in November 2014. More than 30 researchers representing more than 15 research groups from 9 countries participated and discussed thematics relevant to metallic materials in wind turbines. 12 presentations of the specialized capacities and expertise of the EERA partners in the field revealed the complementarity of the groups and opportunities for collaboration. Stimulated by the workshop a joint activity comprising a round robin test on white etched areas – cracks led by Aachen University with the contribution of DTU, BERA – Laborelec, CTC and TUDelft among others started early 2015.
TECNALIA has studied the behaviour of nude materials and anti-corrosion coatings in lab and outdoor conditions. A comparison of the ageing in real environment in different exposition sites is ongoing. Remote corrosion monitoring at lab-scale of metallic materials in immersion and splash conditions have been done.

RT4: Design process of wind turbine components (RT Leader: ForWind)

EERA vision
Aim is to build and improve the required tools and methodologies that will facilitate the design of effective and lightweight wind turbine structural components, such as the support structure, the nacelle main frame and the hub, in order to develop a more efficient wind energy system. For this subject is strongly linked to sub-programme “Offshore wind Energy” for issues regarding sub-structures, foundations and floating platforms (including its mooring and anchoring systems) relevant for offshore wind turbines.

Research efforts are split in following activities:

- Development of design methodologies for joints (bolted, welds, grouted) for towers
- Development and improvement of models for the structural design of substructures/foundations for on- and off-shore wind turbines and floating platforms
- Development of models for structural design of WT components (tower, gearbox case, nacelle, pitch bearing)

Within 2014 the kick-off of IRPWIND commenced activities relevant to the structural analysis of wind turbine support structures. Specifically the work within IRPWIND foresees the validation of design of grouted joints and improvement of knowledge of soil-structure interaction through experiments. Planning of large-scale static tension pile tests in the new "Test Center for Support Structures" in IWES-Hannover has started by ForWind-Hannover. The tests are intended for the evaluation of the maximum static bearing capacity of mainly axial loaded piles and are scheduled for this year 2015.

Regarding the research work associated to the mooring systems for Floating Offshore Wind Turbines, efforts have been made within FibreTaut project for the verification of the feasibility of the use of fibre ropes in the mooring lines. CTC has been in charge of the scientific and technical development of the FibreTaut project, which was supported by the EU Project MARINET.

RT5: New concepts and features, material state monitoring for structural components and repair solutions for blades (RT Leader: IWES)

EERA vision
To increase wind turbine availability and reduce the cost of wind energy production new concepts should be investigated in parallel with health monitoring methodologies for wind turbine structural components and repair solutions for blades. Improved coatings for blades to face long term protection and aerodynamic challenges, contributing to the realization of energy efficient offshore wind turbines. These include coatings possessing improved resistance to wear, erosion, salt, icing and fouling. Similar for towers and substructures coatings with verified long term protective properties so as to reduce corrosion, increase bio-fouling resistance both in the subsea and splash zone environment. Methods of corrective/mitigation actions to counteract the effect of degradation mechanism are required. Adapted and extended methodologies for structural health monitoring (SHM) in parallel to the development of sensors for monitoring material condition for arriving at an effective SHM system improving operation and maintenance strategies ultimately leading to predictive maintenance methodologies of all components of the wind turbine. Complementing the above validated repair methodologies for wind turbine blades will enable effective on-site repairs for the remaining blade’s operational lifetime, but also reduce blade discarding upon the identification of defects during regular production quality controls.

Activities within 2014 included the kick-off of IRPWIND, where actions relevant to the structural health monitoring of wind turbine blades are foreseen. In this first year IWES performed signal analysis processing of the Acoustic Emission data that were available at IWES (from other projects). Initially, the target is to specify the appropriate parameters which will allow in the future the identification of adhesive damage initiation and propagation in bonded adhesive joints. The ultimate target of IWES work is to manage a safe pause of big test components in case of either small damage incidents and/or when something severe is starting.

In parallel, improving operation and maintenance through enhancing available and/or developing new SHM methods is a topic were a lot of sub-programme partners were active within 2014. The EC co-funded project Marewind, national projects running in Spain and Belgium and publication of partners (CRES, CNR) contribute to this direction.

Relevant to repair of blades CRES is involved in the Greek funded project REWIND, were procedures for validation of repair of wind turbine blade are developed.

Fraunhofer IWES has been participating in Blade Tester project investigating the effect of defect of several manufacturing flaws on the structural performance of structural adhesive joints. The tested sub-components were manufactured in house and they were investigated with Non Destructive Inspection (Thermography, Ultrasonics) and Structural Health Monitoring (Acoustic Emission) methods during manufacturing and testing phase respectively.

4.2 Report on Milestones

The list of milestones below was included in the description of work for the Sub-programme on Structures and Materials (July 2014). This list shall be understood as indicative only. It is updated in continued dialogue with the SP partners and adjusted according to success with starting new both national and EC funded projects. Alignment with IRPWIND and InnWind.Eu is partly covered as well as few national research projects. In the future, the table will be aligned with both national and EC projects.

Mile-stone	Objective	Date	Partners	Person months	Comments/ project	Status – end 2014
M1	RT1: Review of wind turbine blade structural design and design of blade joints; including review of design model verification (Report)	*Jul 2014*	CRES, WMC, CENER, DTU, IWES BERA (UGent)	30	Started: **own funding**, Part done within **InnWind.Eu**, ongoing under **IRPWIND**	**DONE** InnWind.Eu D2.2.1 IRPWIND D7.1.1
M2	RT1: Platform for validation of structural analysis models of wind turbine blades (Input data for numerical analysis, including geometry, lamination lay-out, material properties, loads, etc. to perform structural analysis)	*Jul 2014*	CRES, WMC DTU, IWES, CENER, PoliMi	20	Started: **own funding**, ongoing within **InnWind.Eu**, Some partners **own funding**	**DONE** InnWind.Eu D2.2.1
M3	RT1: Performed structural analysis on platform blade with output available for comparisons (Output data of numerical analysis on platform blade M2) - Paper	*Oct 2014*	CRES, WMC DTU, CENER, PoliMi, IWES	15	(Report available) **InnWind.Eu** Some partners **own funding**	**In progress** To be presented in ICCM20 (07/2015)
M4	RT1: New lightweight blade structural designs and blades with passive couplings (InnWind.Eu deliverable D2.22)	*Oct 2015*	CRES, DTU, CENER, PoliMi, WMC, TuDelft	30	**InnWind.Eu**	In Progress
M5	RT1: Test report on blade subcomponents (IRPWIND deliverable D71.2)	*Jul 2017*	IWES, CRES, DTU, CENER, WMC	30	**IRPWIND**	Started
M6	RT1: Report on validation and improvement of blade design tools (IRPWIND deliverable D71.3)	*Nov 2017*	DTU, CRES, IWES, WMC CENER	27	**IRPWIND**	
M7	RT2: Design of experiments necessary for the validation of tools used in the reliability analysis of wind turbine blades	*Nov 2014*	CRES, IWES, CENER, AAU, DTU	12	**IRPWIND**	**In progress** IRPWIND D7.1.1, Ongoing in IRPWIND Task 7.1.2

Mile-stone	Objective	Date	Partners	Person months	Comments/ project	Status – end 2014
M8	RT2: Platform for validation of stochastic methodologies for reliability assessment of wind turbine blades (Input data for probabilistic analysis required for performing reliability analysis of blades, including data from M2)	*Dec 2015*	CRES, AAU, DTU, CENER, WMC, Forwind-H	10	**IRPWIND** Some partners **own funding**	In progress
M9	RT2: Assessment of current reliability level for blades, based on performed reliability analysis on platform blade (M6) (Report)	*Feb 2016*	DTU, AAU, WMC, CRES CENER, IWES, Forwind-H	10	**IRPWIND** Some partners **own funding**	In progress
M10	RT2: Assessment of current reliability level for support structures	*Feb 2016*	WMC, IWES, Forwind-H	10	**IRPWIND**	In progress
M11	RT3: Damage Tolerance (Pre-proposal for research on future EU calls)	*Sep 2014*	DTU, CENER, IWES, CRES, Forwind-H	–	**Own funding**	**DONE** EERA input to H2020
M12	RT3: Update of definition of topics of interest in the field of materials (List of topics for coordination of activities)	*Sep 2014*	WMC (all)	–	(renewal) **Own funding**	
M13	RT3: Database on Adhesive material properties (Data submitted in web/form)	*Feb 2015*	IWES, WMC	10	**Own funding**	In progress
M14	RT3: Characterization & comparison of C/Ep & G/Ep wind quality Pre-pregs and their glued Joints characterization, calculation & correlation	*Dec 2014*	CENER, WMC, IWES, CTC, CRES	30	**Own funding**	**In Progress** Presentation IRPWIND/EERA conf. 2014
M15	RT3: Round robin of testing for core material	*Nov 2014*	IWES, WMC CENER, TECNALIA	10	**Own funding**	In progress
M16	RT3: Workshop on metallic materials	*Oct 2014*	DTU, CRES, CTC	–	**DK national**, Some partners **Own funding**	**DONE** (19/11/2014@ DTU)
M17	RT3: Review of available composite and metallic material databases (IRPWIND milestone)	*Feb 2015*	WMC, CTC, CRES, IWES, CENER	15	**IRPWIND**	In Progress
M18	RT3: Report on material models for blades and support structures (IRPWIND deliverables D73.1 and D73.2)	*Feb 2017*	WMC, CTC, CRES,IWES, CENER	30	**IRPWIND**	
M19	RT4: Review of design methodologies of wind turbine tower joints; including input data, underlying theory and output data required for the design of the joints (grouted, bolted, very large diameter bolts & welded) (Report)	*Sep 2014*	Forwind-H, CTC, CENER, WMC, IK4	30	(Draft available) **Own funding**	Draft available

Mile-stone	Objective	Date	Partners	Person months	Comments/ project	Status – end 2014
M20	RT4: Theoretical benchmark vs. experimental results for full-scale tower joints (Report)	*Jun 2016*	CTC, WMC, IWES, CENER	25	**IRPWIND** Some partners **Own funding**	
M21	RT4: Comparison of calculated results from different analysis models for pitch bearing (Report)	*Mar 2015*	ORE Catapult	6	**Own funding**	
M22	RT4: Report on validation of grouted joints (IRPWIND deliverable D72.1)	*May 2017*	DTU, CTC, AAU	11	**IRPWIND**	
M23	RT5: Review and specifications of testing coatings for wind turbine blades and towers (Report)	*Dec 2014*	SINTEF, CTC, IWES, WMC, TECNALIA	20	(Draft available) **Own funding**	Draft available
M24	RT5: Review of structural health monitoring methodologies for wind turbine Towers and Support Structures (Report)	*Sep 2014*	CTC, AAU, Forwind-H, IK4, TECNALIA	15	(Draft available) **Own funding**	Draft available
M25	RT5: Review of structural health monitoring methodologies for wind turbine blades and methodology for NDT/SHM testing (Report)	*Apr 2016*	IWES, CRES, CENER, CNR, WMC, SINTEF	20	**IRPWIND** Some partners **own funding**	In Progress
M26	RT5: Proposal for research on wind turbine blade repair for future EC calls (Pre-proposal for research on future EU calls)	*Sep 2014*	IWES, CRES, WMC CENER	--	(Partly done) **Own funding**	**DONE** EERA input to H2020
M27	RT5: Review of blade repair issues (Report)	*Jun 2015*	IWES, CRES, WMC, DTU, CENER	30	**GR National** Some partners **Own funding**	In Progress
M28	RT5: Predictive Maintenance state of art, for the support of WTs (report).	*Dec2016*	BERA (ULG, ULB)	15	(on going) **BE National**	In progress

4.3 International collaboration in 2014

<table>
<tr><th colspan="2">INNWIND</th></tr>
<tr><td rowspan="2"></td><td>Participants</td></tr>
<tr><td>DTU, Aalborg University, CRES, TUDelft, NTUA, SINTEF, PoliMi, FORWIND-Hannover, FORWIND-Oldenburg, University of Patras, University of Sheffield, University of Strathclyde, University of Stuttgart, ECN, WMC, CENER, University of Bristol, IWES, DHI, RAMBOLL, Siemens Wind Power, DNV-GL, Magnomatics, SUZLON, GAMESA, EWEA</td></tr>
<tr><td rowspan="2">www.innwind.eu</td><td>General Description</td></tr>
<tr><td>The overall objectives of the INNWIND.EU project are the high performance innovative design of a beyond-state-of-the-art 10-20MW offshore wind turbine and hardware demonstrators of some of the critical components. These ambitious primary objectives lead to a set of secondary objectives, which are the specific innovations, new concepts, new technologies and proof of concepts at the sub system and turbine level.</td></tr>
<tr><td colspan="2">Contribution in Structures and Materials R&D
A specific task focuses on innovative structural solutions for wind turbine blades. The internal structure of the blade is addressed, including solutions incorporating truss structures instead of the traditional shear web configurations, grid and rib reinforced panels, etc. The studies are also coupled together with new innovative rotor concepts to reduce the cost of energy of future 10-20MW offshore turbines. In addition, a specific task is dedicated to active and passive technologies for flow control involving the exploitation of structural bending twist couplings and smart materials.</td></tr>
</table>

<table>
<tr><th colspan="2">IRPWIND WP7: Improved and validated WT structural reliability</th></tr>
<tr><td>IRPWind</td><td>Participants
For WP7:
CRES, CENER, CTC, WMC, DTU, IWES, AAU, ForWind Hannover</td></tr>
<tr><td>www.irpwind.eu</td><td>General Description
Work packages WP7.1-WP7.5 form one of the three core research projects of the IRPWIND programme. The overarching objective of WP7 is to improve and validate the structural reliability of the wind turbine through enhancing the performance of its major structural components. To this end, fatigue, progressive failure, material defects and manufacturing imperfections have to be taken into consideration to form a comprehensive picture of the wind turbine components operational life.</td></tr>
<tr><td colspan="2">Contribution in Structures and Materials R&D
Activities in IRPWIND WP7 are a mirror of the Sub-programme of Structures and materials, addressing the most urgent research needs of this topic. WP7 project encompasses the validation of structural analysis tools both for blades and support structures through experiments, the probabilistic analysis of blade and support structures, material modelling and environmental effects, as well as non destructive testing and structural health monitoring methods to support the experimental findings.</td></tr>
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<table>
<tr><th colspan="2">IEC Certification</th></tr>
<tr><td></td><td>Participants
John Dalsgaard Sørensen (Aalborg University)</td></tr>
<tr><td></td><td>General Description
Development of the new edition (4) of the main wind turbine standard IEC 61400-1 along with a new IEC-standard for wind turbine foundations and towers. Focus on development of probabilistic basis for reliability-based calibration of partial safety factors.</td></tr>
<tr><td colspan="2">Contribution in Structures and Materials R&D
Implementation of probabilistic basis, reliability level and associated partial safety factors in the IEC standards 61600-1 and PT for 61400-6 for wind turbine foundations and towers.</td></tr>
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<table>
<tr><th colspan="2">MARE-WINT</th></tr>
<tr><td></td><td>Participants
The Consortium is composed of 6 Universities (DTU, LIV, NTNU, WMU, K.U.Leuven, UNIFE), 7 Research Institutes (IMP PAN, ECN, NAREC, CENER, MARINTEK, CTC and TASK) and 10 Private Sector enterprises (CTO, LMS, Numeca, TWI, Relex, SSP, Hansen, Gdansk Shipyard, FiberSensing, Axsym ltd).</td></tr>
<tr><td>http://www.marewint.eu/</td><td>General Description
One of the strategic objectives of the industrial initiative of the SET Plan on wind energy is to reduce cost of energy by improving reliability of wind turbines and their components and optimizing operation and maintenance (O&M) strategies. Increasing reliability and optimizing O&M have a direct impact on the availability of wind turbines and thus reduce cost and increase energy output. MARE-WINT will contribute to the achievement of this goal by proving training in the context of doctoral programmes for 14 researchers in multi-disciplinary area of future generation of Offshore Wind Turbines (OWT) engineering focusing on issues having a major impact on the mechanical loading of OWT and which are still not sufficiently understood.</td></tr>
<tr><td colspan="2">Contribution in Structures and Materials R&D
The OWT is the focal point of this project and the object of the investigation. The main scientific concept incorporated within this project is finding the optimal design of OWT maximizing its reliability and minimizing its maintenance cost. Main OWT subsystems are represented by “vertical” Work Packages focusing on technical aspects (Innovative Rotor Blades, Drive Train with Gearbox, Offshore Support Structure). There are two “horizontal” Work Packages integrating outcomes of the former “vertical” group and building further on their results (Reliability and Predictive Maintenance and Fluid-Structure Interaction).</td></tr>
</table>

MARINET	
	Participants Hydraulics & Maritime Research Centre at University College Cork, Aalborg University, Ecole Centrale De Nantes, NAREC Ltd, University of Exeter, European Marine Energy Centre, EVE, TECNALIA, University of Strathclyde, University of Edinburgh, Queen's University Belfast, Sustainable Energy Ireland - Ocean Energy Development Unit, Tidal Testing Centre, FH_IWES, IFREMER, Wave Energy Centre, 1-Tech s.p.r.l., DTU, ECN, SINTEF, UNIFI-CRIACIV, Gottfried Wilhelm Leibniz Universität Hannover (LUH), Laboratory of Experimental Oceanology and Marine Ecology – Tuscia University (UNITUS), University of Stuttgart (USTUTT), NTNU, Plymouth University (PU), IPT Estado de São Paulo S.A., CNR-INSEAN.
http://www.fp7-marinet.eu/	**General Description** MARINET, the Marine Renewables Infrastructure Network, is a network of research centres and organisations that are working together to accelerate the development of marine renewable energy technologies - wave, tidal & offshore-wind. It is co-financed by the European Commission specifically to enhance integration and utilisation of European marine renewable energy research infrastructures and expertise. MARINET offers periods of free-of-charge access to world-class R&D facilities & expertise and conducts joint activities in parallel to standardise testing, improve testing capabilities and enhance training & networking. FP7 ENERGY. 2011-2015.
Contribution in Structures and Materials R&D A specific task in this project focuses on testing and monitoring for offshore wind energy, including foundation performance analysis under different geological conditions. Both the measurement system itself, as well as the analysis methods (structural health monitoring) are addressed.	

<table>
<tr><th colspan="2">FibreTaut: Fibre Ropes for Taut Mooring Lines for Marine Energy Converters</th></tr>
<tr><td></td><td>Participants
WireCo WorldGroup (Lankhorst-Euronete Portugal), Fundación Centro Tecnológico de Componentes - CTC (Spain), and University of Exeter - UoE (UK) as facility provider.</td></tr>
<tr><td>http://www.fp7-marinet.eu/access_user_project_FibreTaut1.html</td><td>General Description
One immediate challenge for the Marine Renewable Energy Converters (MRECs) industry is solving the cost and weight problems of mooring lines in deep water (>75m). Synthetic fibre ropes already offer a solution to the weight problems of using steel lines in deep water offshore O&G installations as they have a very low weight in water. Also, compared to steel, there are a large number of synthetic fibre material compositions with a wide range of material properties. A synthetic rope can therefore be designed to have properties that match the mooring requirements. Several materials have potential for mooring line application. Yarns of these synthetic materials may be built into ropes using a number of constructions, some of which are suited to particular fibres.</td></tr>
<tr><td colspan="2">Contribution in Structures and Materials R&D
Along this project, several tasks have been developed with the aim of verifing the feasibility of the use of fibre ropes in the mooring systems of Floating Offshore Wind Turbines: (i) Perform tests of the fibre ropes in real open water conditions (ii) Determine strength limits and the stiffness and damping properties of fibre ropes with cycling at different loads. (iii) Develop a base line numerical model of the mooring system and rope behaviour based on the rope characteristics. (iv) Validate the model with real data: meta-ocean conditions and measured loads at sea.</td></tr>
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<table>
<tr><th colspan="2">WINDUR</th></tr>
<tr><td></td><td>Participants
WINDUR has 6 SME partners and 3 RTD partners from 5 different European countries: Belgium (Ghent University, INVERTO), Ireland (Gerriko), Spain (CENER, Machachi, Mastergas and Solute Ingenieros), Sweden (University of Uppsala) and United Kingdom (FuturEnergy).
The 3 RTD partners are Ghent University, CENER and University of Uppsala. The partners in charge of the promotion and exploitation of the end product are Mastergas and Machachi.</td></tr>
<tr><td>www.project-windur.eu</td><td>General Description
WINDUR proposes a small vertical axis wind turbine (VAWT) optimized for use in urban environments as a roof-top mounted system. Proposed novel developments include:
• a variable speed control system developed to maximize VAWT's energy yield under the rapidly changing wind speeds,
• an aerodynamic design based on a helical rotor, refined for reducing rotor weight and loads on the roof, to lower WINDUR installation complexity and cost, and
• an assessment of wind resource in urban areas, for characterizing those locations with better wind resources.
WINDUR has a targeted performance of 0.35 kWh/€ at an annual average wind speed of 6.5 m/s for guaranteeing a return on investment period shorter than 15 years.
WINDUR is financed within the 7th Framework Programme (Research for SMEs) of the European Commission.</td></tr>
<tr><td colspan="2">Contribution in Structures and Materials R&D
Structural integrity according to IEC standards needs to be assured for all the wind turbine components. For that purpose, a detailed design including static and fatigue loads, buckling and dynamic analyses will be required. FE tools will be used to carry out these analyses. The challenge is to obtain a competitive design capable to withstand the predicted loads and satisfy the economic objectives of the project.</td></tr>
</table>

4.4 National projects

In addition to the international collaborative projects, relevant research activities are performed at National level by the individual partners. In this chapter, the most relevant to the objectives of the subprogramme on Structures and Materials National projects for the year 2014 (running or completed within 2014) are presented for each country, indicating contributing partners.

4.4.1 Greece (CRES)

REWIND: Validated design rules for REpair of WIND turbine rotor blades	
ReWIND	**Participants**
	University of Patras, CRES, National Technical University of Athens, ROKAS SA, COMPBLADES SA
http://www.core.mech.upatras.gr/index.php/rw	**General Description**
	The project aims at validating the repair procedures of wind turbine blades in terms of performance and integrity. The work concerns stall regulated wind turbines that are actually operating in Greece and has the following objectives: a) Assessment of the performance in nominal, damaged and repaired blade conditions, b) Calculation of the loads (both extreme and fatigue) on the repaired blades, c) Analysis of the repairing procedure and by that its evaluation.
	Contribution in Structures and Materials R&D
	Structural analysis and numerical simulation of repaired location on blades. Development of methodology for evaluation of repair design and procedure.

4.4.2 Germany (DLR, IWES)

Smart Blades	
SB	**Participants**
	DLR, Fraunhofer IWES, ForWind Oldenburg, ForWind Hannover
http://www.smartblades.info/	**General Description**
	Three different approaches for Smart Blades are investigated: Bend-twist-coupling, movable trailing edges and dynamic slats. The first is prepared to be tested on 20m- Scale. Material and production concepts are developed next to simulation of structural behaviour on a 80m blade for all three technologies.
	Contribution in Structures and Materials R&D
	SmartBlades is contributing to new designs for more efficient blade structures, new materials and design processes for smart rotor blades. Furthermore one focus is set on production strategies.

DPWDesign	
	Participants DLR
	General Description DPWDesign is the starting point of developing a wind energy test side and its scientific equipment **Contribution in Structures and Materials R&D** For the long term research themes the development of a structural health monitoring system and load monitoring for validation of design tools are relevant.

BladeMaker – Industrieproduktion statt Rotorblattmanufaktur	
	Participants 16 partners, among them: Fraunhofer IWES, University of Bremen, Fibertech composites, Schmalz, EEW-Protec, Henkel, Siemens, Sinoi, EMG, PDFibreGlass, Momentive, Fraunhofer IFAM
www.blademaker.de	**General Description** The BladeMaker research project funded by the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety, brings together the wind industry, material suppliers, process experts and automation technology suppliers to advance current automation concepts, transfer ideas from other industries and demonstrate the results in a demo centre at IWES. Based on an extensive cost model and process analysis, BladeMaker will finally suggest parts of the blade manufacturing process to be automated for different batch sizes and quantify the expected savings in material and labor costs as well as the feedback to blade design. The target decrease in total blade cost is above 10%. **Contribution in Structures and Materials R&D** Processes in the BladeMaker scope include advanced mold concepts with carbon fiber heating systems, automated continuous and discrete (pick and place) fiber placement, automated roving placement, innovative core foam production in the main mold, automated glue application and automated finishing processes. Based on these processes, the material parameters and possibly the blade design will be adjusted to maximize the automation benefits.

WindMuse	
	**Participants** DLR, Fraunhofer IWES
http://www.dlr.de/ft/desktopdefault.aspx/tabid-1360/1856_read-39647	**General Description** Aim of WindMuse is the development of an interdisciplinary design chain for rotor blades **Contribution in Structures and Materials R&D** WindMuse is contributing to the design process of wind turbine components, at the moment exclusively for blades.

4.4.3 Denmark (Aalborg University)

Reliability-based analysis applied for reduction of cost of energy for offshore wind turbines	
	Participants Aalborg University, DTU, Vestas Wind Systems, DONG Energy
	General Description The aim of the project is to develop probabilistic models for reliability assessment and design of offshore wind turbines with focus on blades, foundations and operation & maintenance using Bayesian statistical models. **Contribution in Structures and Materials R&D** The stochastic models developed in the project are relevant as basis for the research to be performed in IRPWIND with respect to probabilistic analysis of blade and support structures.

4.4.4 Spain (CENER, CTC, IK4, TECNALIA)

MainWind: Monitoring and Predictive Maintenance System for Wind Farm Management	
MainWind	**Participants**
	INGETEAM S.A., LAULAGUN BEARINGS S.A., GLUAL HIDRAULICA S.L., MATZ-ERREKA, S.COOP., AEROBLADE STRUCTURES S.A., XUBI ENGRANAJES S.L., RENOGEAR S.L., SISTEPLANT S.L., FEGEMU AUTOMATISMOS S.L., IKERLAN IK4, CEIT, TEKNIKER IK4, CENTRO STIRLING, CENER
	General Description
	The project aims to design and build a whole Condition Based Maintenance System (CBMS) for Offshore Wind Turbines attending to different components: blades, gears, hydraulic system, bolted joints, electrical circuits. Predictive Maintenance enables decision taking before a failure occurs. Validation is performed through testing. This task is performed through several monitoring and surveillance operations such as oil analysis, vibration and temperature acquisitions, thermography, etc.
	Contribution in Structures and Materials R&D
	Advanced hydro-aero-servo elastic analysis of Offshore Wind Turbine through multi-body simulation. Development of structural health and condition monitoring for pitch bearings and blades. Development of advanced Predictive Maintenance strategies.

ECOMAR	
	Participants
	CTC, Spanish Institute of Oceanography (IEO)
	General Description
	This project aims to study and experimental analysis of coating systems and materials used in devices marine renewable (wind, tidal, wave ...) with improved corrosion / degradation, erosion properties, and marine growth.
	Contribution in Structures and Materials R&D
	The OWT operate in a corrosive marine environment, making necessary to investigate several strategies to mitigate corrosion and marine fouling and to study the interactions between materials and real marine environment as well. For testing these new developments in a realistic manner, a real marine exposure test site is essential. As a result of this project a Marine Corrosion Test Site named “El Bocal” has been commissioned. http://ctcomponentes.es/en/mcts-marine-laboratory-el-bocal-2/

TECOFF: Development of advanced components for a new generation of offshore wind turbines	
	Participants IK4, Tecnalia, Gamesa Innovation And Technologý, S.L., Hine Renovables S.L., Lau Laugun Bearings S.A., Glual Hidraulica S.L., Fundiciones Wind Energy Casting Ii, S.L., Aplicacion Nuevas Tecnologias - Antec Sa, Asociación De Promocion E Investigacion Cluster De Energía
	General Description The project aims at developing advanced components and validating through physical testing (including life prediction) for the new generation of offshore components.
	Contribution in Structures and Materials R&D Design, structural analysis and testing of blades and their connections. Development and validation of advanced metallic based wind mill structure components.

FLOAT SOLUTIONS	
	Participants GENERAL CABLE, ACCIONA ENERGIA, ACCIONA WIND POWER, CENER, ENGINEEA, TECNALIA, VICINAY CADENAS. Spanish Government funding, 2011-2014, coordinated by General Cable
	General Description Float Solutions Project is aimed at researching, developing and validating innovative solutions for very high-capacity wind turbines for future offshore projects.
	Contribution in Structures and Materials R&D -Design and development of cables for marine energy. -Research on fatigue of materials/components for offshore applications. -Study of new materials and composites for marine applications

<table>
<tr><th colspan="2">CIC energiGUNE'12</th></tr>
<tr><td></td><td>Participants
TECNALIA, AZTI, UPV-APERT, CIC-ENERGIGUNE (marine part). Basque Government funding, ETORTEK.</td></tr>
<tr><td></td><td>General Description
The aim of the project is the development of marine technologies & training in BIMEP.
BIMEP is sited near the village of Armintza-Lemoiz (Bizkaia), in one of the areas of highest energy potential on the Basque coast (21 kW/m), very well communicated and with no impact on surrounding beaches or environmentally protected areas. The sea zone covers a total surface area of 5.3 km2. The nearest point to land is 1,700 m away.
Contribution in Structures and Materials R&D
-Testing materials under real conditions.</td></tr>
</table>

<table>
<tr><th colspan="2">CORROSION MONITORING</th></tr>
<tr><td></td><td>Participants
TECNALIA</td></tr>
<tr><td></td><td>General Description
The aim of the project is to develop a remote corrosion monitoring system for off-shore wind mills.
Contribution in Structures and Materials R&D
- Development of a corrosion monitoring system (based on ER and EIS technology) for wind mills.
- Development and validation a prototype at lab scale for the corrosion monitoring (corrosion rate,..) of the immerse part of the wind mill.
- Development of the remote system at lab-scale.</td></tr>
</table>

CORROSION BEHAVIOUR OF MATERIALS FOR MOORING LINES	
	Participants VICINAY , TECNALIA
	General Description The aim of the project is to study the corrosion behaviour of materials for mooring lines at laboratory and in real environment. **Contribution in Structures and Materials R&D** -Corrosion analysis of both coated and non-coated materials at Lab-scale. -Corrosion analysis of both coated and non-coated materials at real scale.

CORROSION BEHAVIOUR OF COATINGS FOR OFF SHORE APPLICATIONS	
	Participants TECNALIA, HEMPEL
	General Description The aim of the project is to study the corrosion behaviour of anti-corrosion coating system in various exposition sites (immersed and tidal/splash area). **Contribution in Structures and Materials R&D** -Corrosion testing of coated materials in marine conditions -Electrochemical corrosion analysis of coated materials at Lab-

NATURAL EXPOSITION SITE FOR MATERIAL DEGRADATION TESTING	
	Participants TECNALIA
	General Description The aim of the project is to develop Natural outdoor exposure sites for material degradation testing **Contribution in Structures and Materials R&D** To develop a facility for research, development, testing & evaluation in the field of marine corrosion. In order to: -Estimate the corrosion resistance of materials in seawater. -Assesses corrosion protection, material selection and prevention depending on the aggressivity of the environment. -Continuous measurement (environment & corrosion)

4.4.5 Italy (PoliMi, CNR)

Industria 2015	
INDUSTRIA 2015	**Participants** Politecnico di Milano – Dip. di Ingegneria Aerospaziale, Leitwind S.p.A., E.E.I. Equipaggiamenti Elettronici Industriali S.p.A., Arca Tecnologie S.r.l.
	General Description Design and testing of wind turbine for mountain and off-shore applications with one or more generators and a direct drive train technology.
	Contribution in Structures and Materials R&D The contributions of the Department of Aerospace Science and Technology of PoliMI have been: 1. Modeling and aeroelastic simulation with more than one generator for on-shore and off-shore applications; 2. Aero-structural design of the rotor; 3. Design of innovative control system for load alleviation.

4.4.6 Belgium (BERA- Univ of Liege & Laborelec)

PREDICTIVE MAINTENANCE OF OWT – Offshore Maintenance	
Université de Liège ulg	**Participants** BERA – University of Liege
http://www.anast.ulg.ac.be /index.php/en	**General Description** The aim of the “Offshore Maintenance” project is to develop a decision making tool used in the maintenance and inspection of floating offshore wind turbines. The tool uses inspection results related to the state of the structure in order to determine the optimum maintenance and repair strategy for the entire farm. This is done by combining real-time damage assessment methods (Finite Element Analysis) with Risk Based Inspection procedures in order to determine the remaining life time of the structure and the associated risk of failure. Inspections are then planed with the aim of optimizing the risk.
	Contribution in Structures and Materials R&D In the context of the project, a fatigue damage assessment procedure has been developed, for the support structure of floating offshore wind turbines. This is done using inspection results from a structural health monitoring system, and real recorded loads.

Corrosion:	
	Participants BERA - Laborelec, Swerea Kimab
	General Description In 2014, a project aiming at testing scribed coating samples undergoing a 1 year atmospheric and splash zone field was started in order to determine the best performing coating system type for off shore wind farms (in collaboration with Swerea Kimab) **Contribution in Structures and Materials R&D** Several offshore wind farms have been installed, more are being developed and even more are planned. The wind and wave loads applied on the wind turbine structure and components are much more demanding than those on traditional offshore installations (like platforms) and offshore windfarms are usually unmanned. Hence, compared to other offshore constructions, it is vital to avoid costly maintenance operations. This can be achieved through the use of adapted protection means.

Composite blades	
	Participants BERA- Laborelec
	General Description In 2014, non destructive testing (NDT) methods like ultrasonic scans, lock-in thermography and shearography were tested on blade parts in order to define a quality control program for material state assessment. Existing condition monitoring systems for blade structural health assessment and remaining lifetime prediction were reviewed. A methodology for blade remaining lifetime prediction was elaborated. The logical chain wind, loads, stress distribution, fatigue damage and remaining lifetime was investigated for simple test cases. **Contribution in Structures and Materials R&D** The evaluation of the structural health of blades, over the complete life cycle, requires a proper coordinated combination of inspection, testing, monitoring, ageing characterization and failure management.

High Strain Steel (HSS)

	Participants BERA Laborelec
	General Description In 2014, a survey of future challenges in offshore foundations and identification of solutions regarding selection of appropriate design, steels and advanced fabrication/inspection technologies based upon the current state-of-the-art. **Contribution in Structures and Materials R&D** Regarding offshore foundations, the combination of HSS and advanced mechanized fabrication/inspection technologies must give raise to cost reductions through serial production, reduction of weight and of inspection intervals.

4.4.7 Netherlands (WMC, ECN)

ADEM (Advanced Dutch Energy Materials)	
	Participants ECN, TUD, WMC
adem-innovationlab.nl	**General Description** ADEM Innovation Lab - A green Deal in Energy Materials ADEM Innovation Lab is A green Deal in Energy Materials in which Industrial partners, ECN and the Universities of Technology of Delft, Eindhoven and Twente have joined forces in research on materials for conversion, storage, and transport of energy. The ADEM program covers the themes of Wind, Storage, Batteries, Membranes, Solar cells and Fuel cells. **Contribution in Structures and Materials R&D** In the context of the project, at WMC research on thick laminates and integrated fatigue models (including the interactions with external influences such as moisture) are tackled in two PhD projects.

MIMIC (Micromechanics-based Modeling and condition monltoring of rotor blade Composites)	
	Participants WMC, TU Delft, TNO, Bright Composites, We4Ce/Tres4, CTC
http://tki-	**General Description**

	A fundamental research programme within the TKI at sea (Topconsortium Knowledge and Innovation), part of the Energy Topsector, aimed at cost reduction through better prediction of fatigue by improved understanding of the sub-ply material behaviour.
	Contribution in Structures and Materials R&D
	A PhD project started within this project at WMC in 2014. First investigation into numerical multi-scale modelling methods, condition monitoring techniques, and influence of humidity were carried out.

FLOW (Far and Large Offshore Wind)	
FLOW	**Participants**
	2-B Energy, Ballast Nedam, ECN, Eneco, IHC Merwede, RWE, TenneT, TU Delft, Van Oord en XEMC Darwind, WMC
http://flow-offshore.nl/	**General Description**
	Research Programme in industry and institutes aimed at cost reduction for offshore wind through accelarating offshore developments, improving reliability.
	Contribution in Structures and Materials R&D
	In the context of the project, at WMC, TU Delft and van Oord, the slip joint concept for a support structure was evaluated numerically and in quasi-static and fatigue experiments. In addition, models and algorithms for offshore turbines were documented and implemented in design software.

D4REL: Design for RELiable power performance	
D4REL Design for Reliable Power Performance	**Participants**
	ECN, TU-Delft, Siemens, Ballast-Nedam, Van Oord, IHC Hydrohammer and Eneco
http://www.d4rel.nl	**General Description**
	Design for RELiable power performance (D4REL) is an R&D project aiming at developing innovative technology & tools for reducing uncertainty in both the design and operation of offshore wind farms. Limiting the design uncertainty makes it possible to reassess and reduce the safety factors which are used in the design of wind turbines to account for the modeling uncertainty in the design process. More accurate modeling allows for lower safety factors, which in turn makes it possible to achieve less conservative (and, hence, cheaper) turbine design. The operational uncertainty will be reduced by using fault tolerant and condition-based control methods. Altogether, reducing design and operational uncertainty is expected to have a significant contribution to the reduction of Cost of Energy of offshore wind farms.
	Contribution in Structures and Materials R&D

	Part of the project (WP2) aims for generating the knowledge and design capability that enables the development of the next generation of larger and lighter offshore wind turbine blades that do not rely on failure prone features. Other part of the project (WP3) aims at realizing cost reduction in the support structure of offshore wind turbines while keeping a sound, safe and reliable design by using integral probabilistic structural design techniques.

4.5 Publications in 2014

The research performed in 2014 produced a significant number of scientific and technical publications. The present chapter aims to provide an overview of such literature production in relation to structural design and materials R&D for wind turbine components. The publications have been ordered per partner.

4.5.1 CRES

1. Kalinin V, Stopps A, Ferrando Chacon A, Artigao E, Kappatos V, Selcuk C, Gan T-H, Lekou D, Ginige R, Novel torque sensor design and enhanced envelope method of acoustic emission signals in condition monitoring of the nacelle in wind turbine, in 11th International Conference on Condition Monitoring and Machinery Failure Prevention Technologies conf. proc., Manchester, UK, 10-12 June 2014, publ. British Institute of Non-Destructive Testing (BINDT), pp. 97-112
2. Lekou DJ, Bacharoudis KC, Farinas AB, Branner K, Croce A, Philippidis TP, de Winkel GD, A critical evaluation of structural analysis tools used for the design of large composite wind turbine rotor blades under ultimate and cycle loading, accepted for publication ICCM20 2015

4.5.2 CENER

1. Amézqueta C. CENER activities within the SP Structural design & materials. IRPWind/EERA JPWind Conference, Amsterdam, September 2014.
2. Fariñas AB, Nuin I. Nueva versión BASSF (Blade Analysis Stress Strain Failure) v8.x. Software para diseño preliminar de palas eólicas. Eolus Spanish Journal, 70, 2014.
3. Sanz M, Del Río M, Sada L. Modelling infusion for wind turbine blades manufacturing. EWEA 2014, Barcelona, March 2014.

4.5.3 CTC

1. Fernández D, Rodríguez R, Gorrochategui I, Schnars H, "Assessment and mitigation of marine corrosion in metallic components in Marine Renewable Energy devices: first experiences from offshore field tests in the North Sea", Thetis EMR 2013 (April 2013).
2. Fernández D, Rodríguez R, Gorrochategui I, "First experiences in the assessment and mitigation of marine corrosion in metallic components for marine renewable energy devices", EUROCORR 2013 (September 2013).
3. Fernández D, Rodríguez R, Rodríguez A, Yedra A, "Degradation and corrosion testing of materials and coating systems for offshore wind turbine substructures in North Sea waters", Proceedings of the International Wind Engineering Conference 2014 - support structures & electrical systems (September 2014).

4. Fernandez D, Rodríguez R, Rodríguez A, Santos B, “Development of the Marine Corrosion Test Site El Bocal”, IRPWIND Conference (September 2014).

4.5.4 IK4

1. Zubillaga L, Turon A, Maimí P, Costa J, Mahdi S, Linde P. An energy based failure criterion for matrix crack induced delamination in laminated composite structures. Composite Structures, Volume 112, p. 339–344, 2014

4.5.5 DLR

1. Beyland L. Advances in Rotor blades for Wind turbines. IQPC Bremen, 25.02.2015
2. Willberg C. Parametrische Multi-Skalen Modellierung für Klebschichten im Gesamt-Entwurf von Windrotorblättern FVWE-Kolloquium 2014; 12.11.2014

4.5.6 Aalborg University

1. Vahdatirad MJ, Andersen LV, Ibsen LB, Sørensen JD. Stochastic dynamic stiffness of surface footing for offshore wind turbines — a subset simulation approach. Soil Dynamics and Earthquake Engineering, Vol. 65, 2014, pp. 89-101.
2. Nielsen JS, Sørensen JD, Methods for Risk-based Planning of Operation and Maintenance. Energies, 2014, Vol. 7, pp. 6645-6664.
3. Vahdatirad MJ, Griffiths DV, Andersen LV, Sørensen JD, Fenton GA. Reliability analysis of a gravity-based foundation for wind turbines: a code-based design assessment. Géotechnique, Vol. 64, 2014

4.5.7 PoliMi

1. Bottasso CL, Cacciola S, `Model Independent Periodic Stability Analysis of Wind Turbines', Wind Energy, doi:10.1002/we.1735, 2014.
2. Bottasso CL, Campagnolo F, Croce A, Tibaldi C, `Fatigue Damage Mitigation by the Integration of Active and Passive Load Control Techniques on Wind Turbines', Wind Energy - Impact of Turbulence, M. Hoelling, J. Peinke and S. Ivanell, Eds., Springer, ISBN: 978-3-642-54695-2 (print) 978-3-642-54696-9 (online), 2014.
3. Bottasso CL, `Computational Tools for Wind Energy Systems, and their Validation and Calibration', Plenary lecture, CWE 2014, 6th International Symposium on Computational Wind Engineering, Hamburg, Germany, June 8-12, 2014.
4. Bottasso CL, Bortolotti P, Croce A, Gualdoni F, Sartori L, `Aero-Structural Design of Rotors', 2014 Sandia Wind Turbine Blade Workshop, Albuquerque, NM, USA, August 26-28, 2014.
5. Bottasso CL, Croce A, Riboldi CED, Salvetti M, `Cyclic Pitch Control for the Reduction of Ultimate Loads on Wind Turbines', The Science of Making Torque from Wind, Copenhagen, Denmark, June 18-20, 2014.
6. Bottasso CL, Croce A, Sartori L, Grasso F, `Free-form Design of Rotor Blades', The Science of Making Torque from Wind, Copenhagen, Denmark, June 18-20, 2014.
7. Bottasso CL, Campagnolo F, Bettini P, Cacciola S, `Testing of Active and Passive Load Alleviation Techniques with Scaled Wind Tunnel Models', The Science of Making Torque from Wind, Copenhagen, Denmark, June 18-20, 2014.
8. Bottasso CL, Croce A, Sartori L, Grasso F, `Free-Form Aero-Structural Optimization of Rotor Blades', poster, EWEA 2014 Annual Event, Barcelona, Spain, March 10-13, 2014.

9. Bottasso CL, Croce A, Gualdoni F, `Simultaneous Structural Sizing of Wind Turbine Rotor and Tower', poster, EWEA 2014 Annual Event, Barcelona, Spain, March 10-13, 2014.
10. Bottasso CL, Cacciola S, Riva R, `Floquet Stability Analysis of Wind Turbines using Input-Output Models', SciTech 2014, AIAA Science and Technology Forum and Exposition, 32nd ASME Wind Energy Symposium, Washington, DC, USA, January 13-17, 2014.

4.5.8 CNR

1. Dessi D, Camerlengo G. Damage identification techniques via modal curvature analysis: Overview and comparison, Mechanical systems and signal processing, **52-53**, 181-205, 2015, doi:10.1016/j.ymssp.2014.05.031

4.5.9 WMC

1. Lahuerta F, Westphal T., Nijssen RPL, Meer FP van der, Sluys LJ., "Static and fatigue performance of thick laminates test design and experimental compression results" in ECCM-16TH European conference on composite materials, Seville, 2014, pp. 1-9.
2. Lahuerta F, Nijssen RPL, Meer FP van der, Sluys LJ. "Effect of laminate thickness on the static and fatigue properties of wind turbine composites". 10th EAWE PhD Seminary. Wind Energy, Orleans: 2014.

4.5.10 IWES

1. Rosemann H, Braun R, Malhotra P, Wang P, Sayer F. "BladeMaker – Advancing and Demonstrating Automated Manufacturing of Rotor Blades" in EWEA 2014, Barcelona, 2014 (PO-025).
2. Antoniou A, Saathoff M, Krause S, 'Trailing edge monitoring with acoustic emission during a static full scale blade test', EWEA, Barcelona, 2014

4.5.11 TECNALIA

1. Tejero M, Jorcin JB, Prieto A, Alhambra T, Ferreiro J, Mentxaka I, Franco J. Behaviour of anti-corrosion coatings: comparison of the ageing in real environment in different exposition sites. EUROCORR 2014, 8-12 September 2014, Pisa, Italy.
2. Sánchez-López JC, Contreras A, Domínguez-Meister S, García-Luis A, Brizuela M. Tribological behaviour at high temperature of hard CrAlN coatings doped with Y or Zr, Thin Solid Films 550 (2014) 413–420.
3. Brizuela M, Sánchez-García JA, Viviente JL. Influence of coating thickness and interlayer on tribological behaviour of MoSx-WC based coatings. 14th International Conference on Plasma Surface Engineering PSE 2014 Garmisch-Partenkirchen September, 15 – 19, 2014
4. Sanchez-Garcia JA, Corengia P, Herrador-Asenjo T, Larrañaga A, Braceras I. Active Screen Plasma Nitriding of austenitic and PH martensitic stainless steels and inner geometries. 14th International Conference on Plasma Surface Engineering PSE 2014 Garmisch-Partenkirchen September, 15 – 19, 2014
5. Sánchez-García JA, Brizuela M, Braceras I, Larrañaga A, Corengia P. Active Screen Plasma Nitriding to improve tribology performance and corrosion resistance for Austenitic and Martensitic Stainless Steels. Xtreme COAT 2014 workshop. Surface engineering for functional applications under extreme conditions, Madrid, Spain. 20-21 October, 2014.

4.5.12 ECN

1. Huijs FA, Savenije FJ, Bruijn R de. Concept Design Verification of a Semi-submersible Floating Wind Turbine Using Coupled Simulations. DeepWind'2014, Trondheim, Norway, 2014.

2. Huijs FA, Ridder E de, Savenije FJ. Comparison of model tests and coupled simulations for a semi-submersible floating wind turbine. OMAE2014, San Francisco, USA, 2014.
3. Peeringa, JM. Fatigue loading on a 5MW offshore wind turbine due to the combined action of waves and current. The Science of Making Torque from Wind, Copenhagen, Denmark, 2014.

4.6 Contact Point for the sub-programme on Structures & Materials

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

<u>SUB-PROGRAMME: Wind Energy Integration</u>

A sub-programme within the Joint Programme:
Wind Energy

Yearly reporting - 2014

5. Sub-programme on Wind Energy Integration

5.1 The Vision

The power supply system is in a phase of the radical change and the transformation to a system, based on renewable energy sources. In this system, wind energy will play the predominant role in the energy generation. The necessary innovations concerning technology, infrastructure and markets for the transformation of the power supply system with a dominating role of wind energy are to be created only by common and coordinated R&D. The most important objectives of the transformation are:

- A remaining alike supply security and power quality by wind power plant capabilities
- A sustainable grid planning and expansion as well as a reliable grid operation
- A European-wide energy and power market with major contribution of renewable energies.

Within this decade, the most important measures for the transformation of the energy supply systems must be initiated or finalized to a large extent since otherwise the necessary development of the wind energy and other RES will stagnate.

Manage wind power as an integral part of the interconnected European electricity supply system.

5.2 Background

The SET-plan, EWI and TP Wind strongly support the need for R&D on wind energy integration. EWI suggests R&D on wind assessment, turbine technology and grid integration both for on- and offshore. TP Wind suggests grid integration R&D within grid connection and power transmission, system dynamics, and balancing.

One of the main barriers to large-scale deployment of the wind energy technology is the limited capacity of the transmission grids. Large-scale fluctuating wind power production can be smoothed due wide area balancing by energy transmission over long distances and will increase the capacity credit. In addition to new transmission lines and interconnections, a better utilisation of existing infrastructure will avoid wasting of large amounts of renewable energy by curtailment of wind power production.

Enhanced pan-European electricity network capacity has been argued in a number of studies to be extremely cost-effective relative to alternatives such as large scale storage for maximizing the utilisation of available renewable energy resources and minimising the costs of system operation when managing the variability of wind. The cost-effective and sustainable enlargement of the transmission capacity and the enhancement of the utilisation of the grids is mainly the task of the European Transmission System Operators and the concerning organisation, the ENTSO-E. This planning and design needs joint actions of grid operators, generators, traders and consumers and depends on realistic representations of the variability and diversity of available wind power. To be practical for use by network planners, such a representation should be succinct and portable.

The wind community, mainly the R&D organisations TP Wind and EERA JP Wind enhance this change by the development and provision of concepts, planning tools, information and data for a better understanding of the characteristics of wind power and the utilisation of advanced wind power plant capabilities.

The dynamic security and stability of power systems rely on ancillary services that are primarily provided by conventional power stations in present power systems. The ancillary services ensure a stable dynamic control of frequency and voltages in the system in normal operation as well as fault situations. Since large scale integration of wind power and other RES technologies will force conventional power stations out, these ancillary services are needed from other sources, including wind power plants. There is an R&D need to further develop electric design and control of wind power plants that can provide these services, and to develop simulation models and demonstrations to validate that such future wind power plant actually support the system security. It should also be considered which services are advantageous to provide from wind power plants, and which are more advantageous to provide from other sources such as flexible loads.

Balancing of power systems with large scale wind power and other RES will not be ensured by grid reinforcement only. There is also a need to develop more flexible energy management with support from storage and more flexible demand and production options. In this context, it will be an essential R&D task to quantify the need for balancing in terms of volume and time, so that the flexible solutions match the need to support large scale integration of wind power and other renewables. Accurate, flexible and unified wind power forecasts will play a key function for this task. It is important to use the potential of the improvement of forecast tools, of both, the numerical weather prediction and the calculation of the related wind power output. Furthermore, new market designs are required to enable energy and capacity markets dominated by wind. This markets should consider the spatial smoothing effect of weather influenced energy sources. This calls for R&D on development and validation of numeric simulation tools for wind power fluctuations and wind power forecast errors.

5.3 Objectives

The RES directive and the SET Plan enforce a high rate of deployment of wind energy, on- and offshore for the European Union's member states leading to a high challenge for research in the two priority areas: Integration and Offshore. The grid integration of wind power implies two major challenges:

Transformation of the electrical supply system to allow large scale deployment of wind energy

To enable wind power plants to be managed as an integral part of the interconnected European electricity supply system

The overall objective is preparing pre-competitive research laying a scientific foundation for cost effective wind power production and integration. The specific objectives are:

- ✓ **Wind power plant capabilities.** Enable wind power plants to offer characteristics similar (but not necessarily identical) to conventional power plants in order to enable power systems to operate securely and economical with less conventional power plants online, especially in cases where wind speeds are high and consumption is low. This includes the ability of wind power plants to supply ancillary power system services such as support to system voltage control and frequency control including contribution to power system inertia, and the power quality of the wind power plants.

- ✓ **Grid planning and operation.** The sustainable grid planning and reliable operation can only be met by jointly actions of the concerning parties – the TSOs, the wind community, the traders and customers. EERA will support the sustainable enlargement of the transmission capacity and the enhancement of the utilisation of the grids by the development and the provision of planning tools considering large penetration and future capabilities of wind power. This implies the assessment of the future European grid structure requirements, the design, control and optimization of (far-) offshore wind power connected to partly AC and partly DC operated systems, multi-terminal operated and controlled trans-national offshore grids, a sustainable grid extension and reinforcement; the development of tools for planning and operating energy supply system with large amounts of wind power and the investigation of the impact of different high wind penetration levels on the European grid.

- ✓ **Wind energy and power management.** The development of tools for energy and power management taking into account the uncertainty (forecast errors) of wind power in different time scales, and supporting the interaction between wind power, other RES, storage and demand side management; the development and utilisation of wind generation aggregation techniques; the improvement of wind power forecast (short and medium term) including the variability of wind and forecast errors at different time scales and the development of business models and market mechanisms to establish wind energy in European energy markets.

5.4 Report on Research Themes

RT1: Wind power plant capabilities

The utilisation of enhanced Wind Power Plant Capabilities requires new approaches and software tools. A focus of the RT was the development of such Tools in the EERA DTOC project. Further, the work of this RT formed the major input of IRPWIND WP81 and the team in SP Wind Energy Intergation delivered input to the project.

The capability of wind power to support the electric supply system was further elaborated and the provision of ancillary services was determined as main focus in 2014. A workshop was prepared and carried out in December 2014.

The results were used to prepare a proposal for the H2020 2015 Call LCE6 “Transmission and Wholesale Markets”.

RT2: Grid planning and operation

Several meetings and discussions with ENTSO-E – regarding the H2020 2015 Call LCE5 “Meshed offshore grids” dominated the work to this RT. In co-operation with EERA JP Smart Grids, a joint catalog of research themes was presented at ENTSO-E in 2014.

The structured linking of the wind farms in the North Sea is major focus of the NSON initiative, a group of national funded projects, funded by the Berlin Model and established in this SP. First results of NSON were presented at the DeepWind Conference in Trondheim in 2015.

RT3: Wind energy and power management

The needed improvements of forecast-tools is one focus of this RT and was elaborated and discussed in a joined workshop with Sub-Program Wind Conditions (SP1), which covers the meteorological aspects. The adaptation for the different applications, such as new market mechanisms, new busines models and the assessment of the value of forecast systems were discussed and further developed and used as input for IRPWIND WP83.

Mechanisms for a better procurement of ancillary services were discussed at the workshop on ancillary services in December and provided input for the proposal development for the H2020 2015 LCE6 Call.

5.5 Report on Milestones

Mile-stone	Objective	Date	Partners	Person months	Comments/ project	Status – end 2014
M1	RT2: North Sea Offshore and Storage Network (NSON) – proposal submission of national funded projects	*Jun 2013* ongoing	SINTEF, UoS, IWES, DTU, ECN	 3 3 6 0.5	part of NSON	Three national Projects are funded
M2	RT1/RT3: Workshop: Role of forecast tools for grid integration and energy markets – joint workshop of SP grid integration and SP wind conditions	*Jan 2014*	DTU, IWES, IREC, VTT, UoS, CNR	30 30 4	*National funded projects* *Report* *National funded projects I-AMICA PON03_00363, RES-NOVAE PON04a2_E*	*Workshop successful, report is available, presentations are available*
M3	RT1/RT2/RT3: Workshop and Kick-Off: IRP Wind Work Package "European wide measures and structures for a large scale wind energy integration"	*March/ May 2014 ongoing*	IWES, DTU, UoS, ECN, SINTEF, CRES, NTNU, CENER, CNR IREC	6 6 1 6 7	*Part of IRPWIND* *Own Funding* *National funded projects I-AMICA PON03_00363, RES-NOVAE PON04a2_E*	*IRPWIND WP8 started successfully*
M4	RT2: First results of national funded projects under the umbrella of NSON	*Dec 2014* Ongoing	SINTEF, IWES, UoS, DTU, ECN	 12 12	NSON	Prosented on DeepWind Conference
M5	RT1: Workshop on Ancillary Service Provision by Wind Power Report	*Dec 2014*	IWES, DTU, SINTEF, UoS, IREC, LNEG, CRES, CNR	20 1 12 5 1	 Own Funding	Workshop successfully, results were implemented in pre-proposal for H2020 LCE6
M6	RT2: Joint proposal (H2020) of JP wind, JP smart grids and EEGI/ENTSO-E - manage wind power as an integral part – addressing LCE 5 and LCE 6	*Jan 2015* ongoing	IWES, DTU SINTEF, UoS, CRES	8 5	 Own Funding	

Mile-stone	Objective	Date	Partners	Person months	Comments/ project	Status – end 2014
M7	RT1: Workshop on Control Strategies for ancillary services provision and grid compliance	*Jun 2015*	IWES, DTU, SINTEF, UoS, LNEG, CRES, TECNALIA ,IREC	5 1	Part of IRP Wind WP 8.1 Own Funding	
M8	RT3: Workshop on Business models for economic provision of ancillary services	*Oct 2015*	IWES, DTU, SINTEF, UoS, LNEG, CRES, CNR,	6 1	Part of IRP Wind WP 8.3 Own Funding	
M9	Workshop on NSON first results	*May 2016*	IWES, DTU, SINTEF, UoS ECN			

5.6 International collaboration in 2014

EERA DTOC – Part Wind Cluster Managemant System	
	Participants
	IWES, Risoe DTU, CENER, ECN, EWEA, SINTEF, FORWIND OL, CRES, CIEMAT, UPORTO, Strath, IU, CLS, Statkraft, IBR, Statoil, Overspeed, BARD, Hexicon, Carbon Trust, EON, RES
	General Description
	The Design Tool for Offshore Clusters- Wind Farm Cluster Modelling & Simulation (DTOC-WCMS) is designed to estimate the provision of system services. It has been adapted from an existing operational version known as Wind Cluster Management System (WCMS). The wind power plants (WPP) are considered dispatchable units that can be committed to provide a service or to schedule active power to the power system either day-head or intraday. In this context, the forecasted power for the WPP are used to create schedules of power that can be used either as a reserve or allocated as active power scheduled day-head -both based on the day-head forecast- or as balancing power schedules, based on intraday forecasts. The differences between the addition of those schedules and the real active power production are considered as undispatchable and therefore considered as losses due to (forecast) uncertainty. In addition WPP can also provide voltage support by providing reactive power and reactive current on different time scales. The run flow of the DTOC-WCMS can basically divided in three main blocks or modes (1) Check/ planning mode, (2) Reserve mode and (3) Voltage mode. A

	congestion detection is automatically implemented for each calculation due to the fact, the best option in terms of electrical losses reduction and component utilization reduction is selected.
	Contribution in Grid Integration R&D • Estimation tool for provision of offshore system services

North Sea Offshore Network NSON	
	Participants
	SINTEF, UoS, IWES, DTU, ECN, UCD
	General Description
	In addition to increasing energy efficiency the use of renewable energy is crucial for achieving our greenhouse gas reduction goals. To reach this target one cannot speak anymore of "integrating" renewable energy into the system, it is rather the transformation of the whole energy system structure (electricity supply, heat supply and transport) that is needed. Offshore wind energy will play a central role in this transformation. This implies that huge amounts of energy have to be transported from the North and Baltic Sea to the load centers. This leads to an extension of the high voltage grid offshore, at the coast and inland. The fluctuating nature of wind energy increases the extension effort, since large energy surpluses occur for strong wind situations and energy deficits occur for weak wind situations within few days. For balancing these fluctuations this project aims at investigating new strategies which have a promising cost reduction potential and help to stabilize the transmission grid. The approach suggested here combines three different strategies: a meshed multi-terminal high voltage DC network, the connection to existing storage capacities in Norway and the United Kingdom and the offshore integration of new underwater pump storage plants for the provision of balancing power to the transmission grid. The concept of underwater pump storage uses the sea itself as the upper storage reservoir. The lower reservoir at 600 – max 800m below sea level consists of a hollow concrete body of the sea floor, which is emptied in pumping mode and filled with water by a turbine to drive a generator in generating mode. The Norwegian trench is the only area in the North Sea that has adequate water

	depths of more than 500 m. At the east part of the trench between Norway and Denmark an area of 1000 km² with water depths between 600 and 800 m is situated. This represents a more than sufficient area for the installation of energy storage systems. The nearest connection to an electricity line is the line between Southern Norway and the Northern tip of Denmark with a distance of about 50 km. A storage system at this site would be directly connected to the Northsea Offshore-Grid, to which the German, British and Danish offshore wind farms of the North Sea supply their electricity. It is specifically this storage system which can improve system security and the profitability of the offshore network: the large Norwegian storage capacity of 80 TWh is only equipped with a turbine capacity of 27 GW, which designed for national supply. In comparison, underwater pump storage plants have a relatively small storage capacity on the order of a few GWh, but their power can be increased into the GW scale. This way the exchange of large amounts of energy with onshore storage hydro power over longer timescales with relatively little power can be achieved. As a result offshore transmission grids can be layed out for smaller power and achieve a higher capacity factor, increasing their profitability. The peak shaving by underwater storage plants is not only of advantage for offshore wind energy, but also improves the utilization ratio of onhore grids of the connected countries. In order to assure the sustainability of such an investment with enormous importance, detailed simulations and analyses that take into account all relevant boundary conditions are necessary.
	Contribution in Grid Intergation R&D The fluctuations of offshore wind energy and the electrical demand of North Sea neighboring countries are to be determined. On this basis the need for conventional power generation and electricity transport as well as storage needs are to be deduced. The storage potential – with priority for pump hydro storage and storage hydro power in Germany, Great-Britain and Scandinavia (mainly Norway) as well as underwater pump storage in the North Sea – in conjunction with the different Options for an offshore transport network will be modeled, simulated and analyzed In addition to this analysis a planning tool for the assessment of different storage connection and dispatch options is to be developed. Approach 1. Drafting of different possibilities for the design of a meshed offshore

	transmission grid 2. Analysis of storage needs of all North Sea neighboring countries 3. Analysis of storage potentials in Scandinavia, the UK, Germany and the sea taking into account: a. the technical tapping potential b. The options for connection to an offshore electricity grid c. ecological aspects d. social aspects and aspects of public acceptance e. effects on the electricity prices of the countries connected to the offshore grid 4. Potential analysis and simulation of underwater pump storage 5. Development of a simulation tool with which user-defined scenarios and extension options can be modeled and analyzed.

IEA Task 25	
	Participants VTT, Hydro Quebec, Energinet.dk, EWEA, IWES, TERNA, UCD, SINTEF, LNEG, Univ. Castilla La Mancha, KTH, NREL, UVIG
	General Description The ultimate objective is to provide information to facilitate the highest economically feasible wind energy penetration within electricity power systems worldwide. This task supports this goal by analysing and further developing the methodology to assess the impact of wind power on power systems. The Task has established an international forum for exchange of knowledge and experiences related to power system operation with large amounts of wind power. The challenge is to create coherence between parallel activities with Transmission System Operators and other research and development work worldwide. The participants collect and share information on the experience gained and the studies conducted up to and during the task. The case studies address different aspects of power system operation and design: reserve requirements, balancing and generation efficiency, capacity credit of wind power, efficient use of existing transmission capacity and requirements for new network investments, bottlenecks, cross-border trade and system stability issues. The main emphasis is on the technical operation. Costs are assessed when necessary as a basis for comparison. Also technology that supports enhanced penetration are being addressed: wind farm controls and operating procedures; dynamic line ratings; storage; demand side management (DSM), etc.

	Contribution in Grid Integration R&D State-of-the-art report that collected the knowledge and results through 2008. This report was updated through 2011 as a final report of the current term. The task will end with developing guidelines on the recommended methodologies when estimating the system impacts and the costs of wind power integration. Also best practice recommendations will be formulated on system operation practices and planning methodologies for high wind penetration.

5.7 National projects (running in 2014)

5.7.1 Denmark

Enhanced Ancillary Services from Wind Power Plants (EASEWIND)	
	Participants Vestas, DTU Wind Energy, DTU Electrical Engineering, DTU Compute, AAU Energy Technology
	General Description EASEwind addresses particularly features requiring fast (sub-second or cycles) modulation of the wind power plant active power output: inertial response, power oscillation damping, and synchronising power. The project has targeted development and demonstration of the ancillary service control features in a wind power plant control architecture.
	Contribution in Grid Integration R&D The PhD was started in 2014, so no major contributions at this stage

Simulation of Balancing in the Danish power system (Simba)	
	Participants Energinet.dk, DTU Wind Energy
	General Description Energinet.dk is developing and testing new Simba software to simulate the TSO balancing in the Danish power system. In order to account for the main imbalances in the system, DTU Wind Energy has further developed the CorWind software so that it simulates consistent aggregated time series for available wind power and day-ahead forecasts and hour-ahead forecasts.
	Contribution in Grid Integration R&D Development of CorWind web interface (2014) Verification of Corwind models Generic methodology to simulated aggregated fluctuations and forecast error

Impact of wind power uncertainty on electric power system reliability (PhD in EU GARPUR)	
	Participants

	DTU Wind Energy, Energinet.dk
	General Description The main objective of this project is to analyse the effect of renewable energy sources on power system reliability. Aggregated statistical models to represent variability and uncertainty of renewable generation (mainly wind) at a pan-European level will be developed, implemented and validated for different time scales raging from real-time operation to power system planning
	Contribution in Grid Integration R&D The PhD was started in November 2014, so no major contributions at this stage

Integration of wind power & other renewables in power system defence plans (PhD in EU iTesla)	
	Participants DTU Wind Energy
	General Description The objective of the PhD project is to study how wind power and other renewable generation affect power system defence plans preventing major disturbances to develop into system black-outs (defence plans). The impact of wind power on the requirements to changes in defence plans are studied, together with possible contributions from wind power to defence plan improvements.
	Contribution in Grid Integration R&D Assessment of aspects of relevance for renewables in defence plans. Assessment of increased need for primary reserves in 2020 and 2030 due to wind power uncertainties

Possible Power of down-regulated Offshore Wind power plants	
	Participants DTU Wind Energy, DTU Compute, Vattenfall, Vestas, Siemens Wind Power
	General Description The purpose of this project is to develop and verify an internationally acepted methodology to determine the possible power of a down regulated offshore wind farm. The method takes into account the impact that the down regulation has on the wakes in the wind farm.
	Contribution in Grid Integration R&D Development, description and experimental verification of the new methodology (ongoing)

5.7.2 Finland

SGEM – Smart Grids and Electricy Markets	
	Participants Cleen ltd., Aalto University, Lappeenranta University of Technology, MIKES, Tampere University of Technology, University of Eastern Finland, University of Oulu, University of Vaasa, VTT, ABB, Aidon, Alstom Grid, Cybersoft, Elektrobit, Empower,

	Emtele, Fingrid, Fortum Sähkönsiirto, Helen Sähköverkko, Nokia Siemens Networks, Suur-Savon Sähkö, TeliaSonera, There Corporation, Tekla, The Switch, Tieto, Vantaan Energia Sähköverkko, Vattenfall Verkko
	General Description The research program for Smart Grids and Energy Market has a 5-year overall research plan. The research program is divided into five different research themes: 1) Smart Grids architectures 2) Future infrastructure of power distribution 3) Active resources 4) Intelligent management and operation of smart grids 5) Energy market
	Contribution in Grid Integration R&D Controllable demand, dynamic line rating, wind power grid connection models, wind power forecast errors in the power markets, flexibility options for integratind wind power

5.7.3 Germany

RESTORE 2050	
	Participants Next Energy– EWE Forschungszentrum für Energietechnologie e.V. (Oldenburg, Germany), Wuppertal Institute for Climate, Environment and Energy (Germany) University Oldenburg (ForWind-OL)
	General Description Recent studies show that in the year 2050 a power supply system for Germany and Europe that is based on almost to 100% on renewable energies is possible. However, those studies do not address adequately all important aspects and questions concerning the transition to a future power supply system. Some of these aspects are the systematic relation between the developing transmission network across Europe, the intermittent availability wind and solar power on different temporal and spatial scale and the adequate analysis of required storage capacities and interconnectors. RESTORE 2050 address these and other strategic aspects by combining meta analysis of available studies and detailed system modeling. The focus is on quantifying the requirement and effect of storage capacities and demand side management considering the effect of pan-European power balancing due to the availability of interconnectors with varying capacities. The overall goal of the project is to develop consistent political recommendations how to stimulate the transformation of the German power system considering the European dimension of the future power supply by Renewables.
	Contribution in Grid Integration R&D Within the project ForWind-OL studies the capacity needs for interconnectors in Germany and Europe in particular with respect to the usage of Norwegian hydro storage and the connection of Northern Africa for solar power imports.

Baltic I	
	Participants
	University Oldenburg (ForWind-OL), Universität Stuttgart (Germany), EnBW Erneuerbare Energien GmbH (Germany)
	General Description
	The research project Baltic I focuses on an improved operation of offshore wind farms, which is achieved by the enhancement of power and load monitoring, wind power predictions and by new strategies for operational management of individual wind turbines and whole wind farms. The research project is carried on the first commercial offshore wind farm in Germany “EnBW Baltic 1”, which is formed by 21 Siemens 2.3-93 wind turbines, located north of the peninsula ‘Darß-Zingst’ in the Baltic Sea. The location and layout of the wind farm provides interesting conditions, since its short distance to the coastline allows, from a scientific point of view, studying land-see flow interaction and its triangle-shaped layout creates different wake propagation scenarios.
	Contribution in Grid Integration R&D
	Accurate wind power forecasts are an important aspect for trading wind power on the energy market. In addition to single-valued deterministic forecasts, probabilistic forecasts provide estimates of the forecast uncertainty, which lead to more value for the operational management of a wind farm. The raw ensemble wind forecasts from ensemble prediction systems are subject to forecast biases and unreliable forecast uncertainties. As shown in Junk et al., 2014, the bivariate recursive and adaptive wind vector calibration (Pinson, 2012) is a promising and computationally cheap method to reduce biases and to generate reliable probabilistic wind forecasts. The transformation of wind to wind power ensemble forecasts requires suitable power curves. The application of ANN to train power curves at each turbine at “EnBW Baltic 1” reduces the forecast errors compared to the manufacturers’ power curve. The modeling of wake effects by using power deficit factors at each turbine further improves the ensemble forecasts. The consideration of all improvements leads to ensemble forecasts with reliable forecast uncertainties, reduced systematic errors and up to 20 % improvements in the Continuous Ranked Probability Score (CRPS).

SEE – System Integration of Renewable Energy	
	Participants
	Research Groups at the University Oldenburg (Germany)
	General Description
	The PhD program "system integration of renewable energy" focuses on the integration of renewable energy sources into the electric grid. Applicants were the Faculty II computer science, economics and law sciences, Faculty V Mathematics and Natural Sciences, Department of Civil Engineering and Geoinformation of the Jade University. The focus of the doctoral program are performance prediction and network management as well as the development of new technologies and systems that will lead to a functional, safe and economical energy supply from

	renewable sources. Research focus of the doctoral students are forecast models for wind and solar energy, the management and control of smart grid, storage, and renewable energy and hybrid systems for geographic and economic planning system of planned renewable energy networks.
	Contribution in Grid Integration R&D
	The future power grid includes an increasing number of renewable and decentralized energy components. In order to manage these new components, there is a need for information and communication technology: the power grid changes towards a smart grid. In these systems, many challenges arise to optimize stability, security and sustainability. One promising way to handle this complexity is given by self-organized approaches. These approaches tap into many different topics like short term probabilistic power forecasting, simulation, development of new management and prediction strategies, and grid development in general. Various PhD projects deal with simulation tools, evaluation criteria, scenario analyses and meteorological applications to master increasing shares of renewables in the grid.

EWELINE	
	Participants
	IWES, DWD, TenneT, Amprion, 50 Hertz, TransnetBW
	General Description
	High quality power forecasts are becoming increasingly important for maintaining a financially viable and secure energy system, especially as the proportion of weather dependent energy sources to total power production increases. In Germany the goal is to produce 35% of all power production from renewable sources by 2020. In the research project EWeLiNE, the Deutscher Wetterdienst (German Meteorological Service) and Fraunhofer Institute for Wind Energy and Energy System Technology are working together with the three German TSOs Amprion GmbH, TenneT TSO GmbH und 50 Hertz Transmission GmbH to improve the weather and power forecasts for wind turbines and PV plants and to develop new forecast products, especially focusing on the grid stability.
	Contribution in Grid Integration R&D
	The overarching goal of the project is to improve the wind and PV power forecasts by combining improved power forecast models and optimized weather forecasts. During the project, the weather forecasts by Deutscher Wetterdienst will be generally optimized towards improved wind power and PV forecasts. For instance, it will be investigated whether the assimilation of new types of data, e.g. power production data, can lead to improved weather forecasts. With regard to the probabilistic forecasts, the focus is on the generation of ensembles and ensemble calibration. One important aspect of the project is to integrate the probabilistic information into decision making processes by developing user-specified products. The product development will take place in a close collaboration with the end users. To define the requirements for existing and future power forecasts, the Transmission System Operators Amprion GmbH, TenneT TSO GmbH and 50 Hertz Transmission GmbH are taking part in the project

IMOWEN

	Participants
	IWES, AVACON, Senvion
	General Description
	Around 30 % of the installed wind energy in Germany is electrically connected to the 110-kV sub transmission grid. The main focus of the project IMOWEN ("Integration of large amount on- and offshore installed wind energy by use of intelligent grid analysis and cluster management") is to cluster this amount of wind energy and operate the wind parks in such a way that requirements of the TSO (especially the exchange of reactive power between the high voltage and extra high voltage) can be fulfilled.
	Contribution in Grid Integration R&D
	New infomration structure in the electrical grid operation (Continious grid analysis to deviate set points for wind parks) New optimization techniques to calculate the set point out of the mentioned information structure

5.7.4 Norway

NOWITECH	
	Participants
	SINTEF Energy Research, NTNU, MARINTEK, SINTEF Stiftelsen, IFE, and industry partners
	General Description
	The Norwegian Research Centre for Offshore Wind Technology is an 8 year centre (2009 – 2017) with an objective to dopre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on "deep-sea" (+30 m) including bottom-fixed and floating wind turbines.
	Contribution in Grid Integration R&D
	A separate work package on grid integration, covering electrical system from wind turbine generator to power system market integration.

NORCOWE	
	Participants
	CMR, UiBergen, UiAgder, UiStavanger, UniResearch, Aalborg U, and industry partners
	General Description
	Norcowe is a similar centre for offshore wind as Nowitech, however with different focus – more on metocean conditions and less on electrical systems
	Contribution in Grid Integration R&D
	Wind farm power control and prediction

ProOfGrids	
	Participants
	SINTEF Energy Research, NTNU, RWTH Aachen University, and 8 industry partners
	General Description
	The objective of the ProOfGrids project is to establish tools to improve the availability of future offshore grids by limiting the effects of failures and the risks associated to unexpected interactions between components.
	Contribution in Grid Integration R&D
	Modelling, analysis and laboratory testing of control schemes for offshore HVDC grids, including multi-termiinal grids, for transmission of wind power from offshore wind power plants or clusters to onshore load centres

Reliable and energy efficient renewable energy systems	
	Participants
	SINTEF Energy Research, NTNU, TU Chemnitz, and 3 industry partners
	General Description
	The Offshore Power Electronics project focusses on important converter basic characteristics such as reliability, efficiency and control problems related to converters interacting with complex grid systems. These are all crucial issues for offshore wind power conversion systems due to remote locations and harsh environment.
	Contribution in Grid Integration R&D
	Detailed converter c**omponent** modelling for grid integration analysis. Laboratory testing to characterise components. Control algorithms for improved operation of HVDC stations.

5.7.5 Spain

CONNECT-DC: Topologies and control of power electronic converters for offshore high voltage DC energy transmission	
	Participants
	Fundacion Tecnalia Research & Innovation (TECNALIA) Universitat Politècnica de Catalunya (UPC)
	General Description
	This project will enable to deepen in the study of a medium voltage DC transmission architecture avoiding the use of the offshore platform, developing and validating technology solutions based on power converters for this application.
	Contribution in Grid Integration R&D
	New topologies to evacuate energy from wind farms developed and demonstrated.

5.8 Publications in 2014

5.8.1 Denmark

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5.8.2 Germany

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Offshore Wind Energy

A sub-programme within the Joint Programme:
Wind Energy

Yearly reporting - 2014

6. Sub-programme on Offshore Wind Energy

6.1 Report on Research Themes

The research is structured around a) development of theory and models, b) data from experiments and c) validation. Five long-term *research themes (RTs)* are addressed:

Description	Schedule
RT 1: Design optimization through validation studies offshore The objective is to accelerate the design optimization of wind turbines and support structures for offshore wind farms through validation of integrated design models and actual safety level and subsequent development of methods and design criteria. This RT is on schedule and being addressed mainly through EERA IRPwind WP6.	2014-2018
RT 2: Characterization and interaction of wind, wave and current The goal is to gain an improved understanding of micro-scale wind, wave and ocean current as input for developing standard design load cases for large deep offshore wind turbines. Key elements to be considered are wind turbulence and profile, wave and current characteristics, co-variance of wind, waves and current, both in terms of strength and direction, extreme values and modelling of non-linear irregular waves, wind and current. This RT mainly expected being addressed mainly through the ERA-net cofund European wind atlas project.	2015-2020

RT 3: Innovative wind farm electric grid connection for offshore applications The objective is to bring major innovations in the design of the wind farm grids for offshore applications. Alternative solutions should be assessed including solutions that may provide for reduced complexity of the wind turbines and more compact and lightweight sub-stations for connection to the HV transmission system. The cable system and connection to the transmission system should also be assessed, including grouping of multiple wind farms in clusters and connection to multi-terminal HVDC systems. Wind farm cost savings, efficiency, reliability, controllability, protection and fault handling should be verified through analysis, numerical simulations and lab-scale test and demonstration. There is some national activities on this RT, e.g. within NOWITECH, but to accelerate the European development within this field, there are expectations for future H2020 calls to address this RT.	2015-2020
RT4: Control, Operation and Maintenance of offshore wind farms The overall objective is to come up with technologies and services for substantial reduction of operational costs in offshore wind farms taking the life-cycle perspective into account. Radical design improvements taking maintainability and controllability into account and advanced condition monitoring concepts should be investigated. Smart structures, sensor technology, wireless sensor networks, remote inspection / even remote maintenance intelligent load and condition monitoring, predictive health monitoring and optimization & control are all areas that should be addressed. The models used to control the wind farm and single wind turbines should not only be depending on the actual sensor information, but also on predictive models for weather conditions, performance and degradation of the components. To accelerate the European development within this field, there are expectations for future H2020 calls to address this RT, ref also M3.	2015-2020 2020-2030

RT 5: Novel cost-competitive concepts for deep sea, including multi-use of wind farm areas The aim of this RT is to assess various possible novel designs of turbine and sub-structure for deep sea, bottom-fixed and floating, and giving step-changes in technology for reducing cost of energy from offshore wind farms. Aspects of consideration are larger wind turbines, lower top mass for large turbines, more robust design, more easy installation, and overall lower cost of energy. Multi-use of the wind farm area should also be considered, e.g. wave energy, fish farming etc. To accelerate the European development within this field, there are expectations for future H2020 calls to address this RT, ref also M4.	2015-2020 2020-2030

6.2 Report on Milestones

The table below gives milestones and objectives for 2014-2017

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	Explantion of symbols in Tables in the report
√	Goal has been reached (and maybe even exceeded).
●	Ongoing activity / prior to deadline
X	Goal has not been reached

Mile-stone	Objective	Date	Partners	Person moths	Comment	Status –end 2014
M1	RT1-5: Knowledge sharing and dissemination EERA DeepWind R&D Offshore Wind Conference	January 2014	SINTEF Energy; SP partners		+30 peer-review journal papers by EERA partners	√
M2	RT1: Kick-off IRPwind WP6 Offshore.	June 2014	SINTEF Energy; IRPwind partners			√
M3	RT4: H2020 applications on control and O&M	Sept. 2014	SP partners		More initiatives in preparation	(√) Applications were submitted, but not awarded funding.
M4	RT5: H2020 applications on novel concepts	Sept. 2014	SP partners		More initiatives in preparation	(√) Applications were submitted, but not awarded funding.

M5	RT1: Workshop on open data access	Oct. 2014	DTU; IRPwind partners		IRPwind WP2 activity aligned with WP6. Workshop with research and industry partners to achieve more openness in sharing measurement data from offshore wind farms	√ Was planned to be prepared with TPwind, but since TPwind is still not operational, the workshop was postponed and held as part of EERA DeepWind February 2015.
M6	RT2: Workshop on met-ocean conditions for knowledge sharing and to plan activities	Nov. 2014	DTU; SP partners		In alignment with ERA-NET+ European Wind Atlas and EERA SP wind conditions	X
M7	RT1-5: Knowledge sharing and dissemination EERA DeepWind R&D Offshore Wind Conference	January 2015	SINTEF Energy; SP partners		+30 peer-review journal papers by EERA partners	√
M8	RT1: Model evaluation protocol defined	March 2015	CENER; IRPwind partners	48	IRPwind MS21	√
M9	RT3: Roadmap for technology availability for offshore grid components and offshore storage options	April 2015	SINTEF Energy; Strathclyde, Fh IWES, ..	12	NSON M1	√
M10	RT3: Established method and framework for assessment of cost-benefit sharing models	April 2015	SINTEF Energy; Strathclyde, Fh IWES, ..	12	NSON M3	●
M11	RT3: Workshop on political drivers and cost-benefit sharing options	Sept. 2015	SINTEF Energy; Strathclyde, Fh IWES, ..		NSON M2	●
M12	RT3: Established Strategic Research Agenda for North Sea offshore grids	Dec. 2015	SINTEF Energy; Strathclyde, Fh IWES, ..	12	NSON M3	●

M13	RT1-5: Knowledge sharing and dissemination EERA DeepWind R&D Offshore Wind Conference	January 2016	SINTEF Energy; SP partners		+30 peer-review journal papers by EERA partners	
M14	RT1: Benchmarks scheduled and launched	March 2016	CENER; IRPwind partners	18	IRPwind MS22	
M15	RT1: Data in database for benchmark exercise	Sept. 2016	Hannover; IRPwind partners	46	IRPwind MS20	
M16	RT1-5: Knowledge sharing and dissemination EERA DeepWind R&D Offshore Wind Conference	January 2017	SINTEF Energy; SP partners		+30 peer-review journal papers by EERA partners	
M17	RT1: Integrated design tools and guidelines	March 2018	Strathclyde; IRPwind partners	66	IRPwind MS23	
M18	RT1&5: Investigation of new control systems	March 2018	Strathclyde; IRPwind partners	86	IRPwind MS24	

6.3 International collaboration in 2014

Examples of main international research collaboration with link to EERA sub programme on offshore wind energy are listed below:

- EERA DTOC, kick-off 2012
- EERA InnWind, kick-off 2013
- ABYSS (DK-NO), kick-off 2014
- NSON (NO-UK-DE), kick-off 2014
- EERA IRPWind, kick-off 2014
- IEA Wind Task30: OC5, kick-off 2014
- LIFES 50plus, kick-off 2015

6.4 National projects

Examples of main national research projects within offshore wind energy are listed below:

Name of project	Start year	End year	Project coordinator	(Main) Project partners	Total Budget	Funding agency
NOWITECH (NO)	2009	2017	SINTEF Energy	NTNU, MARINTEK, SINTEF, IFE, 10 industry partners	40 M€	Research Council of Norway (50 %),
NORCOWE (NO)	2009	2017	CMR	Uni Research Uni. of Agder Uni. of Bergen Uni. of Stavanger Uni. of Aalborg 8 Industry partners	30M€	Research Council of Norway (50 %),
Wind Farm (DK)	2011	2014	DTU Wind Energy,	DONG ENERGY A/S, Vestas Wind Systems A/S	927 k€	EUDP (Energy Technology Development and Demo Program)
EUDP LEX (DK)	2013	2016	Bladena	DTU Wind Energy, DTU MEK, AAU Inst. f. Byg og Anlæg, Vattenfall, ao.	1.3 M€	EUDP
Nysted 2, Wakes (DK)	2010	2014	DTU Wind Energy	E.ON, Grontmij-Carl Bro	724k€	Energinet.dk
P_NETS-NAUTILUS (ES)	2013	2015	Tecnalia	Astilleros Murueta, TAMOIN, Widewall Investments (VELATIA group), VICINAY Cadenas, TECNALIA Ventures, ETIAMRACSO	1.7M€	NETs Program 2013-2014 Basque Government
RETOS NAUTILUS (ES)	2014	2016	Widewall Investments	Astilleros Murueta, TAMOIN, Widewall Investments (VELATIA group), VICINAY Marine Innovation	2M€	MINECO - Economy and Competitiveness Ministry of the Spanish Government
INNPACTO Nanomicro (ES)	2011	2014	Cementos Portland Valderrivas	FCC Construcción, S.A.; Norten Prefabricados de Hormigón, S.L.; Gamesa Innovation and Technology, S.L.; Fundación Investigación y Desarrollo en Nanotecnología, CENER	3.7 M€	MICINN (Spanish Government)

6.5 Publications in 2014

Author(s)	Article title	Journal Title	Date of publi-cation	Page no
John Olav Giæver Tande, Trond Kvamsdal, Michael Muskulus	Editorial	Energy Procedia - EERA Deepwind 2014, 11th Deep Sea Offshore Wind R&D Conference	2014	Page 1
Fons Huijs, Rogier de Bruijn, Feike Savenije	Concept Design Verification of a Semi-submersible Floating Wind Turbine Using Coupled Simulations	--- "---	2014	Pages 2-12
Matt Smith, Michael Harris, John Medley, Chris Slinger	Necessity is the Mother of Invention: Nacelle-mounted Lidar for Measurement of Turbine Performance	--- "---	2014	Pages 13-22
Uwe S. Paulsen, Helge A. Madsen, Knud A. Kragh, Per H. Nielsen, Ismet Baran, Jesper Hattel, Ewen Ritchie, Krisztina Leban, Harald Svendsen, Petter A. Berthelsen	DeepWind-from Idea to 5 MW Concept	--- "---	2014	Pages 23-33
Z. Zhang, S.M. Muyeen, A. Al-Durra, R. Nilssen, A. Nysveen	Multiphysics 3D Modelling of Ironless Permanent Magnet Generators	--- "---	2014	Pages 34-43
Zhiyu Jiang, Limin Yang, Zhen Gao, Torgeir Moan	Numerical Simulation of a Wind Turbine with a Hydraulic Transmission System	--- "---	2014	Pages 44-55
K. Wang, M.O.L. Hansen, T. Moan	Dynamic Analysis of a Floating Vertical Axis Wind Turbine Under Emergency Shutdown Using Hydrodynamic Brake	--- "---	2014	Pages 56-69
Hossein Farahmand, Leif Warland, Daniel Huertas-Hernando	The Impact of Active Power Losses on the Wind Energy Exploitation of the North Sea	--- "---	2014	Pages 70-85

Juan C. Nambo Martinez, Kamila Nieradzinska, Olimpo Anaya-Lara	Dynamic Series Compensation for the Reinforcement of Network Connections with High Wind Penetration	--- "---	2014	Pages 86-94
Phen Chiak See, Olav Bjarte Fosso, Kuan Yew Wong	Cross-border Transfer of Electric Power Under Uncertainty: A Game of Incomplete Information	--- "---	2014	Pages 95-103
Raymundo E. Torres-Olguin, Atle R. Årdal, Hanne Støylen, Atsede G. Endegnanew, Kjell Ljøkelsøy, John Olav Tande	Experimental Verification of a Voltage Droop Control for Grid Integration of Offshore Wind Farms Using Multi-terminal HVDC	--- "---	2014	Pages 104-113
Tobias Hennig, Lothar Löwer, Luis Mariano Faiella, Sebastian Stock, Malte Jansen, Lutz Hofmann, Kurt Rohrig	Ancillary Services Analysis of an Offshore Wind Farm Cluster – Technical Integration Steps of a Simulation Tool	--- "---	2014	Pages 114-123
Vin Cent Tai, Kjetil Uhlen	Design and Optimisation of Offshore Grids in Baltic Sea for Scenario Year 2030	--- "---	2014	Pages 124-134
Adil Rasheed, Runar Holdahl, Trond Kvamsdal, Espen Åkervik	A Comprehensive Simulation Methodology for Fluid-structure Interaction of Offshore Wind Turbines	--- "---	2014	Pages 135-145
G. Wolken-Möhlmann, J. Gottschall, B. Lange	First Verification Test and Wake Measurement Results Using a SHIP-LIDAR System	--- "---	2014	Pages 146-155
J. Gottschall, G. Wolken-Möhlmann, T. Viergutz, B. Lange	Results and Conclusions of a Floating-lidar Offshore Test	--- "---	2014	Pages 156-161
Konstantinos Christakos, George Varlas, Joachim Reuder, Petros Katsafados, Anastasios Papadopoulos	Analysis of a Low-level Coastal Jet off the Western Coast of Norway	--- "---	2014	Pages 162-172

Line Båserud, Martin Flügge, Anak Bhandari, Joachim Reuder	Characterization of the SUMO Turbulence Measurement System for Wind Turbine Wake Assessment	--- "---	2014	Pages 173-183
M. Bakhoday Paskyabi, S. Zieger, A.D. Jenkins, A.V. Babanin, D. Chalikov	Sea Surface Gravity Wave-wind Interaction in the Marine Atmospheric Boundary Layer	--- "---	2014	Pages 184-192
Ole Henrik Segtnan	Wave Refraction Analyses at the Coast of Norway for Offshore Applications	--- "---	2014	Pages 193-201
Siri Kalvig, Eirik Manger, Bjørn H. Hjertager, Jasna B. Jakobsen	Wave Influenced Wind and the Effect on Offshore Wind Turbine Performance	--- "---	2014	Pages 202-213
Valerie-M. Kumer, Joachim Reuder, Birgitte R. Furevik	A Comparison of LiDAR and Radiosonde Wind Measurements	--- "---	2014	Pages 214-220
Iver Bakken Sperstad, Elin E. Halvorsen-Weare, Matthias Hofmann, Lars Magne Nonås, Magnus Stålhane, MingKang Wu	A Comparison of Single- and Multi-parameter Wave Criteria for Accessing Wind Turbines in Strategic Maintenance and Logistics Models for Offshore Wind Farms	--- "---	2014	Pages 221-230
Matthias Hofmann, Iver Bakken Sperstad	Will 10 MW Wind Turbines Bring Down the Operation and Maintenance Cost of Offshore Wind Farms?	--- "---	2014	Pages 231-238
Øyvind Netland, Iver Bakken Sperstad, Matthias Hofmann, Amund Skavhaug	Cost-benefit Evaluation of Remote Inspection of Offshore Wind Farms by Simulating the Operation and Maintenance Phase	--- "---	2014	Pages 239-247
Amir Rasekhi Nejad, Zhen Gao, Torgeir Moan	Fatigue Reliability-based Inspection and Maintenance Planning of Gearbox Components in Wind Turbine Drivetrains	--- "---	2014	Pages 248-257

Mark L. Brodersen, Jan Høgsberg	Damping of Offshore Wind Turbine Tower Vibrations by a Stroke Amplifying Brace	--- "---	2014	Pages 258-267
Michael Borg, Maurizio Collu	A Comparison on the Dynamics of a Floating Vertical Axis Wind Turbine on Three Different Floating Support Structures	--- "---	2014	Pages 268-279
Ronan Meere, Jonathan Ruddy, Terence O'Donnell	Variable Frequency Operation for Future Offshore Wind Farm Design: A Comparison with Conventional Wind Turbines	--- "---	2014	Pages 280-289
Adil Rasheed, Jakob Kristoffer Süld, Trond Kvamsdal	A Multiscale Wind and Power Forecast System for Wind Farms	--- "---	2014	Pages 290-299
Henrik Kirkeby, John Olav Tande	The NOWITECH Reference Wind Farm	--- "---	2014	Pages 300-312
I. Bayati, M. Belloli, D. Ferrari, F. Fossati, H. Giberti	Design of a 6-DoF Robotic Platform for Wind Tunnel Tests of Floating Wind Turbines	--- "---	2014	Pages 313-323
E. Cantero, C.B. Hasager, P.-E. Réthoré, A. Peña, K. Hansen, J. Badger, J.G. Schepers, L.M. Faiella, D. Iuga, G. Giebel, S. Lozano, J. Sanz, G. Sieros, P. Stuart, T. Young, A. Palomares, J. Navarro	Energy Yield Prediction of Offshore Wind Farm Clusters at the EERA-DTOC European Project	--- "---	2014	Pages 324-341
N. Simisiroglou, S.-P. Breton, G. Crasto, K.S. Hansen, S. Ivanell	Numerical CFD Comparison of Lillgrund Employing RANS	--- "---	2014	Pages 342-351
C.B. Hasager, A. Mouche (et al)	Wind farm wake observed from satellite SAR and comparison to wake model results.	EERA DTOC	2014	
J. Azcona, F. Bouchotrouch, M. González, J. Garciandía, X. Munduate, F. Kelberlau and T. A. Nygaard	Aerodynamic Thrust Modelling in Wave Tank Tests of Offshore Floating Wind Turbines Using a Ducted Fan	J. Phys.: Conf. Ser. 524 012089	2014	

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Research Infrastructures

A sub-programme within the Joint Programme:
Wind Energy

Yearly reporting - 2014

7. Sub-programme on Research Infrastructures

The background for having a separate programme on research infrastructure is the importance of achieving as much synergy as possible and enough critical mass among the EERA partners, to improve their ability to perform very large and advanced experiments as well as pre-commercial testing of prototypes from where obtained data are essential for the design and deployment of the large future wind turbines, and in the end to fulfil the SET Plan and the RES Directive.

The general objectives of the sub-programme are:

1. To mobilize and coordinate EU research and investment on infrastructures in the field of wind energy,
2. To optimize the use of the facilities making the most of their output,
3. To create the conditions for the long-term development and enlargement of the wind energy research facilities,
4. To create synergies between the partner of the EERA common research program in the field of Wind Energy.

The specific objectives for the period 2013-2016 are:

- Implement the actions required by the EERA Wind Strategy for the period (Strategy),
- Implement the Strategic Action Plan 2013-2016 (SAP) actions,
- Integrate the following projects into the RI Strategy & SAP:
  - o Atlas-27
  - o Windscanner.eu – Preparatory Phase
  - o EERA-DTOC

RT1: Networks on relevant RI

The IRPWind Work Package 3 (WP3) “Infrastructures” has the general objective of promoting alignment plus focusing of national research activities through joint experiments carried out in European research facilities and the effective joint use of European research facilities.

The focus and aligment will be gained by means of:

1) Creation of access protocols to selected European research facilities and definition of prioritization procedures for selecting the most urgent and relevant experiments in the European context.
2) Implementation of a technical committee to select the experiments that will benefit the most national research activities and promote cooperation and alignment and to match experiment with the most appropriate European research facility.
3) Funding of selected strategic joint experiments, including infrastructure use, at chosen national facilities supporting national R&D efforts

The promotion will be provided through the creation of awareness about existing facilities and their specific characteristics, the application of common and transparent access procedures for experiment and facility selection and the required support both for the host and the guests. Synergy and effectiveness will be derived from networking for data and exchange of best practices.

By doing this, the joint use of European research facilities shall be carried out in a strategically focused and coordinated way, in which selected nationally operated facilities are employed to run specific high value carefully designed and chosen experiments, to ultimately support coordinated joint research nationally supported actions. This will, Europe-wide, lead to a more effective use of assets and better support of national R&D efforts that are alignment to a European strategy as required by the SET-Plan and as outlined in the EERA-DOW.

Task of the WP3 Infrastructures are:

- Task 3.1 "Networking of RI
- Task 3.2 "Experiments selection and supported access to facilities"

First Task is the creation of Networking's of Research Infrastructures. Sharing and join working are expected to create synergy and effectiveness or value of future results.
The first Networks should be created for the following priority research facility types:

- ✓ Research Wind Turbines for aerodynamics and loads study
- ✓ Wind Tunnels for wind energy research.
- ✓ Testing Facilities for Grid integration

The procedure for the networks creation has the following activities:

- Request of Expression of Interest (EoI): EoI will be requested to IRPWIND and EERA members and candidate members.
- Establishment of three networks: According to the EoI's received, the networks will be created.
- Appointment of the Core Group (CG): The Work Package Coordinator (WPC) will call a core group to set-up the working team. This CG will configure the Working Group (WG) composition and dedication as well as output required.
- The WG will provide recommendations on research experiments and new European research facilities that will promote integration of national research and strengthen the European research capability.
- Review of Results. The coordinator will evaluate the dynamics and results of the different working networks.

EoI's were requested in May 2014 to IRPWIND and EERA Wind JP members and candidate members to participate in the Networks Group. In Annex I is presented the template created for the EoI and sent to the EERA JP Members.
In total seven participants are interested to participate in the Research Wind turbines Network, of which three (CRES, CENER and CATAPULT) are onshore and the other four offshore. For the network of Wind Tunnels for wind energy research for the time being there are six participants (two of them are in construction). Last for the network of Testing Facilities for Grid integration, seven centers have expressed their interest to participate in this Network.
Following table list the centers participating in the three networks.

Research Wind Turbines		
ORGANIZATION	COUNTRY	Contact
BERA - Belgian Energy Research Aliance	BELGIUM	Prof. Dr. Ir. Christof Devriendt
ForWind - Center for Wind Energy research	GERMANY	Dr. Stephan Barth
CRES - Centre for Renewable Energy Sources and Saving	GREECE	Fragiskos Mouzakis
NTNU -Norwegian University of Science and Technology	NORWAY	Michael Musculus & Jan Onarheim
SINTEF Energy Research	NORWAY	Karl Merz
CENER – Spanish National Research Centre for Renewable Energies	SPAIN	Antonio Ugarte
Offshore Renewable Energy Catapult	UK	Dr. Chong Ng
Wind Tunnels		
ORGANIZATION	COUNTRY	Contact
DTU - Technical University of Denmark	DENMARK	Christian Bak
ForWind - Center for Wind Energy research	GERMANY	Dr. Stephan Barth
CIRIVE - Politecnico di Milano Wind Tunnel	ITALY	Prof. Alberto Zasso
Delft University of Technology	NETHERLANDS	Carlos Simao Ferreira, Nando Timmer
NTNU - Norwegian University of Science and Technology	NORWAY	Prof. Lars Saetran
METUWIND - Center for Wind Energy	TURKEY	Prof. Dr. Oguz Uzol r
Testing Facilities for Grid Integration		
ORGANIZATION	COUNTRY	Contact
Delft Univ. of Technology	NETHERLANDS	Henk Polinder
SINTEF Energy Research	NORWAY	Ole Christian Spro
IREC - Catalonia Institute for Energy Research	SPAIN	Dr. Oriol Gomis-Bellmunt
CIRCE - Research Centre for Energy Resources and Consumption	SPAIN	Miguel García-Gracia
TECNALIA - Research & Innovation	SPAIN	Susana Apiñániz Germán Perez
University of Strathclyde	UK	Prof. William Leithead Dr. Olimpo Anaya-Lara
Offshore Renewable Energy Catapult	UK	Dr. Chong Ng

RT2: Coordination of inter MS access to facilities and support for important experiments.

Second task of this WP is “Experiments selection and supported access to facilities”

This task contemplate the following actions for the first year of theproject:

- Publication of the Catalogue of Facilities Available to the IRPWIND
- Creation of the Technical Committee for granting support for experiments and access. A Committee to strategically and technically prioritize experiments, define procedures, set required public outputs, set support conditions and supervise the experiments will be created.
- Creation of the Rules & Conditions for joint experiment and access. Rules shall stimulate cooperation and alignment of nationally financed activities and be of benefit for at least three institutional participants and the EERA program. Alignment with the EERA program objectives will be given priority.

The first step required is to give visibility to the facilities which are made available by the partners. A document containing the characteristics of the facilities for wind energy research existing at the present time in the EERA Wind JP partners has been created. Data has been provided for partners as to understand the nature of the facility and access offered. Contact persons have been added to help reader contact the operator.

Once the final catalogue will be approved by the Technical Committee of this WP,.will be published.

In 2011 was elaborated a catalog under the umbrella of the SJP of the EERA Wind JP. Now the target was to update the existing catalog. The process followed to get the information was to send the current data and new template to all EERA Wind JP members requesting to update the information.

From the total 41 EERA Wind JP members, 30 have supplied the requested information about their RI, making a total of more than 140 installations.

In order to facilitate to the readers to find the information about specific Research Infrastructures, the RI has been group according to the following structure:

- Wind Measurement Test Stations
- Wind Turbines Test Sites
- Small Wind Turbines Test Sites
- Offshore Wind Test Fields
- Component Test Facilities
- Material Testing Laboratories
- Acoustic Laboratories (for Wind Energy)
- Wind Tunnels (for Wind Energy)
- Flow & Wave basins
- Electrical Test Facilities
- Applications Testing Facilities
- Other Test Facilities

Following table maps the RI of the EERA Wind JP members.

	WMTS	WTTS	SWTTS	OWT	CTS	MTL	AL	WT	F&W	ETF	ATF	OTF
BERA		*										
CATAPULT	*			*	*					*		
CENER	*		*		*	*				*		
CIEMAT	*				*						*	
CIRCE	*		*		*		*			*	*	
CMR												
CNR-ISAC	*			*			*		*			
CRES	*	*			*	*		*				
CTC					*	*						*
DHI									*			
DLR												
DTU Wind Energy		*			*			*				
ECN		*										
Fraunhofer IWES	*			*	*							
ForWind Bremen												
ForWind Hannover	*				*			*				
ForWind Oldenburg								*				
IC3												
IEn												
IFE		*										
IK4-IKERLAND					*	*				*		
IREC	*									*		*
LNEG/INETI	*		*	*							*	
Marintek				*					*			
NTNU	*	*	*									
Politecnico de Milano								*				
SINTEF	*	*	*			*			*	*	*	
SINTEF MC												
TECNALIA										*		
Technical Univ. of								*				
Tubitac										*		
Univ. of Aalbourg												
Univ. of Athens				*				*				
Univ. of Bregen												
Univ. College of Dublin												
Univ. of Porto												
Univ. of Strantchclyde										*		
University of Stuttgart												
VTT	*	*			*	*		*				

WMC	*	*										

Second action is the creation of the Technical Committee. A Committee to strategically and technically prioritize experiments, define procedures, set required public outputs, set support conditions and supervise the experiments will be created. The Technical Committee was created i during the kick-off meeting of the IRPWind project in Barcelona were Pablo Ayesa (CENER) presented the main objectives and activities of WP 3. It was agreed that the Technical Committee to select the experiments will be the Management Board of the EERA Wind JP, consisting of all the sub-programme coordinators.

Third action is the elaboration of the Rules & Conditions for joint experiment and access to the RI. Rules shall stimulate cooperation and alignment of nationally financed activities and be of benefit for at least three institutional participants and the EERA program. Alignment with the EERA program objectives will be given priority.

Main activities of this action are:

- Rules and Conditions for calls
- Analysis of existing schemes
- Draft of working document
- Work document discussion
- Final Publication

It is expected to have the work document for discussion at the beginning of June.

RT3: Measuring of Windflow

The new WINDSCANNER research infrastructure facility has been conceived in the logic of the SET Plan and the vision of the European Innovation Union (Europe 2020 Strategy). The WINDSCANNER aims to enhance the European competitiveness in the wind energy sector and maintain European technological leadership in detailed high-resolution remote sensing measurement methodologies of wind and turbulence for wind energy

The WindScanner.eu facility is a laser-based wind measurement system that can generate detailed maps of wind conditions above and from inside a wind farm covering several square kilometers. The facility, headed up by Department of Wind Energy at the Technical University of Denmark (DTU Wind Energy) relies on innovative remote sensing laser-based wind measurement devises called Lidars (Light detection and ranging). Its vision is: to develop, establish and operate a joint European distributed (and mobile) Research Infrastructure for experimental research in wind and turbulence fields for wind Energy.
In pursuit of the Commission's Europe 2020 Strategy and the SET-Plan strategy, the new European WindScanner.eu facility will be established to spur and create accelerated synergies

including innovation between the existing European EERA partners much beyond the individual sum of existing national level R&D services. As a result, enhanced information exchange and innovation activities are envisioned among Europe's atmospheric research communities and the wind energy society and industry engaged.

The WindScanner.eu measurement technology enables innovative three-dimensional (3D) "view" of the wind movements in real-time, thus improving our fundamental understanding of the complex turbulent wind flow and its interaction with e.g. operating wind turbines.

Innovative mobile WindScanner.eu Lidar equipment and products, reflecting the newest technological, aesthetic and social innovation obtainable through common sharing of ideas and visions within the EERA consortium, will provide a new generation of WindScanner.eu equipment, to be distributed to the consortia 6-7 new regional distributed WindScanner.eu nodes, including detailed manufacturing plans and test prototypes.

The WindScanner.eu aims to be an Open Access distributed and mobile research infrastructure promoting the dissemination of results including innovation products and their exploitation.

The WindScanner.eu is a distributed facility and requires the implementation at a central entity – referred to as the WindScanner.eu Central Hub (WCH) - and at several MS located entities called National Nodes (NN). Adding more complexity to the matter of the distributed facility we found that investment decision criteria and research support is not coherent in the partners' countries. The implementation of the WCH and the NNs requires being coordinated for a sensible and successful implementation. This has been entitled to WP4 of the Preparatory Phase with the following objectives:

1. Establish coherence and scheduling for the implementation of the distributed WindScanner.eu Facilities in the NNs and to ensure the coordination of the activities conducted.
2. To set out the principles for the services provided by the WCH to the NNs as well as the conditions applying.
3. To create a good synergy and optimal use of resources between the measurements requirements and measurement projects developed by EERA and the WindScanner.eu.

<u>The Kassel Experiment</u>

The Kassel experiment has been planed and performed as a demonstration case for the long range Windscanner system, based on the Leosphere Windcube 200-S lidars. The experiment included one set of 3 Windscanners based on the Windcube 200-S lidar version 1 (v1), and one set on 3 Windscanners based on the Windcube 200-S lidar version 2 (v2). The systems have been installed at several distances and directions from a tall 200 m highmeteorological mast, instrumented with sonic anemometers at several heights. The time period of the experiment included the months of July and August 2014.

Some of the objectives of the Kassel experiment include: to verify the correct operation of the individual Windscanners, to verify the correct time synchronization of all the units done by the master controller, to compare the Windscanner measurements against sonic anemometers installed in a tall met mast at several heights, to assess the data quality from the Windscanners installed at different distances, to assess the data availability during the measurement campaign, to quantify the amount of data generated during the measurement campaign, to share the wind velocity data among the project partners and to develop common criteria for the data analysis.

The Kassel Windscanner experiment has been developed within the context of the FP7 ESFRI WindScanner Preparatory Phase project, which is currently ongoing and will end by late 2015.

The Kassel experiment will contribute to the timely preparation of the technical aspects, necessary for the establishment and operation of the future joint and distributed European WindScanner.eu facility.

FP7-INFRASTRUCTURES-2012-1. WINDSCANNER— WindScanner.eu - The European WindScanner Facility	
WindScanner.eu	**Partcipants** DANMARKS TEKNISKE UNIVERSITET (DTU), FUNDACION CENER-CIEMAT (CENER), STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND (ECN), KENTRO ANANEOSIMON PIGON KE EXIKONOMISIS ENERGEIAS (CRES), FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V (Fraunhofer), SINTEF ENERGI AS (SINTEF), Laboratorio Nacional de Energia e Geologia I.P. (LNEG/INETI), CARL VON OSSIETZKY UNIVERSITAET OLDENBURG (FORWIND), UNIVERSIDADE DO PORTO (Uporto), INSTITUTTET FOR PRODUKTUDVIKLING - IPU (IPU).
http://www.windscanner.eu/	**General Description** The ESFRI WindScanner Preparatory Phase (PP) project develops the governance scheme, legal model, and the final technological design and associated budget and financing models for its construction by 2016. The WINDSCANNER PP project will address coordinated European development of the facility in a joint technological and economically substantial European approach.
	Contribution in Aerodynamic R&D 3D measurements of the wind field with a range up to 6 km for the long range Windscanner. This allows the characterization and mapping of the wind resource in a determine site. Additionally the short range wind scanner can measure at high resolution the wind field approaching a wind turbine and the turbine wake, allowing the implementation of improved turbine control techniques.

7.1 Report on Milestones

Mile-stone	Objective	Date	Partners	Person months	Comments /project	Status - end 2014
M1	RT2: EERA facilities catalogue	March 2015	CENER	2	IRPWIND	COMPLETED
			All EERA[i]	2		
M2	RT2: Rules and Conditions for Joint Tests	March 2015	CENER	2	IRPWIND	ON GOING
M3	RT2: Call for Experiments for Existing Facilities (IRP)	10-2015 06-2016 01-2017	All EERA[ii]	5 5 5	IRPWIND, start 2015	ON GOING
M4	RT3: Definition of Windbench.eu work program	March 2015	CENER	2	IRPWIND	ON GOING
			ECN[iii]	1	Windscanner.eu	ON GOING
M5	RT4: Start of Drive Train Working Group	February 2014	BERA[iv] CENER DTU IWES NAREC	1,0 1,0 1,0 1,0 1,0	INFRAIA	???
M6	RT1: Report on Networking Activities	03-2015 03-2016 03-2017 03-2018	IRPWIND	1,5 x 4	IRPWIND	COMPLETED
			BERA[v] ForWind (2) CRES NTNU SINTEF CENER UDelft (2) METU Tecnalia UStrath. IREC	2x3 4x3 2x3 2x3 2x3 2x3 4x3 2x3 2x3 2x3 2x3		
M7	RT3: Roadmap for the construction phase of the european Windscanner.eu	October 2015	DTU[vi] CENER ECN CRES IWES SINTEF LNEG FORWIND UPorto	67 33 33 27 33 33 27 27 27	Winscanner PP	ON GOING
M8	RT3: Planning for the implementing of the national nodes of windscanner.	April 2015	DTU CENER ECN CRES IWES SINTEF LNEG FORWIND UPorto	3 3 3 3 3 3 3 3 3	Winscanner PP	ON GOING

M9	RT3: Start of operation of Windbench.eu	December 2015	CENER[vii]	6	IRPWIND and others	ON GOING

7.2 Contact Point

Att. Antonio Ugarte, Head of Wind Energy Division
CENER – National Renewable Energy Centre
Avenida de la Innovación, nº 7
31621 Sarriguren
Spain
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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Economic and social aspects of wind integration

Yearly reporting - 2014

8. Sub-programme on Economic and social aspects of wind integration

A new sub-programme was launched in October 2014. The new sub-programme will explore the major economic and social challenges for wind energy now and in the future and will investigate how they can be addressed and mitigated.
The sub-programme was approved by the EERA jp Wind steering committee in September '14. From the launch there has been very good support to the new sub-programme. The official kick-off meeting of the sub-programme was held at DTU Management Engineering in Roskilde (Denmark) in November 2014 with 22 participants from 14 different EERA Wind member institutions.

8.1 Report on Milestones

Milestone	Objectives	Project Month	Status - end 2014
M1-2	*Kick-off meeting and preparation of research roadmap for the sub-programme*	*3*	*Done 13 Nov 2014*
	Contribute to EERA jp WIND's suggestions for H2020 WP 2016-17	*4*	*Done December 2014*
	Organise session at EERA DeepWind conference	*8*	*Scheduled 5 February 2015*
M3	*RT1: Workshop and review report on 'status-quo' of component and system cost development and related research needs*	*9*	*Scheduled to May 2015*
M4	*RT6: Workshop on public acceptance issues of onshore wind energy*	*9*	*Scheduled 9 March 2015*
	Make Call for EoI within market uptake of wind and public acceptance	*9*	*February - March 2015*
M5	*RT2: Report on future policy support options for offshore wind energy in Europe*	*12 - 14*	*2015*
M6	*RT3: Workshop on economic integration options and how to model effects in energy systems models for high wind energy scenarios*	*14*	*2015*
M7	*RT4: Report on merit-order effects of wind power on spot markets*	*18*	*2016*
M8	*RT5: Report on a comparison and assessment of different methods to evaluate environmental impacts on wind energy*	*24*	*2016*

8.2 International collaboration in 2014

Several groups of members were formed at the Kick-off meeting in order to start creating EoI's and organizing the different milestones. By the end of 2014 no concrete international projects had been funded.

8.3 National projects

A mapping of interest and ongoing projects within the sub-group members were made in connection to the Kick-off meeting in November 2014.

8.4 Publications in 2014

No publications were made in 2014. However, several presentation were made, e.g. at the EERA conference in Amsterdam in September 2014.

8.5 Contact Point for the sub-programme on Economic and social aspects of wind integration

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[i] **This is the total effort of members to document and format their labs.**
[ii] **This will be the effort to design, negotiate, budget and Schedule the experiments proposed to the calls.**
[iii] **Windscanner is planning study cases managemente and ECN as coordinator will see how to apply Windbench.eu. CENER's contribution has not been added but might also be required if it is finally incorporated.**
[iv] **This is a very conservative estimation of the efforts to design a workprogram and the proposal preparation.**
[v] **This is an estimation of the participation. First year has less Activity. These are the institutes who sent an EOI.**
[vi] **The PP serves this pourpouse. Only national Coordination of nodes is excluded and added afterwards.**
[vii] **Estimation of effort top ut i ton operation.**