IRPWind

Integrated Research Programme
on Wind Energy

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Definitions

EERA	European Energy Research Alliance	SP	Sub programme
JP	Joint Programme	SAP	Strategic Action Plan
EERA JP Wind	EERA Joint Programme on Wind Energy	SR	Strategy and Roadmap
IRP	Integrated Research Programme	EWI	European Wind Initiative
WP	Work Package		

1. Executive Summary

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

2015 has been a year for revision as well as increased operationalisation in JPWind and the IRPWind project. The latter has clearly given a significant boost to the coordinating activities in JPWind; the mobility programme and the IRPWind conferences being good examples of this. However, during 2015 we are also starting to see how the Joint Programme can leverage the activities done in the IRPWind; the EuropeanWindProjects database launched as part of IRPWind was considered so important that an improved version of the database will be funded by JPWind membership fees; and the IRPWind core projects have been integrated into the JPWind project portfolio which will also include the LIFE50+ project funded under Horizon 2020 awarded in 2015.

The LIFE50+ was however the exception to an otherwise poor statistics in the success rate for Horizon 2020 proposals by JPWind consortia. Compared to FP7 where JPWind consortia won more than 80% of proposals in the last part of the programme, the success rate dropped significantly in H2020. Although the bulk of activities in JPWind are funded by national funding, European projects remain the most important source for projects which link national efforts together and increase the research coordination in JPWind. At the JPWind Steering Committee meeting in Paris November 2015 a number of initiatives was therefore launched to improve this. First of all the process for setting up JPWind consortia H2020 will be revised, secondly the JPs Sub-programme structure will be evaluated and last but not least a number of pilot initiatives will be launched in 2016 to increase the competitive advantage of JPwind consortia for future calls.

Meanwhile, the IRPWind project moved from the start-up phase to operationalisation. 8 applications for mobility grants were approved for the 2nd and 3rd mobility call during 2015. The second IRPWind conference was also held and the first call for joint experiments under the research infrastructure scheme was prepared for launch in early 2016. The three core projects delivered on offshore benchmark exercises, material models for structural analysis as well as elaborated on the work on providing ancillary services and grid stability mechanisms similar to conventional power plants. This work will continue with undiminished speed in 2016.

1.2 Mobility

In 2015 the mobility programme continued to receive a steady number of applications, but less than targeted. The numbers for the first calls, including call 2 and 3 approved in 2015 can be seen in the table below.

Name	Call	Home Institute	Months	Days	Travel	Expenses	Total
Javier Estarriaga	1	CENER	1	30	600	4830	5430
Callies	1	IWES	3	90	600	9450	10050
Busmann	1	IWES	3	90	600	9450	10050
Ainara Irisarri Ruiz	1	CENER	3	90	600	9450	10050
Jens Sørensen	1	DTU	1	30	600	4830	5430
Olimpo Anya-Lara	1	U-Strath.	1	30	600	4830	5430
Hannele Holttinen 1	2	VTT	3	90	600	9450	10050
Hannele Holttinen 2	2	VTT	3	90	600	9450	10050
Xavier Munduate	2	CENER	3	90	600	9450	10050
Wiggelinkhuizen	2	ECN	1	30	600	4830	5430
Vasiljievic (TEM)	2	DTU	3	90	600	9450	10050
Malo Rosemeier	3	IWES	3	90	600	9450	10050
Dominguez-Garcia	3	IREC	3	90	600	9450	10050
Nestor Ramos Garcia (FLU)	3	DTU	1	30	600	4830	5430
* 2nd pilot scheme			Weeks				
Hannele Holttinen 3 *	4	VTT	7	49	600	5145	5745
Teresa Lofeudo*	4	CNR	4	28	600	4508	5108
Pawel Garcanski *	4	CENER	4	28	600	4508	5108
Kristian Vrana*	4	SINTEF	17	119	600	12495	13095
Ariane Frere*	4	BERA	13	91	600	9555	10155
DePrada*	4	IREC	12	84	600	8820	9420
Philipp Härtel*	4	IWES	13	91	600	9555	10155
TOTAL for year 1 and 2							**176386**

In order to incentivise the applications, discussions were opened with IRPWind and EERA researchers when discussing the European Mobility best practices during the two IRPWind general assemblies in 2014 and 2015. From the analysis of the statistics, it emerges that issue here is not the scheme but the inertia of applying due to family logistics. Following this, a proposal for an amendment to the mobility scheme was therefore presented to the European Commission to increase the flexibility of the scheme.

1.3 IRPWIND KPIs – 2014 values

Collection of KPI for all JPWind full participants covering 2014		Figures collected 2014	Starting values for IRPWInd	Target after 24 months	Target after 48 Months
KPI_1.	Number of national research programmes contributing to the long-term R&D strategy defined at EU level	33	13	13	13
KPI_2.	Total budget from national research programmes contributing to the long-term R&D strategy defined at EU level		30	30	30
KPI_3.	Number of joint publications by IRP participants supported by EU funding accepted/published in peer-reviewed journals	17	17*	>40	>100

KPI_4.	Number of joint publications by IRP participants supported by national funding accepted/published in peer-reviewed journals	50	>20	>25	>60
KPI_5.	Number of tests carried out at the facilities of each IRP participant	11	2	3	6
KPI_6.	Number of round-robin sessions carried out at the facilities of each IRP participant	6	0	2	4
KPI_7.	Number of joint tests carried out by two or more IRP participants	29	2	3	6
KPI_8.	Total duration (days) of joint tests carried out by two or more IRP participants	126	36	36	48
KPI_9.	Number of cross tests carried out by two or more IRP participants during the last 2 years				
KPI_10.	Total duration (days) of cross tests carried out by two or more IRP participants during the last 2 years				
KPI_11.	Number of jointly planned new research facilities at national level	9	0	0	0
KPI_12.	Number of jointly planned new research facilities at international level	7	0	1	1
KPI_13.	Number of Memoranda of Understanding (MoU) and agreements on the joint use and development of research facilities	2	2	3	6
KPI_14.	Number of researchers involved in mobility and exchange programmes	9	0	23	>36
KPI_15.	Number of reports from researchers involved in mobility and exchange programmes	4	0	11	>36
KPI_16.	Number of days of mobility and exchange	273	0	900	1800
KPI_17.	Number of joint publications related to the participation in the exchange programmes	0	0	>5	>25
KPI_18.	Number of dissemination events related to the participation in the exchange programmes	1	0	1	3
KPI_19.	Number of agreements between each IRP participants and industry (among others: contract research, license agreements, cooperation agreements, etc.)	426	>700	>1000	>1500
KPI_20.	Number of agreements between at least two IRP participants and industry (contract research, license agreements, cooperation agreements, etc.)	35	>20	>40	>60
KPI_21.	Number of patent applications submitted by IRP Participants	9	14	14	>14

KPI_22.	Number of patent applications by at least two IRP participants	0	0	0	0
KPI_23.	Number of IP assets entered into the web-based IP show case, maintained by the EERA Secretariat	0	0	>100	>100
KPI_24.	Number of industry stakeholders involved in IRP R&D, or accessing IRP research facilities, or licensees of the IP generated within the IRP, or partners in the mobility programme	70	>10	>40	>50

In 2015 IRPWind collected KPIs from all full participants of EERA JPWind covering 2014. KPI data for 2015 will be collected from all EERA JPWind full and associate participants during May-June 2015. The KPIs are included here to provide first data on collected information as an activity initiated in 2015.
The KPIs collected for 2014 shows satisfying numbers with only 3 KPIs out of 24 scoring below target. However, the discrepancy between starting values based on assessment by full partners also shows the difficulties in reporting on some KPIs as well as the lack of knowledge/data in certain areas. For example a total of 33 national programmes was identified funding wind research in the countries of full participants compared to the estimated 13 indicated at starting values. The lack of knowledge about national programmes was also visible in the survey conducted during the 1st year of IRPWInd on national funding sources with reference to deliverable 2.5.

Based on the preparation of starting values and the collection of the first round of KPIs, the EERA JPWind management board has decided to focus attention on a limited set of the above KPIs which are considered particularly relevant for the development of the JP as they directly reflects activities ongoing in both IRPWind and JPWind. In some cases, IRPWind KPIs have been merged to ensure a focused reporting. The KPIs identified by JP Wind are:

Publications: In place of the current KPIs1-4, *JPWind will track the number of publications from all EERA Projects*

Research facilities: KPIs 7-8 and 12-13

Mobility: KPI 14-17

Innovation: KPIs 21-24

Progress on these selected KPIs will be presented and discussed at JPWind Steering Committee Meetings once every year.

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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 2015

1.5 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.

Fraunhofer IWES is working in collaboration with the universities of Oldenburg on the generation of turbulent inflow fields for CFD-Simulations. The aim is to include the intermittent characteristics of wind in the wind field simulations. However, it has been guaranteed, that the physis characteristics of the turbulence are not violated. Therefore, an generator for turbulent inflow based on the CTRW-wind field model has been implemented in the open source CFD code OpenFOAM.
USTUTT-IAG focussed to study the impact of atmospheric turbulent inflow conditions on the unsteady loads and performance of wind turbines by means of high-fidelity time-resolving numerical methods. Unsteady anisotropic flow fields are fed in the CFD simulation domain and during 2015 the evolution and potential decay of turbulence caused by numerical effects has been studied. Based on the findings of these studies best practices have been derived. Different synthetic turbulence generators are examined and the impact of the numerical scheme and the discretization have been investigated. The simulations have been expanded to the consideration of complex terrain effects and wake impacts of interacting turbines.
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.

In the field of aerodynamics several works have been done in the collaboration between the university of Oldenburg and Fraunhofer IWES. One field was the investigation of fluid structure interaction effects on wind turbine aerodynamics. Here a fully coupled fluid structure interaction model has been implemented in OpenFOAM. Also investigations on 3D effects on wind turbine rotors and the temporal effect of towers on down wind turbines were in the focus of the research.

At USTUTT-IAG noise prediction models are continuously enhanced with regard to better consideration of turbulence anisotropy effects and weak flow separation from the blade. To predict the underlying aerodynamic flow fields different classes of aerodynamic prediction models from fast design codes to time-resolving LES approaches are being utilized. The enhanced methods are applied to design low noise airfoil and to verify their performance. Further, design and analysis models are developed for the design of active noise reduction devices.

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 is currently 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. Within Mexnext-III a first round of calculations is performed and compared with New Mexic measurements. The agreement between calculations and measurements was better than before but some of the discrepancies need further investigations

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, airfoil measurements were carried out in the pressurized tunnel of DNW-HDG where the pressurization leads to Reynolds numbers up to 15 Million which are representative for large wind turbines but which on normal wind tunnel scale cannot be reached under atmospheric circumstances.

Results of the blind test confirm that some boundary layer transition models (in particular the so-called e^N method) perform much better than others, e.g. correlation based transition models A website has been created www.eera-avatar.eu.

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.

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 a software based on 2D and 3D Navier Stokes solvers for noise calculations.

DTU: MIRAS is a computational model for predicting the aerodynamic behavior 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. 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. 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.

CNR research activity has been focused on the development and validation of computational models for the analysis of wind rotor performance. This includes both viscous flow models (RANSE, LES, DES) as well as on inviscid flow models (Blade Element Methods, Boundary Element Methods). Dealing with CFD models, in the framework of the Blind Test Workshop series organized by the Norwegian University of Science and Technology (NTNU), CNR is performing an ongoing research activity focused on the aerodynamics of a three-bladed horizontal axis wind turbine (HAWT) model. This model has been thoroughly studied in the NTNU wind tunnel facility providing a valuable experimental database that is well suited for the validation of numerical solvers. In a recent activity, the CFD team of CNR has investigated a novel numerical technique to efficiently take into account the wind tunnel blockage effects retaining accurate prediction of the HAWT wake features. In the area of inviscid-flow models, the activity is aimed at developing 2D/3D computational aerodynamics models for the aeroelastic analysis of horizontal-axis wind turbine rotors under axial/yawed flow conditions and with a significant vertical shear layer. Blade sectional aerodynamics is described by the Beddoes-Leishman unsteady, compressible state-space formulation which take into account the nonlinear effects induced by flow separation and dynamic stall. Three-dimensional wake inflow is predicted by a free-wake Boundary Element Method (BEM) for attached, potential flows around lifting bodies. Widely-used semi-empirical corrections based on the laminar boundary layer theory are used to take into account stall delay, deep stall and post-stall conditions.

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.

Fraunhofer IWES has developed a method to model wind turbine wakes, based on CFD precalculations. Using this work, the focus of the research on wakes was mainly on the behaviour of wakes in complex terrain. Different models have been compared to full CFD calculations of the wake in complex terrain.

At USTUTT-IAG the impact of atmospheric inflow and complex terrain on the development of wind turbine wakes are simulated by means of eddy resolving hybrid RANS/LES methods in combination with high order WENO reconstruction schemes. Further the impact of interaction with wakes of other wind turbines in a wind park are studies. For this purpose the actuator line method is applied or fully meshed wind turbines are considered. The current focus is on the near wake effects which is one task within MexNext III.

At ECN a large project in the context of the FLOW (Fart and Large Offshore Wind) programme has been finished. Detailed and accurate wake models have been developed and tested that are suitable for the development of wind farm control, also called Active Wake Control.

CNR has started a preliminary CFD analysis of wake effects on wind turbines flow and performance in a small wind farm. In details, a notional setup consisting of two wind turbines addressed by an experimental campaign performed by the Norwegian University of Science and Technology (NTNU), allows to study the aerodynamic interaction between two wind turbines considering different configurations.

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.

At USTUTT-IAG a CFD-based aeroelastic coupling has been improved by implementation of a new mesh deformator enabling consideration of arbitrary deformations as well as active trailing and leading edge flaps. During 2015 the coupling to a second beam-based structural model has been realized. The coupled codes are used to examine the impact of high-fidelity CFD-based aerodynamic predictions within aeroelastic simulations compared to simplified BEM-based aerodynamics. In particular the rotor load spectra under atmospheric inflow conditions in flat and complex terrain are analyzed.

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.

CNR has developed a Finite Element Method (FEM)-based aeroelastic solver for the analysis of turbine rotor response and performance. Turbine rotor aeroelastic model is achieved by coupling a beam-like blade structural dynamics formulation with the unsteady aerodynamics load model described in section RT4.

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.

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. One focus of the 2015 activities was to study the impact of spanwise limited flaps on the wake and the resulting (unsteady) radial load distribution to identify weaknesses in BEM-based calculations and available wake models for rotors with active flaps.

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

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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. These measurements have been analysed in collaboration in 2016.
In the framework of the innovative rotor aerodynamic designs of INNWIND.EU CRES the concept of Low Induction Rotors (LIRs) has been investigated. 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. Within INNWIND.EU a new family of low design lift profiles are developed which maximize the benefits of LIR operation.

1.6 Reporting on Milestones and deliverables

Mile-stone	Objective/title	Nature	Delivery	Lead partners	Comments	Status – end 2015
1	Evaluation of the AVATAR RWT and cross-comparison with the	report	Evaluation of the AVATAR RWT and cross-comparison	2.6		Finished
2	Workshop spring 2015	workshop	March 2015	All		Finished
	Workshop autumn 2015	workshop	Sept 2015	All		Finished

1.7 International collaboration in 2015

The partners in EERA-Aerodynamics are involved a.o. in the European collaborative projects AVATAR, InnWind and ESWIRP and are all active member 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	
	Partcipants 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 airfoils 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	
	Partcipants 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	
iea wind	**Partcipants** CWEA , DTU Wind Energy, University of Stuttgart (IAG), University of Applied Sciences, Kiel, Forwind and Fraunhofer IWES, WindNovation, Technion, Mie University, ECN, TUDelft, Suzlon Blade Technology, University of Twente, IFE/NTNU, CENER, University of Uppsala , NREL, CORIA, EDF, ONERA, IFPEN
http://www.mexnext.org/	**General Description** The objective of IEA Wind Task MEXNEX(T) is a thorough investigation of various aerodynamic measurements with emphasis on the so-called '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.	

Cluster Design	
	Partcipants 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

NORCOWE	
norcowe Norwegian Centre for Offshore Wind Energy	**Partcipants** Christian Michelsen Research AS (project manager), Uni Research, University of Agder, University of Bergen, University of Stavanger, Aalborg University, Acona Flow Technology, Aquiloz, AXYS Technologies, Leosphere, Norwegian Meteorological Institute (MET), Statkraft, Statoil and StormGeo
www.norcowe.no/	**General Description** NORCOWE is a Norwegian centre for Offshore Wind Energy, partially funded for eight years by the Research Council of Norway, which has three international partners: Aalborg University, AXYS Technologies and Leosphere. The research areas cover wind and ocean conditions, wind energy estimation and offshore deployment and operations. The centre has MoUs with Fraunhofer IWES, NREL, ECN and DTU.
	Contribution in Aerodynamic R&D In 2015 OBLEX-F1 at FINO1 was started – a comprehensive measurement campaign that will continue until September 2016. The measurement campaign involves, in addition to NORCOWE partners, FuE-Zentrum FH Kiel, Fraunhofer IWES, RAVE and ForWind.

CNR is also partner of the Norwegian Centre of Excellence AMOS, NTNU (Centre for Autonomous Marine Operations and Systems). This centre has among its interests: optimization and fault-tolerant control of offshore renewable energy systems; autonomous marine operations in extreme seas, violent water-structure interactions, deep waters and Arctic; consequences of accidental and abnormal events on ships and offshore structures. CNR-INSEAN has also started a cooperation with the Technical University of Denmark (DTU) - Department of Wind Energy on the subject "Remaining lifetime of wind turbines blades".

USTUTT-IAG is involved in the European collaborative wind projects AVATAR and InnWind.eu and is furthermore an active member of the IEA Annex MexNext III. Besides basic research activities in the field of aerodynamics and aeroacoustics the IAG cooperates with different national and international wind turbine manufacturers.
CENER is involved in European projects under the scope of FP7 such as INNWIND.EU, AVATAR, WINDTRUST and WINDUR. The main activities in the aerodynamics field are CFD development calculations both in 2D configurations and 3D configurations (airfoil level and wind turbine level), offshore activities such as platform design, wave tank tests design and performance, airfoil dynamics calculations (Adaptfoil and Dystool), blade design (BladeOASIS), airfoil design, vertical axis wind turbine design and design and performance of airfoil wind tunnel tests.

1.8 National projects

NORCOWE: Within NORCOWE (see above) Christian Michelsen Research is involved in WP1 (Met-Ocean Data) and WP2 (Wind energy estimation) as well as being project manager. Within WP1 our main focus is measurement campaigns, while the work within WP2 is focused on replacing CFD with model reduction for optimizing the layout of offshore wind farms.

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), LiDAR Complex (time-resolved flow simulations of wind turbines in complex terrain), OWEA Loads (simulation of interacting offshore wind turbines) and heads the ActiQuieter project (active noise reduction).

CNR participates in the national flagship project RITMARE. It is the leading national marine research project for the period 2012-2016; the overall project budget amounts to 250 million euros, co-funded by public and private resources. This project is coordinated by the National Research Council (CNR) and involves an integrated effort of most of the scientific community working on marine and maritime issues, as well as some major industrial groups. Within this project, CNR-INSEAN is responsible, among other activities, for the development of experimental techniques and numerical tools for the analysis and design of renewable energy devices to exploit wind and marine currents.

CENER participates in several national projects; the AEROS project is focused on the inspection of WT using RPA´s and in the evaluation using CFD of the performance of the blades including erosion, manufacturing defects, etc. The Aditech-projects funds the development and improvement of CENER blade design tool (BladeOASIS).

DTU is working on a project under the title *Effect of hub height on power curve.* The work is commissioned by DONG Energy Wind Power A/S and the report is confidential. The influence of the hub height on the power coefficient is investigated using Computational Fluid Dynamics.

1.9 Publications in 2015

Fraunhofer

- Herraez, J. Peinke, B. Stoevesandt, “Numerical Study of Rotational Effects on Wind Turbines”, Proceedings of the 12th DEWEK conference 2015, http://www.dewi.de/DwK15pRocD/
- B. Stoevesandt, F. Habib, B. Mehra, H. Rahimi, J. Peinke, “Numerical Investigation on Tower Effects for Downwind Turbines”, Proceedings of the 12th DEWEK conference 2015, http://www.dewi.de/DwK15pRocD/
- B. Dose, J. Peinke, B. Stoevesandt: “Studying the Effect of Blade Deflections on the Aerodynamic Performance of Wind Turbine Blades Using OpenFOAM”, Proceedings of the 12th DEWEK conference 2015, http://www.dewi.de/DwK15pRocD/
- Caldas, J. , Zaparoli, E. L., Chang, C. Y.,Peralta, C., Schmidt, J. and Stoevesandt, B., Topographic effects on the wakes of a large wind farm, Proceedings of the 12th DEWEK conference 2015, http://www.dewi.de/DwK15pRocD/

- Jonas Schmidt, Bernhard Stoevesandt: The impact of wake models on wind farm layout optimization, Journal of Physics Conference Series 06/2015; 625(1), Proceeding of the Wind farm Wakes Conf 2015, GW-Wakes, DOI:10.1088/1742-6596/625/1/012040
- Jonas Schmidt, Bernhard Stoevesandt: Wind Farm Layout Optimization in Complex Terrain with CFD Wakes, Proceedings of the EWEA 2015

NORCOWE:

- Kumer V.-M., Reuder J., Svardal B., Saetre C., Eecen P.: Characterisation of single wind turbine wakes with static and scanning WINTWEX-W LiDAR data, accepted for publication in Energy Procedia
- M. Flugge , S. Benny, J. Reuder, M. Bakhoday Paskyabi, The Norwegian Offshore Boundary Layer Observatory for wind energy assessment , Deep Wind 2015, Trondheim, Norway.
- J. W. Wagenaar, K. Boorsma, E. Bot, S. Davoust, B. Svardal, Using backward nacelle LiDAR in wake characterization for wind farm optimization, EWEA Offshore 2015
- Heggelund Y., Khalil M., Jarvis C., Reduced order modeling of wind farms based on CFD: wind speed effects, Conference paper, EWEA Offshore 2015, Copenhagen, Denmark, 10-12 March 2015.
- Heggelund Y., Khalil M., Jarvis C. A fast reduced order method for assessment of wind farm layouts. Poster. EWEA Offshore 2015 conference, Copenhagen, 10-12 March 2015.

CNR

- Calabretta, A., Testa, C., Greco, L., Gennaretti, M. (2015), "Finite Element Analysis of Horizontal Axis Wind Turbines Performance," 6th International Conference on Computational Methods in Marine Engineering (MARINE 2015), Rome (Italy), June 2015.
- Calabretta, A., Testa, C., Greco, L., Gennaretti, M (2015) "Assessment of a FEM-based Formulation for Horizontal Axis Wind Turbine Rotors Aeroelasticity ," Applied Mechanics and Materials, Vol. 798, pp. 75-84.
- Greco, L., Pucci, M., Testa, C., Vitale, G., Cirrincione, M. (2015), "Effectiveness of a GNG-based MPPT and related Control System for Marine Current Turbines in Unsteady Operating Conditions," IEEE Energy Conversion Congress and Exposition (ECCE2015), Montreal (Canada), September 2015.
- Marino, E., Nguyen, H., Lugni, C., Manuel, L., and Borri, C. (2015), "Irregular Nonlinear Wave Simulation and Associated Loads on Offshore Wind Turbines". In: J. Offshore Mech. Arct. Eng. 137(2), doi: 10.1115/1.4029212.

USTUTT-IAG

- Th. Lutz, B. Arnold, D. Bekiropoulos, J. Illg, E. Krämer, A. Wolf, R. Hann and M. Kamruzzaman: „Prediction of Flow-Induced Noise Sources of Wind Turbines“, Special Issue of the International Journal of Aeroacoustics, Volume 14, Issue 5-6, 2015, DOI: 10.1260/1475-472X.14.5-6.675.
- Fischer, Th. Lutz, E. Krämer, U. Cordes, K. Hufnagel and C. Tropea: "Experimental and Numerical Generation of Turbulent Inflow Conditions for Wind Turbine Airfoils", Proc. 12th German Wind Energy Conference DEWEK, 19./20. May 2015, Bremen, Germany, conference proceedings, 2015.
- Th. Lutz, D. Bekiropoulos, J. Illg, W. Würz, J. Dembowski, E. Krämer: "RANS Based Prediction of the Airfoil Turbulent Boundary Layer – Trailing Edge Interaction Noise for Mildly Separated Flow Conditions", Proc. 12th German Wind Energy Conference DEWEK, 19./20. May 2015, Bremen, Germany.

- J. Illg, Th. Lutz and E. Krämer: “Aeroacoustic Simulation of an Airfoil in Turbulent Inflow”, Proc. 6th International Conference on Wind Turbine Noise, Glasgow, 20.-23. April 2015
- J. Illg, Th. Lutz, I. Neunaber und E. Krämer: “Numerische Untersuchung von Vorder- und Hinterkantenläarm eines Profils in turbulenter Anströmung”, Proc. 41. Jahrestagung für Akustik DAGA, Nürnberg, 16. - 19. März 2015.
- Y. Kim, W. Pascal, Th. Lutz: “An accurate wind resource assessment in complex terrain using numerical simulations“, Proc. 12th German wind energy conference, DEWEK 2015, May, Bremen, Germany.
- Y. Kim, C. Schulz, Th. Lutz: "Synthetic turbulence inflow method for atmospheric turbulence and its application in complex terrain", Proc. EAWE PhD seminar 2015, Stuttgart, Germany.
- Y. Kim, P. Weihing, C. Schulz, E. Jost, Th. Lutz: “Turbulence inflow generation for a turbulent boundary layer over rough hills under neutral and stable conditions”, Large wind-power plants: interaction, control and Integration. Proc. Windfarms 2015, July, Leuven, Belgium.
- G. Bangga, Th. Lutz and E. Krämer: "Numerical investigation of unsteady aerodynamic effects on thick flatback airfoils", Proc. German Wind Energy Conference 12 DEWEK 2015, 19-20 May 2015, Bremen, Germany.
- G. Bangga, Th. Lutz and E. Krämer: "An examination of rotational effects on large wind turbine blades", Proc. 11th EAWE PhD Seminar on Wind Energy in Europe, 23-25 September 2015, Stuttgart, Germany.
- M. Kamruzzaman, D. Bekiropoulos, Th. Lutz, W. Würz and E. Krämer: „A semi-empirical surface pressure spectrum model for airfoil trailing-edge noise prediction,“Special Issue of the Int. Journal of Aeroacoustics, Volume 14, Issue 5-6, 2015.
- Schulz, A. Fischer, P. Weihing, Th. Lutz and E. Krämer: "Evaluation and Control of Wind Turbines under Different Operation Conditions by means of CFD", "High Performance Computing in Science and Engineering '15", Springer International Publishing.
- Fischer, Th. Lutz, E. Krämer: "Numerical investigations of an airfoil in the wake of a slotted cylinder", Proc. 11th EAWE PhD Seminar on Wind Energy in Europe, 23.-25. September 2015, Stuttgart, Germany.
- E. Jost, Th. Lutz, E. Krämer: "Steady and unsteady CFD power curve simulation of generic 10 MW turbines", 11th EAWE PhD Seminar on Wind Energy in Europe, 23.-25. September 2015, Stuttgart, Germany.

CENER

- Nygaard T A., Azcona, J Design, Analysis and Wave Tank Testing of a Semi-Submersible Braceless Concrete Offshore Wind Turbine Platform. DeepWind'2015, 12th Deep Sea Offshore Wind R&D Conference, Trondheim, Norway, 2015.
- Sandner, f., Amann, F., Matha, D., Azcona, J., Munduate, X., Bottasso, C. L., Campagnolo, F., Bredmose, H., Manjock, A., Pereira, R. and Robertson, A. Model Building and Scaled Testing of a 5MW and 10MW Semi-Submersible Wind Turbines. . DeepWind'2015, 12th Deep Sea Offshore Wind R&D Conference, Trondheim, Norway, 2015.
- José Azcona, Frank Sandner, Andreas Manjock, Henrik Bredmose Rotor aerodynamics for tank testing of scaled floating wind turbines. EWEA Offshore 2015,Copenhagen, 10-12 March 2015
- M. Carrion, M. Woodgate,R. Steijl,G. Barakos, S. Gomez-Iradi, X. Munduate. Understanding Wind-Turbine Wake Breakdown Using Computational Fluid Dynamics. AIAA Journal. 53 (3). pp. 588-602 (2015)

- B. Mendez, A Muñoz, X. Munduate. Study of distributed roughness effect over wind turbine airfoil performance using CFD. AIAA 2015-0994. AIAA Scitech 33rd Wind Energy Symposium, Florida, January 2015.
- M. Carrion, M. Woodgate, R. Steijl, G. Barakos, S. Gomez-Iradi y X. Munduate. Computational fluid dynamics analysis of the wake behind the MEXICO rotor in axial flow conditions. Wind Energy journal: Vol. 18, No. June 2015

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- Analysis of Two-Dimensional Inflow Measurements by Lidar-Based Wind Scanners. / Meyer Forsting, Alexander Raul; Troldborg, Niels; Sathe, Ameya; Angelou, Nikolas. 2015. Paper presented at 11th EAWE PhD seminar on Wind Energy in Europe, Stuttgart, Germany.
- Analytical velocity field in just a sec. / Branlard, Emmanuel Simon Pierre; Meyer Forsting, Alexander Raul. 2015. Poster session presented at EWEA Offshore 2015 Conference, Copenhagen, Denmark.
- Broadband Trailing-Edge Noise Predictions - Overview of BANC-III Results. / Herr, M.; Ewert, R.; Rautmann, C.; Kamruzzaman, M.; Bekiropoulos, D.; Iob, A.; Arina, R.; Batten, P.; Chakravarthy, S.; Bertagnolio, Franck.
- Proceedings of 21st AIAA/CEAS Aeriaciystucs Conference. American Institute of Aeronautics & Astronautics, 2015. AIAA 2015-2847.
- Concurrent Aeroservoelastic Design and Optimization of Wind Turbines. / Tibaldi, Carlo; Bak, Christian (Main supervisor); Henriksen, Lars Christian (Supervisor). DTU Wind Energy, 2015. 204 p.
- Measurement of turbine inflow with a 3D windscanner system and a spinnerlidar. / Wagner, Rozenn; Vignaroli, Andrea; Angelou, Nikolas; Sathe, Ameya; Meyer Forsting, Alexander Raul; Sjöholm, Mikael; Mikkelsen, Torben Krogh. Proceedings of DEWEK 2015, 12th German Wind Energy Conference. DEWI, 2015.
- Using a cylindrical vortex model to assess the induction zone infront of aligned and yawed rotors. / Branlard, Emmanuel Simon Pierre; Meyer Forsting, Alexander Raul. Proceedings of EWEA Offshore 2015 Conference. European Wind Energy Association (EWEA), 2015.

1.10 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 - 2015

2. Sub-programme on Wind Conditions

The activities of the Sub Programme Wind Conditions partly constitute the backbone of some activities carried out in other SPs such as Aerodynamics (Inflow Conditions and Wakes, RT1); Offshore (Wakes, RT1) and Wind Integration (Weather forecasting models, RT3).
The Sub Programme has not a related IRPWind "Core Project"; therefore activities have been going on alongside active projects funded in FP7, H2020, and National projects or/and in International tasks such as within the International Energy Agency or COST Actions where the IRPWind and EERA partners are involved. The main project is the ERA NET + project New European Wind Atlas, NEWA. (Section 2.3)

In November 2015, a wiki has been implemented that host information on wind energy research projects, related to the SP Wind Conditions, being undertaken across Europe at both at International and National level. The wiki www.EuropeanWindProjects.eu was initially thought for serving the purpose of the SP Wind Conditions, e.g. easily retrieve information, organizing activities, follow up of the SP and SP reporting. At present, the wiki host a sample of European and National funded projects in Denmark and Spain. Information can be found by the wiki searching engine. Users can add own projects using the provided template and instructions at EUWindProjects. A further step has been proposed to expand the wiki to the other Sub Programmes. DTU Wind Energy is the leading organization.
Contact points: Hans E. Jørgensen, and Anna Maria Sempreviva.

A session has been organized at the IRPWind Conference in Amsterdam, September 2015. http://www.irpwindconf.eu/program/ . Below the programme of the session is shown.

IRP Conference: Wind Conditions Sponsored by: **IRP Wind Energy**

28/09/2015	Presenter
TIME	
10:00-10:20	Introduction to wind conditions and an Overview of related European/National activities Hans Jørgensen, DTU, DK
10:20 - 10:40	The European Wind Atlas First phase Bernard Lange, IWES, GE
10:40-11:00	The Wind Scanner platform for Wind Conditions - Nikola Vasiljevic, DTU, DK
11:00-11:20	Wakebench - status and future perspectives, Pawel Gancarski - CENER, SP
11:20-11:40	Uncertainties in ressource assesment - a status of the IEC working group and Measnet - Martin Straks - WindGuard, GE
11:40-12:00	Results from the meso scale Benchmarking exercise, Anna Maria Sempreviva, DTU, DK
Afternoon 16:00 - 17:00, challenges	
16:00-17:00	Highlight from the Wake conference 2015 in Visby, SE. Jens Nørkjar Sørensen, DTU
16:15-16:30	WAsP online - a wind climatology tool for builts environment, Andreas, Bechmann, DTU, DK
16:15-16:45	Analog Ensamble method: application to Resources assessment ForWind, Bruno Schyska, Forwind, GE.
16:45-16:00	Discussion on how to link the different resarch projects, Hans Jørgensen, DTU

2.1 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.

3.1.1. RT1: Applicability of the models of wind conditions in the atmospheric boundary layer.

RT1 EERA VISION
Activities for this Research Theme include further development of high resolution micro scale models coupled to tailored meso-scale models with special emphasis on profiles of mean wind and turbulence to heights relevant for modern turbines (up to 1 kilometer) accounting for atmospheric stability, coherent structures, wind gusts and extremes, directional and wind speed shear, inhomogeneous and non-stationary conditions; development of models for siting in complex terrain such as hilly and/or forested areas. Development of improved engineering inflow wind field models including wind speed and directional shear, coherence, extremes, consistent with conservation laws, to be used as input for aerodynamic design and aero-elastic simulations. This includes the setup of a dedicated database that contains a large variety of realistic wind-field time series that are obtained from high-resolution flow simulations such as large-eddy simulations. Development of improved unsteady wake models including phenomena such as wake meandering, overlapping wake, ground effects, and interaction with the atmospheric boundary layer that can be used in wind farm modeling. Development of flow models which include wind and wave coupling together with the offshore sub programme. To facilitate the access of model data and measurements, a viable solution would be to establish a EERA collaborative e-platforms (local or cloud distributed) for data mining, with user-friendly interfaces designed and implemented for model chain implementation an integrated model/ measurements analysis. The platform should be adaptive for different needs and scalable for implementing new data, models and at different time and space scales

Concerning RT1, a benchmarking exercise has been launched, co-organized with EWEA. DTU, ForWind - Oldenbulg,, NKUA , CENER, University of Porto, and CNR participated to this exercise.
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/
The overall purpose of this exercise is to evaluate 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 analysis of the time series from twenty-four entries from 16 International groups including EERA partners have shown to be an invaluable source of information about state of the art in wind modeling with mesoscale models. Biases between the simulated and observed wind speeds at hub heights (80-100 m AGL) from the various models are around 1.0 m/s and fairly independent of the site and do not seem to be directly related to the model horizontal resolution used in the modeling. As probably expected, the wind speeds from the simulations using the various version of the WRF model cluster close to each other, especially in their description of the wind profile.
Results were presented at the third edition of EWEA's technology workshops on wind resource assessment that took place on 2nd and 3rd June 2015 in Helsinki, Finland. The workshop had the specific focus on dealing with and reducing uncertainty, common to all topics and sessions. As a results of this presentation, three more groups submitted they results.
Contact points Anna Maria Sempreviva and Hans Jørgensen.

3.1.2. RT2: Establish an experimental basis for uncertainty assessment and evaluation of model uncertainties. (Experimental Matrix)

RT2 EERA VISION
Knowledge of the uncertain level of the calculated resources, loads, production and forecasts will improve the value of wind energy contributing optimizing the risk analysis for all phases of the wind farm lifecycle. Activities for this objective are strongly connected to the development and verification of the Model Chain. Six to eight specific designed full-scale field experiments shall cover the variation of topography and climatology in the EU countries. As part of the effort, it is necessary to develop statistical models for calculating uncertainty estimates of wind resources and design conditions from large scale models to small scale including the measurements and sensitivity analysis. This also includes the development of inverse modeling techniques that allow tracing back the measured uncertainties to the related input uncertainties on the different model boundary conditions. A special database shall cover wakes from wind farms offshore on scales from rotor dimensions to regional scale. Design of Experiment shall take advantage innovative measurement techniques i.e. remote sensing (particularly the use of the ESFRI RI WindScanner project). In the design and implementation of experiments, synergy with the Sub-Programme on Research Infrastructures is vital as are inventories of experimental equipment from potential participating research organizations

This activity has been carried out within the New European Wind Atlas (NEWA) project (Section 2.3). A pre experiment has been completed: in Perdigão (PT) within 2015.
Another important activity is carried out within the Norwegian National project "Offshore boundary layer experiment at FINO1 (OBLEX-FINO1) in the frame of NORCOWE, (Section 2.4).

3.1.3. RT3: Numerical weather models for short- and medium-term forecasting

RT3 EERA VISION
Short-term wind and wind power forecasts increase the value of wind energy considerably and are getting even more important with increasing shares of wind energy. Thus, the goal of this RT3 is to improve the spatial and temporal wind forecast by applying the model chain described under RT1 for forecasting of wind fields. Surface measurements that are already established by wind energy stakeholders like nacelle wind speeds, lidar observations and even wind power production are valuable input into data

assimilation systems of weather centres to improve analyses and weather forecasts. There is the need to collect and openly disseminate those observations that can be used locally by statistical models to improve short-term forecasts for regions. The collaborative e-platforms (local or distributed) in RT1 would serve to the purpose.
Also new observation techniques currently not commonly used in wind energy applications like rain radar and lightning detection should be explored to alert for sharp ramps or exceedance of cut-off wind speeds in thunderstorms or convective conditions. In general, all observations are used to verify and to improve meso-scale models in their ability to simulate and forecast local wind conditions that are characterized by high spatial and temporal variability (e.g. convection, wind wave-interaction, complex terrain). With increasing shares of wind and solar it is of particular importance that the spatial and temporal correlation of meteorological variables like wind, temperature (for dynamic line rating and demand forecasts) and solar irradiance is well represented and forecasted by meso-scale models. It is necessary to overcome deficits by revised physical parameterizations or by statistical post-processing of model outputs.
Numerical weather models must become a trusted tool in forecasting and simulating renewable generation patterns to model future power system scenarios with very high spatial (<1 km) and temporal (<10 min) resolution. Although the accuracy of weather models will continuously increase, the handling of forecast uncertainty must be improved by calibration and combination of ensemble forecasts and new probabilistic forecasting methods like Analog Ensembles. Work on ensemble prediction enables to provide skillful forecast even beyond the medium-term to optimize the management of renewable energies in Europe.

This activity is partly carried out jointly with the Sub Programme “Wind Integration”. An IEA Task has been submitted and accepted within the IEA Wind and will start in 2016. The activity concerning the revision of physical parameterization is a common issue with the RT1, but here the focus is on the short-term forecast capability

3.1.4. RT4: Future climate: resource trends, variability and predictability.

RT4 EERA VISION
Recent studies suggest that climate variability and anthropogenic climate change also manifest as changes in atmospheric circulation patterns (e.g. shift of the storm tracks or interanual changes in the frequency of the North Atlantic weather types). This could be of relevance for the assessment of future wind resources as circulation changes have an impact on regional wind variability and predictability. The activities envisaged for this objective are to analyze climate predictions (i.e. in prognostic mode with real data initialization) and projections for time horizons ranging from months, to years and even decades. The availability of more detailed experimental data sets (objective 2) is further used to develop regional climate downscaling, to assess the impact of climate simulations at scales representative for wind energy analyses. The final aim is to provide estimates of changes in climate variability, predictability and long-term trends and their impact on future wind resource at the wind-farm siting level. At the same time, the impact of large wind-farms on the regional climate is also investigated. Direct links to objectives 2 (uncertainty assessment and provision of reliability estimates) and 3 (model initialization, forecast verification etc.) should be considered, especially in the context of the development of fully seamless approaches.

This is a very important theme also related to the Sub Programme Wind Integration. However, at present, there is neither activity nor collaborative efforts in the Sub Programme concerning this theme;

3.1.5. RT5: Innovative measurement techniques.

RT5 EERA VISION
The key for the improved understanding of the interaction of the atmospheric boundary layer and wind turbines/wind farms on various scales (single turbine wakes/multiple wake effects inside a wind farm/far wake of a wind farm) is an extension of corresponding measurement capabilities far beyond the actual state. These effects cannot be adequately described and investigated by one static 100 m mast or punctual wind lidar measurements, but requires an approach toward quasi-3D measurements of the wind and temperature field in and around wind turbines and wind farms up to the top of the Atmospheric Boundary Layer. This requires the refinement and improvement of existing technology (e.g. lidar, radar, sodar) with respect to range and spatial and temporal resolution of the measurements and the introduction of new measurement technologies into the field of wind energy, e.g. passive microwave remote sensing for temperature profiling or the use of Remotely Piloted Aircraft Systems (RPAS), available in a wide range of size, payload capacity and operational range.

The activity in RT5 is carried out in the NEWA project and relate to the design of experiments using lidar technology i.e. wind lidars and wind scanners. Another relevant project is the Danish National RUNE at Hovsøre in Denmark where lidars and wind scanners are positioned at the coast line to scan wind fields over the sea.

A unique measurement campaigns 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 and Fraunhofer IWES. A new prototype was field-tested of new designed test manufactured extended range (300+ m).
A Workshop on NEWA Forested Hill Experiment was held on 2-3 November, 2015 in Kassel. The aim of the workshop has been to further elaborate the design of the experiment including modeling aspects and plan the campaign at Perdigão in Portugal.
WINDSCANNER : Contact point: Nikola Vasiljevic and Torben Mikkelsen, DTU.

A further project including experimenta activity with lidars is the Danish project “Rune” (see section 3.4). Here lidars and wind scanners located in coastal onshore area to detect the structure of the Boundary layer offshore.
Contact point: Alfredo Peña, DTU Wind Energy.

2.2 Report on milestones and deliverables

Table 1. List of Milestones in 2015

Mile-stone	Objective/Title	Nature[1]	Delivery	Lead Partner	Comments /project	Status – end 2015
M1	RT5/RT2 Pre-Experiment with wind scanner on hilly forested areas. Kassel (GE)	O	January 2015	IWES	Research Infrastructures Wind Scanner	Moved to August 2016
M3	RT2/RT3 DTOC 1.0 tools ready	O	April 2015	EERA DTOC Consortium	EERA DTOC	Done
M4	RT5/RT2 Innovative WINDSCANNER.eu short and long-range new scanner design and manufacturing plans.	O	April 2015	DTU	RI Wind Scanner Consortium	Done
M5	RT1/ WAKEBENCH.Model Evaluation Protocol	P	April 2015	CENER	IEA Task 31	Done
M6	RT1/ WAKEBENCH : Best practice Guidelines		April 2015	CENER	IEA Task 31	On track
M7	RT1 Vision2030 and Draft protocol for development of the Model Chain:	R	June 2015	ALL	NEWA	Delayed
M8	RT1, RT2, RT3,RT5 Vision and draft for a web-based platform for data mining, for the integrated model/ measurements uncertainty analysis.	R	June 2015	DTU	NEWA	Delayed
M9	RT1,RT2 EERA SP Wind Conditions and "Preliminary Results of the benchmark exercise on meso-scale models for wind	O	June 2015 Helsinki	DTU, CENER, CNR, Forwin-Old, NKUA,	EERA/NEWA	Done

[1] R = Report, P = Prototype, D = Demonstrator, O = Other

Mile-stone	Objective/Title	Nature[1]	Delivery	Lead Partner	Comments /project	Status – end 2015
	energy atlases" Co-organised with EWEA			Uni-Porto		
M10	"Wind Conditions" session at the Annual Conference	O	September 2015 Amsterdam			Done
M11	RT1 Presentation of the results of the benchmark exercise on meso-scale models for wind energy atlases" Co-organised with EWEA at IRPWind Annual conference.	O	September 2015 Amsterdam	DTU, CENER, CNR, Forwin-Old, NKUA, Uni-Porto		Done
M12	Measurements from the RUNE project started	O	November 2015	DTU		Done
M13	Workshop on the design of NEWA experiments in Kassel and Perdigão including modelling aspects	O	November, 2015	IWES	NEWA	Done

2.3 International collaboration in 2015

The New European Wind Atlas	
NEWA	**Participants** DTU Wind Energy (DK), ForWind Oldenbulg (GE), NKUA (GR), CENER (SP), UPorto (PT), IWES (GE), CIEMAT (SP).
http://www.vindenergi.dtu.dk/english/News/2015/03/New-European-Wind-Atlas-kick-off	**General Description** The NEWA project is related to the activities within RT1 and RT2 and the project had the kick-off meeting at DTU On 19-20 March 2015. Up to 50 scientists from the NEWA consortium participated at the meeting. NEWA is based on improved modelling competencies on atmospheric flow, together with the guide-lines and best practices for the use of data. It will become a key tool for manufacturers, developers, public authorities and decision-makers. NEWA will provide a unified high resolution and freely available data-set of wind energy resource in Europe. The statistics in the atlas will cover Europe with a resolution 20-30 meters in at least 10 wind turbine relevant heights. NEWA will replace the European Wind Atlas published by Risø National Laboratory for the European Commission in 1989. The team behind NEWA consists of 30 partners from 8 different European countries. The group is active in several relevant committees and expert groups on national and international level; including EERA, IEC and IEA. The New European Wind Atlas (NEWA) has a total budget of 13,1 M EUR and is funded by the European Commission and 9 national funding agencies. Contact Points: Jakob

	Mann and Hans Jørgensen, DTU, DK.
Contribution in Interaction wake – atmospheric background. 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	

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 Wind Conditions 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	

Global Wind Atlas	
	Participants DTU Wind Energy Contact point: Jake badger (DTU)
http://globalwindatlas.com/	**General Description** The objective of the Global Wind Atlas is • to provide wind resource data accounting for high resolution effects • use microscale modelling to capture small scale wind speed variability (crucial for better estimates of total wind resource) • use a unified methodology • ensure transparency about the methodology used • verify the results in representative selected areas The correct usage of the Global Wind Atlas dataset and tools is for aggregation, upscaling analysis and energy integration modelling for energy planners and policy makers. It is not correct to use the data and tools for wind farm siting.

Contribution in Wind Conditions. The tools developed in this project constitute a basis and guidance for developing further micro-scale tools other tools. Maps deriving from this procedure are of reference for other methodologies.

IEA-Wind Task 31, WAKEBENCH II	
iea wind	**EERA Participants** CENER, CRES, DTU, FRAUNHOFER IWES, Forwind Oldenburg
	General Description **Organized by:** CENER / NREL **Start date:** October 1, 2011, **End date:** September 31, 2014 **Objective:** Provide a forum for industrial, governmental and academic partners to develop, define quality-check procedures and improve atmospheric boundary layer and wind turbine wake models for use in wind energy **Expected outcome:** A set of benchmarkings of different type of wind and wake models as well as Best Practice Guide for the benchmarked models. **Project website:** IEA Task 31
Support to Wind Conditions. Benchmarking platform for wind models for resource assessment; To make an inventory of state-of-the-art models for the simulation of wind and wakes for site assessment applications: inputs, model equations, outputs et. Databases of joint case studies. Model evaluation protocol and best practice guidelines for wind farm flow models.	

IEA-Wind Task 32, Wind Lidar Systems for Wind Energy Deployment	
iea wind	**EERA Participants** CENER, CMR, DTU, ECN, Forwind Oldenburg, FRAUNHOFER IWES, University of Bergen, University of Delft
	General Description **Organized by:** Stuttgart Wind Energy **Start date:** January 1st 2016, **End date:** December 31, 2019. **Objective:** The general objective of the Task 32 is to identify and mitigate barriers to the use of lidar for following wind energy applications: Site Assessment, Power Performance, Loads and Control, and Complex Flow. **Expected outcome:** Provide an international open platform for regular and continuous exchange of experience and progress from individual research activities and existing measurement projects on the performance of lidar devices and associated measurement techniques. Interconnect and leverage experience from several international research projects. Identify areas for further research and development as well as standardization needs. Continue to collect and summarize competences gained in IEA Recommended Practices and Expert Reports. **Project website:** http://www.ieawindtask32.ifb.uni-stuttgart.de/
Contribution in Wind Conditions. Explore ways to improve lidar systems regarding cost, reliability and accuracy.	

IEC 61400-15 Site Assessment	
	EERA Participants DTU
	General Description **Organized by:** International Electrotechnical Commission (IEC), Convenor Mr. Robert W Sherwin **Start date:** 2013 **End date:** 2017 **Objective:** The IEC 61400-15 Wind turbines – "Part 15: Assessment of site specific wind conditions for wind power stations" intends to define a framework for assessment and reporting of the wind resource, energy yield and site suitability input conditions for both onshore and offshore wind power plants. **Expected outcome:** IEC 61400-15 international standard **Project website (restricted):** http://www.iec.ch/dyn/restricted/f?p=103:14:7371389685032::::FSP_ORG_ID,FSP_LANG_ID:10314,25
Relevance to Wind Conditions. The activity in the Wind Condition SP is aligned to the objectives of this IEC task.	

IEC 61400-12 Power Curve Measurement	
	EERA Participants Fraunhofer IWES, DTU
	General Description **Organized by:** International Electrotechnical Commission (IEC), Convenor Mr. Robert W Sherwin **Start date:** 2013 **End date:** 2017 **Objective:** IEC 61400-12-1 Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines **Expected outcome:** IEC 61400-12 international standard
Relevance to Wind Conditions. The activity in this SP is aligned to the objectives of this IEC task.	

IEA-Wind Task 25, Design and Operation of Power Systems with Large Amounts of Wind Power	
iea wind	**EERA Participants** VTT, Fraunhofer IWES, DTU Wind, SINTEF, ECN, LNEG
	General Description

	Organized by: VTT **Start date:** 2006, **End date:** 2017. **Objective:** 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. **Expected outcome:** 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. **Project website:** http://www.ieawind.org/task_25.html
Contribution in Wind Conditions: Integration of wind energy; Optimized models for the simulation and prediction of wind speed characteristics	

MEASNET – Site Assessment Working Group	
	EERA Participants CIRCE, CRES, DTU Wind Energy
	General Description **Organized by:** Measnet **Start date:** 2004 **End date:** n/a **Objective:** Development and dissemination of Measnet Procedure: Evaluation of site-specific wind conditions. Development and implementation of Round-Robin evaluation procedures in site and resource assessment. **Expected outcome:** Version 1 of procedure published in November 2009. Version 2 exists in draft format and is expected to be published in 2016. First public Round-Robin evaluation exercise planned for 2016. **Project website:** http://www.measnet.com/

Relevance to Wind Conditions. Defining a procedure and requirements for input data, methodologies and handling of uncertainties for site-specific assessment of wind conditions, and assessments of site suitability, energy yield and project risks based thereupon. Definition of rules for the assessment of suitability and completeness of wind measurement data, considerations on data integrity and risks arising from this, definition of a scope to be addressed to assess the parameters relevant for stability of a wind turbine, assessment of uncertainties according to the state of the scientific knowledge and a mutual assessment and control scheme implemented by the expert group.

2.4 National projects

Belgium

BERA/CENAERO

List of ongoing international and national projects
- Winercost – TUD COST Action TU1304; http://www.winercost.com/
"Wind energy technology reconsideration to enhance the concept of smart cities." [BERA/VKI]
- ITN Aeolus4future:
http://www.ltu.se/research/subjects/Stalbyggnad/Forskningsprojekt/AEOLUS4FUTURE?l=en
"Efficient harvesting of the wind energy." [BERA/VKI]
- From atmospheric circulation to electrons: an integrated approach for optimization and control of large-scale wind farms. IDO KU Leuven, 10/2012-09/2016. PI: J. Meyers, W. Desmet, J. Driesen, N. Van Lipzig (see http://www.kuleuven.be/research/researchdatabase/project/3E12/3E120223.htm)

From Atmospheric circulation to electrons: an integrated approach for op timization and control of large-scale wind farms.

Objectives: Nowadays, wind farms are growing in size, with larger turbines, and covering increasingly larger surface areas. At current scales, large wind-turbine arrays start to interact with the Atmospheric Boundary Layer reducing the available wind at farm level, and significantly increasing turbulence levels. This leads to lower turbine efficiency, increased turbulence-induced fatigue loading, and reduced power quality, all leading to an increase of cost-to-power ratios. Moreover, strong indications exist that the deployment of large wind farms impacts atmospheric conditions well beyond the farms installation region. Thus, for better understanding and improved design of future large-scale wind farms, a multi-disciplinary approach is required that includes aspects of atmospheric dynamics, planetary boundary-layer physics, turbine aerodynamics, structural mechanics, and electricity generation into one integrated approach. In the current project, we set up a multi-disciplinary research team to tackle these ambitions.
Expected outcome: Wind-farm simulation and optimal control tools are developed to take into account the bi-directional coupling between large-scale climatic, and weather effects (1000 km to 1 km scale), atmospheric turbulence (10 km to 1 mm scale), structural mechanics (100 m down to micro-meter bearing tolerances), and electricity generation and power quality. These simulation tools consist of a regional climate model, large-eddy simulations of wind farms and the atmospheric boundary layer (including an optimal control module), high-fidelity flexible

multi-body models of wind turbines and drive trains, integrated models for wind farm power grids and generators.

Denmark, DTU Wind Energy

FarmOpt

Objective: To develop and provide new reliable tools for designing wind farms located in complex terrain through full scale measurements in wind farms.
Expected outcome: Optimization tools for layout optimization when planning wind farms in complex terrain, which will also be integrated in Danish commercial software (WAsP and WindPRO).

RUNE. Reducing the Uncertainty of Near-shore Energy. (DTU)

Objective: To reduce the uncertainty of near-shore wind resource estimates by using onshore scanning lidar technology combined with ocean and satellite information.
Expected outcome: To reduce the uncertainty of near-shore wind resource estimates by using onshore scanning lidar technology combined with ocean and satellite information.
Contact Points: Alfredo Penã, DTU.

X-WiWa Extreme winds and waves for offshore turbines (DTU)

Objective: To develop an atmospheric and wave (and ocean) coupled modeling system for storm simulations in the (Danish) coastal areas.
Expected outcome: A new modeling system coupling WRF and MIKE, improved extreme wind and extreme wave statistics for design criteria in the coastal offshore zones.
Contact Points: Xiaoli G. Larsen, DTU.

WAsP Online (DTU)

Objective: Provide developers, consultants, manufactures and homeowners a way of making good investment decisions for small turbines and strengthen EMD and DTU marked position within software for wind turbines.
Expected outcome: A low-cost user friendly web-based tool for planning of small and medium sized turbines that will be used world-wide and has particular impact in Denmark.
Contact Point: Andrea Bechman

Germany

ForWind – Universität Oldenburg,, DLR, Universität Stuttgart.

DFWind – Phase 1 ('Deutsche Forschungsplattform für Windenergie')

The National Research Alliance for Wind Energy consisting of the partners DLR, Fraunhofer IWES and ForWind works on the development of a wind energy test site in Northern Germany. The test site will comprise several wind turbines as well as extensive meteorological and other measurements. To get access to the full data of the wind turbines is a key criterion in the tendering process for the wind turbines to be installed at the test site.
With its high-quality and extensive amount of meteorological instrumentation including e.g. a met mast array that allows for the analysis of spatial characteristics of turbulent flows and several eddy-covariance stations that will provide detailed information on the interaction between atmosphere and land, the test site will be able to contribute to RT2 of the EERA SP on

Wind Conditions. The test site will provide high-quality data that can be used for model evaluation. As there will be simultaneous measurements of the free-flow as well as of the flow conditions in the wake of wind turbines and as the wind turbine data will also be accessible, the test site is also well-suited to gain a better understanding of the interaction between atmospheric properties and wind turbines and to validate the ability of models to properly reproduce the conditions in the wake. The development of the test site is a project which extends over several years.

Ventus efficiens ('Verbundforschung zur Steigerung der Effizienz von Windenergieanlagen im Energiesystem')
In the framework of this common project between two of the three ForWind universities, Leibniz Universität Hannover and Universität Oldenburg, funded by the German federal state of Lower Saxony the existing chain between the meso-scale model WRF, the large-eddy simulation model PALM and the aeroelastic code FAST should be further developed. Currently, only PALM and FAST are fully two-way-coupled, while WRF provides driving data for PALM only. One of the research questions is whether the introduction of measurements, in this case especially data from a spinner-lidar, into the model chain leads to a better reproduction of the simulated with the measured wind conditions at other sites within the model domain. Using the data from the DFWind test site atmospheric conditions that come along with high loads at wind turbines will be extracted. The model chain will be applied to these situations in order to check whether the model chain is able to reproduce the measured condition.

OWEA-LOADS ('Probabilistische Lastbeschreibung, Monitoring und Reduktion der Lasten zukünftiger Offshore-Windenergieanlagen')
RT3 Numerical weather models for short- and medium-term-forecasting.
This project is funded by the German Federal Ministry for Economic Affairs and Energy of the project partners University of Stuttgart and ForWind–Universität Oldenburg . Here, ForWind deals with obtaining an improved description of the (meteorological) environmental conditions of offshore wind turbines in the German North Sea. As the deployment of measurements in the offshore region is expensive, the objective of the project is to improve the accuracy of meso-scale models in this region. The approach currently followed in the project is to adapt the MYNN planetary boundary layer scheme for the offshore environment on the basis of a data set that consists of extensive simulations with the large-eddy simulation model PALM, data from existing met masts in the North Sea as well as measurement campaigns with an unmanned aerial vehicle that is operated by subcontractors from Universität Tübingen.
The modified MYNN planetary boundary layer scheme should be available in August 2016, when the OWEA-LOADS project ends.

Fraunhofer- IWES

Fino-Wind
Funded by the German Federal Ministry for Economic Affairs and Energy. The goal of the FINO - WIND project is to develop a system for a standardised provision of FINO wind data. On the one hand, this is aimed at improving the comparability of the measurements from all three platforms and enabling consistent archiving of the data in the FINO database of the Federal Maritime and Hydrographic Agency (BSH). On the other hand, it serves the aim to enable intercomparability of the wind speed measurements in the light of wind climates of the North and Baltic Seas. This may also lead to proposals how to adapt measurement structures and analysis methods accordingly.

Project partners are German Weather Service (DWD), Bundesamt für Seeschifffahrt und Hydrographie (BSH), Deutsches Windenergie-Institut (DEWI), DNV GL-Energy (DNV GL), Fraunhofer IWES and WIND-consult GmbH (WICO). The research project FINO-WIND is headed by DWD.
Contact points: Ilona Bastigkeit, Bernhard Lange, Fraunhofer IWES

ETESIAN - Extended THETA for Site Assessment
Funded by the German Federal Ministry for Economic Affairs and Energy.
Main aim of the project is to make the CFD-solver THETA, which is established in the industrial flow simulation, usable for wind power site assessment by including the thermal stratification of the atmosphere.
Contact points: Bernahrd Stoevesandt, Fraunhofer IWES, Björn Witha, ForWind Oldenburg

EWeLiNE Development of innovative weather and power forecast models for the grid integration of weather dependent energy sources
Funded by the German Federal Ministry for Economic Affairs and Energy.
Objectives: The German energy system is going through a fundamental change. Based on the energy plans of the German federal government, the share of power production from renewables should increase to 35% by 2020. Increasing the average power production from renewables to 35% means that in the near future, renewable energies will provide Germany's entire power production at certain times. By the year 2050, 80% of the total power supply in Germany should be provided by renewables. Power production from renewables is dominated by weather-dependent components such as wind energy and photovoltaics (PV). Operating a power supply system with a large share of weather-dependent power sources in a secure way, requires global as well as regional weather forecasts. The most promising strategy to improve the existing wind power and PV forecasts, is to optimize the underlying weather forecasts and to enhance the collaboration between the meteorology and energy sector. Here the development and establishment of new forecast products in decision making processes, as well as the integration of information provided by the energy sector into the weather forecast models, are of particular importance.
Relevant outcome: Improved wind speed forecasts.
Contact Points: M. Siefert, J.Dobschinski / Fraunhofer IWES.

Italy

CNR
I-AMICA - High technology infrastructure for Integrated Climatic-Environmental monitoring
Funded by the Italian Ministry of Research within National Operation Program "Ricerca e Competitività" (Research and Competitiveness) 2007-2013.
Objective. The I-AMICA goal is to implement of an integrated network of climatic-environmental monitoring facility to provide the European Convergence Regions with useful facilities and tools which can upgrade operational standards and the public research system thus encouraging the development of entrepreneurial activities.
Expected results: Setup regional GAW-WMO sites. The infrastructures will supply useful information for decision regarding the environment and environment management
Contact point: Claudia R. Calidonna. CNR.

RES-NOVAE - Grids, Building, Roads, new objectives for the Environment and the Energy

Funded by the Italian Ministry of Research within National Operation Program “Ricerca e Competitività” (Research and Competitiveness) 2007-2013. Within the Smart Cities activities.
Objective: Renewable energy mapping tools and meteorological parameters forecasting for smart cities.
Expected results: Best practices and tools for management of town concerning meteorology.
Contact point: Claudia R. Calidonna. CNR.

Green Ports

Objective: To develop renewable energy systems for harbors.
Expected results: Resources mapping tools.
Contact point: Claudia R. Calidonna. CNR.

RSE

Wind energy: resource assessment in the Sicily channel

Objective: to improve resource assessment of an offshore and onshore area containing the south-Western part of the Sicily Channel where water depth and wind resource seem to be adequate for future settlements of offshore wind plants and to reduce the offshore maps uncertainty of the Wind Atlas of Italy (http://atlanteeolico.rse-web.it/viewer.htm).
Expected outcome: onland wind measures and direct offshore measures performed by RSE MOBI (Marine Offshore Buoy for Investigation), buoy, installed in 2012 in the Sicily Channel 5 km off the coast of Mazara del Vallo. Resource assessment through correlation analysis and model simulations.

Norway, CMR, UoB

OBLEX-F1, Offshore Boundary Layer Experiment at FINO1 (CMR, UoB)

Objective: to increase the understanding of the marine atmospheric boundary layer (MABL) and the oceanic mixed layer (OML) and their complex interactions with relevance for offshore wind installations.
Expected outcome: comprehensive data set (4 month for oceanographic parameters, >1 year for atmospheric parameteres) for MABL and OML in offshore conditions at FINO1. Measurements started in May 2015.
Contact Points: Benny Svaldar (MCR), Joachim Reuder (UoB)

Spain, CENER

Unified Mesoscale to Wind Turbine Wake Downscaling Based on an Open-Source Model Chain (MesoWake)

The project has been funded by the FP7 Marie Curie grants, outgoing fellowship activity.
Objectives: The main objective is to leverage open-source codes that can be used for high-fidelity modelling of the mesoscale to microscale processes that influence the performance of wind turbines. WRF, developed by NCAR, and SOWFA, developed by NREL and based on openFOAM, are both based on large-eddy simulation and provide two alternatives for meso-micro coupling: dynamic coupling within the same code (WRF-LES) and offline coupling with SOWFA forced by mesoscale inputs from WRF. After a rigorous verification and validation process, these codes can be used as virtual laboratories to produce databases to complement existing experiments and support the development of reduced-order engineering models. The codes have been installed in the MareNostrum high-performance computer, hosted by BSC

and part of the European research infrastructure for supercomputing (PRACE). A PRACE project will produce the first virtual experiments looking at fundamental physics of the atmosphere and its interaction with wind turbines.
Outcome: The project has also been used to align research strategies in NEWA and the U.S. Atmosphere to Electrons program, both interested in the development of open-access models and experimental basis for validation. This will result in a jointly developed model evaluation framework established within the IEA Task 31 Wakebench. Contact Points: Javier Sanz Rodrigo and Iván Moya Mallafré. CENER, ES.

The Netherland

Dutch offshore wind measurements (ECN)

Objectives: Connected to a national programme to deliver site conditions (wind, wave, soil, etc) to the developers of offshore wind farms ECN performs measurement campaigns since 2010 on offshore measurement masts and lidars on offshore platforms.
The measurement mast will be decommissioned early 2016, additional lidars on platforms will be placed.
Expected Impact: A more reliable site assessment for offshore project development.
Contact Points: Peter Eecen, Arno Brand

ISSWIND (NL, ECN)

Satellite data are being applied to improve the accuracy of wind expectations. ECN has the role to develop services specific for the wind industry based on the improved expectations supplied by satellite data analysis companies.
Contact Points: Peter Eecen, Arno Brand

Table 2. List of National projects with links to "Wind Conditions"

#	Project title and web address	Total budget (MEUR)	Start-End Year	Coordinator	Country
1	RUNE	0.5	2015-2016	DTU	DK
2	X-WiWa	0.8	2014-2017	DTU	DK
3	FarmOpt	1.46	2014-2017	DTU	DK
4	NORCOWE/OBLEX-F1	0.5	2015-2017	CMR/UoB	NO
5	Dutch offshore wind measurement	5	2010-2015	ECN	NL
7	LAWINE	2	2012-2016	ECN	NL
8	WAsP Online	0.15	2014-2015	DTU	DK
9	I-AMICA	1.2	2013-2015	CNR	IT
10	Fino-Wind	N/A	2013-2016	DWD	DE
11	ETESIAN	N/A	2015-2018	IWES	DE
12	EWeLiNE	7	2012-2016	IWES	DE
13	Res Novae	0.6	2013.2015	CNR	IT
14	Green Ports	0.01	2015-2015	CNR	IT
15	DFWind	2.84	2015-2017	DLR	GE
16	Ventus efficiens	5.0	2014-2019	ForWind	GE
17	OWEA-LOADS	1.01	2012-2016	Universität Stuttgart	GE
18	Wind energy: resource assessment in the Sicily channel	N/A	2012-2016	RSE	IT

2.5 Publications in 2015

BERA/CENARO

Barlas E., S. Buckingham, J. van Beeck Roughness Effects on Wind-Turbine Wake Dynamics in a Boundary-Layer Wind Tunnel. In: Boundary-Layer Meteorology, Vol. 158, No. 1, 2016, p. 27-42.

Allaerts D., Meyers J.,. Large eddy simulation of a large wind-turbine array in a conventionally neutral atmospheric boundary layer. Physics of Fluids 27 (6), art.nr. 065108 (2015)

DTU

Sathe, A, Mann, J, Vasiljevic, N & Lea, G 2015, 'A six-beam method to measure turbulence statistics using ground-based wind lidars' Atmospheric Measurement Techniques, vol 8, pp. 729-740., 10.5194/amt-8-729-2015

Berg, J, Vasiljevic, N, Kelly, MC, Lea, G & Courtney, M 2015, 'Addressing Spatial Variability of Surface-Layer Wind with Long-Range WindScanners' Journal of Atmospheric and Oceanic Technology, vol 32, no. 3, pp. 518-527., 10.1175/JTECH-D-14-00123.1

Hasager, CB, Vincent, P, Husson, R, Mouche, A, Badger, M, Pena Diaz, A, Volker, P, Badger, J, di Bella, A, Palomares, A, Cantero, E & Correia, PMF 2015, 'Comparing satellite SAR and wind farm wake models' Journal of Physics: Conference Series (Online), vol 625, 012035., 10.1088/1742-6596/625/1/012035

Murcia Leon, JP, Réthoré, P-E, Natarajan, A & Sørensen, JD 2015, 'How Many Model Evaluations Are Required To Predict The AEP Of A Wind Power Plant?' Journal of Physics: Conference Series (Online), vol 625, 012030., 10.1088/1742-6596/625/1/012030

Peña, A, Gryning, S-E & Floors, RR 2015, 'Lidar observations of marine boundary-layer winds and heights: a preliminary study' Meteorologische Zeitschrift, vol 24, no. 6, pp. 581-589., 10.1127/metz/2015/0636

Hasager, CB, Badger, M, Nawri, N, Rugaard Furevik, B, Petersen, GN, Björnsson, H & Clausen, N-E 2015, 'Mapping Offshore Winds Around Iceland Using Satellite Synthetic Aperture Radar and Mesoscale Model Simulations' I E E E Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol 8, no. 12, pp. 5541-5552., 10.1109/JSTARS.2015.2443981

Hasager, CB, Mouche, A, Badger, M, Bingöl, F, Karagali, I, Driesenaar, T, Stoffelen, A, Peña, A & Longépé, N 2015, ' Offshore wind climatology based on synergetic use of Envisat ASAR, ASCAT and QuikSCAT' Remote Sensing of Environment, vol 156, pp. 247–263., 10.1016/j.rse.2014.09.030

Sogachev, A & Kelly, MC 2015, 'On Displacement Height, from Classical to Practical Formulation: Stress, Turbulent Transport and Vorticity Considerations' Boundary-Layer Meteorology., 10.1007/s10546-015-0093-x

Suomi, I, Gryning, S-E, Floors, RR, Vihma, T & Fortelius, C 2015, 'On the vertical structure of wind gusts' Royal Meteorological Society. Quarterly Journal, vol 141, pp. 1658–1670., 10.1002/qj.2468

Peña, A, Floors, RR & Gryning, S-E 2015, 'Reply to the Comment by Bergmann on "The Høvsøre Tall Wind-Profile Experiment: A Description of Wind Profile Observations in the

Atmospheric Boundary Layer"' Boundary-layer Meteorology , vol 157, no. 3, pp. 547-551., 10.1007/s10546-015-0077-x

Floors, RR, Peña, A & Gryning, S-E 2015, 'The effect of baroclinicity on the wind in the planetary boundary layer' Royal Meteorological Society. Quarterly Journal, vol 141, no. 687, pp. 619-630., 10.1002/qj.2386

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Larsén, XG, Larsen, SE & Lundtang Petersen, E 2015, 'The full scale spectrum of the boundary layer wind' EMS Annual Meeting Abstracts, vol 12, EMS2015-127

Vincent, CL & Hahmann, AN 2015, 'The impact of grid and spectral nudging on the variance of the near-surface wind speed' Journal of Applied Meteorology and Climatology, vol 54, pp. 1021–1038., 10.1175/JAMC-D-14-0047.

CNR - DTU

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Tiriolo, L, Torcasio, RC, Montesanti, S, Sempreviva, AM, Calidonna, CR, Transerici, C & Federico, S 2015, 'Forecasting wind power production from a wind farm using the RAMS model' Advances in Science and Research, vol 12, pp. 37–44., 10.5194/asr-12-37-2015

CENER

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Frías, F. Mallor L., I. Moya, M. Gastón. “Advances in the Temporal Distortion Index and their use to analyze and compare wind energy forecast models”. EWEA 2015 Annual Event. November 17-20, 2015. Paris (France).

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Frías, E. Pascal L., M. Gastón. “Designing an optimal network measurement sensors for monitoring geographical wind resource: Statistical techniques and GIS”. EWEA resource assessment 2015. June 2-3 2015; Helsinki (Finland).

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Sanz Rodrigo J, Cantero E, García B, Borbón F, Irigoyen U, Lozano S, Fernandes P-M, Chávez RA (2015) Atmospheric stability assessment for the characterization of offshore wind conditions. Journal of Physics: Conference Series 625: 012044, doi:10.1088/1742-6596/625/1/012044

CMR

Kumer, V-M; Sætre, Camilla; Svardal, Benny; Reuder, J; Eecen, P: Characterisation of single wind turbine wakes with static and scanning WINTWEX-W LiDAR data. 12th Deep Sea Oshore Wind R&D Conference, EERA DeepWind'2015, Trondheim, Norway; Conference paper.

Heggelund, Yngve; Jarvis, Chad; Y; Khalil: Reduced order modeling of wind farms based on CFD: wind speed effects.EWEA Offshore 2015, Copenhagen, Denmark; Conference Paper.

ECN

Wagenaar, J.W.: Ring analysis floating LiDAR, static LiDAR and offshore meteorological mast. ECN-M--15-047, December 2015.

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2.6 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 2015

3. Sub-programme on Structures & Materials

The overall objective of the sub-programme 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 sub-programme 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”.

3.1 Report on Research Themes

Below a 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 2015 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.

Early 2015 the work on the benchmark exercise within the InnWind.Eu project was completed. Numerical models from six organizations (CRES, CENER, DTU, PoliMi, WMC and University of Patras) have been collected and compared against each other using as reference the 10MW wind turbine blade of DTU (geometry, internal material layout and material properties). Comparison of the structural analysis tools for wind turbine blades through estimations on mass and stiffness properties, dynamic response, strength under extreme and cyclic loads, as well as strains, stresses and critical buckling loads revealed increased variation in strength properties (both fatigue and extreme loading). This pinpoints the required direction for experimental validations. A collaborative paper was also prepared and presented during ICCM20 for the subject.

In parallel, a review of the testing methodologies for the validation of modelling tools used in wind turbine blade structural analysis was completed in the frame of the IRPWIND programme. CRES, CENER, DTU, Fraunhofer IWES and WMC cooperated to prepare for the methodology needed to be applied for the verification of the numerical approach followed in the blade design loop. 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 delivered within IRPWIND shows the limitation of both numerical and experimental approach and may be used as reference 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. Within 2015 the InnWind.Eu deliverable D2.22 “New lightweight structural blade designs and blade designs with build-in structural couplings” includes more than 10 solutions from 8 project partners (http://www.innwind.eu/Publications/Deliverable-reports). Among those, the use of an internal space truss structure to replace the shear webs by University of Patras, the

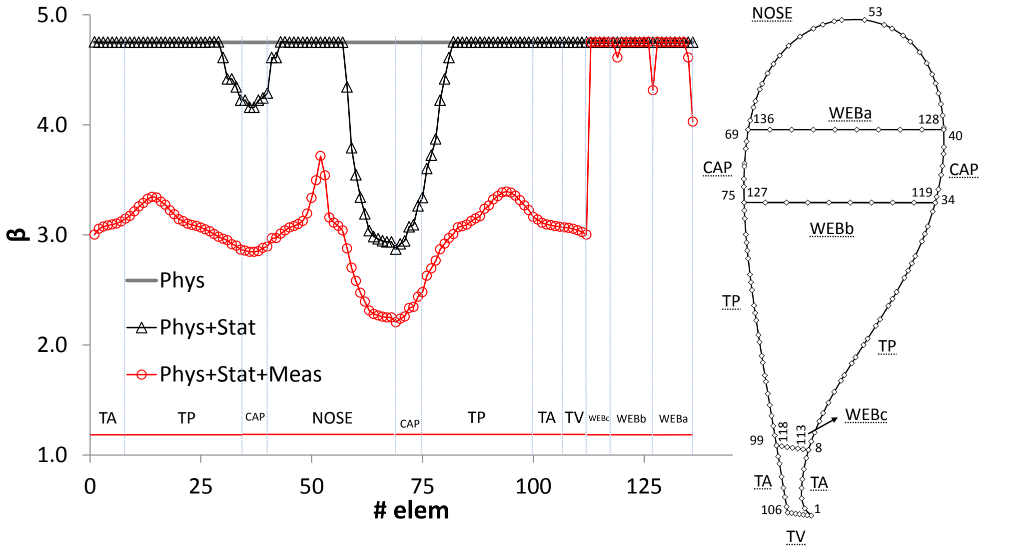
use of grid reinforced panels for the shell structure of the blade by TUDelft, structural solutions to support new aerodynamic concepts (as e.g. that of CRES) and solutions including passive load alleviation through bend-twist-coupling by PoliMi.
The effect of active load alleviation solutions on the blade structure was also investigated within 2015 and reported within the InnWind.Eu project in deliverable D2.23 “New morphing blade section designs and structural solutions for smart blades”. As an example DTU investigated the blade response and the structural behaviour when the trailing edge is modified to accommodate trailing edge flaps.
In parallel, 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.
During the reported year 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.
Fraunhofer IWES continues to coordinate BladeMaker funded by the German Federal Ministry for Economic Affairs and Energy. BladeMaker 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.
Developments that show the need to validate the numerical results through experiments.

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.
Within the IRPWIND project University of Aalborg, DTU, IWES, CRES and CENER collaborate to develop probabilistic methods for blades and support structures. During 2015 DTU reviewed the available databases reporting failures from operating wind turbines. On the other hand, CRES improved the probabilistic analysis tool for blade structures incorporating measurement and modelling uncertainty and estimating probability of failure at the layer level for buckling, extreme loads and fatigue strength. As an example the effect of the measurement and

modelling uncertainty over the “traditionally” used physical and statistical on the reliability at a blade section is shown in the following figure. Results of this work indicate that more work is needed to improve the uncertainties in the many parameters involved in the analysis, including material properties and load estimations.



Effect of various types of uncertainty related to material properties at the blade section

For a probabilistic analysis the requirements for the input databases (materials, loads, etc.) are significantly higher than that for a deterministic one, irrespective whether the data come from experimental or numerical efforts. Partners are working on obtaining the required data in parallel to developing the required reliability analysis methods. Over the next couple of years substantial progress is expected.
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 is to understand and accurately model the material behaviour 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 should be improved to account for thick laminates, layer based fatigue models, micromechanical modelling, ageing, marine environment influence & extreme conditions, etc.

During the first year of the project IRPWIND, early year 2015, the review of available material databases and material models for blades and support structures has been concluded. Results indicate that there are a lot of open issues relevant to the materials of the major structural components of the wind turbine. CTC performed the review for the metallic materials and

models used for wind turbine support structures, where gaps where indicated relevant to the fatigue and fracture properties, especially under non-normal environmental conditions. CRES focused on revisiting composite material databases to extract measurement uncertainty properties from past experiments, needed for probabilistic analysis. Result there indicate that increased effort should be placed for fatigue properties in tension/compression or compression/compression cases.
During 2015 a round robin test on white etch cracks for wind turbine bearing has been conducted under the lead of Aachen University. RWTH Aachen, DTU, BERA (Laborelec and University of Ghent) contributed in the round robin and compared their experimental methods in cracks identification. Results have been discussed between the partners within 2015 and will be published through a collaborative paper in a scientific journal.

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 included actions within IRPWIND relevant to the determination of the geometry of subcomponents to be tested within the project. 3D geometric details were acquired by CRES on blade subcomponents offered by DTU to be tested by DTU, IWES and WMC within the EC funded project. In parallel IWES continued working on signal analysis processing of the Acoustic Emission data to prepare for the identification of first cracks/failures on the blade subcomponents.

Relevant to repair of blades CRES and University of Patras were involved in the Greek funded project REWIND, were procedures for validation of repair of wind turbine blade are developed. The project concluded within year 2015 with results on the validation of repair methods through experiments on blade subcomponents presented within EWEA 2015 conference.

3.2 Reporting on Milestones and deliverables

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 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 and directly indicating relevant deliverables. Furthermore, the milestones that were completed within 2014 are not indicated (without changing the numbering though).

Mile-stone	Objective/title	Nature[2]	Delivery	Lead partners	Comments	Status – end 2015
M1	RT1: Review of wind turbine blade structural design and design of blade joints; including review of design model verification	R	*Jul 2014*	CRES, WMC, CENER, DTU, IWES		**DONE** InnWind.Eu D2.21 IRPWIND D7.1.1
M3	RT1: Performed structural analysis on platform blade with output available for comparisons	R	*Oct 2014*	CRES, WMC DTU, CENER, PoliMi, IWES		**DONE** InnWind.EU D2.21

[2] R=Report, O=Other

Mile-stone	Objective/title	Nature[2]	Delivery	Lead partners	Comments	Status – end 2015
						Paper ICCM20
M4	RT1: New lightweight blade structural designs and blades with passive couplings	R	*Oct 2015*	CRES, DTU, CENER, PoliMi, WMC, TuDelft	**InnWind.Eu** deliverable D2.22	**DONE** InnWind.EU D2.22
M5	RT1: Test report on blade subcomponents	R	*Jul 2017*	IWES, CRES, DTU, CENER, WMC	**IRPWIND** deliverable D71.2	In progress
M6	RT1: Report on validation and improvement of blade design tools	R	*Nov 2017*	DTU, CRES, IWES, WMC CENER	**IRPWIND** deliverable D71.3	
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	**IRPWIND**	**DONE** IRPWIND D7.1.1, Ongoing in IRPWIND Task 7.1.2
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	Reference blade of **InnWind** Probabilistic properties in **IRPWIND** Some partners **own funding**	**DONE** Paper ICCM20, EWEA 2015
M9	RT2: Assessment of current reliability level for blades, based on performed reliability analysis on platform blade	R	*Feb 2016*	DTU, AAU, WMC, CRES CENER, IWES, Forwind-H	**IRPWIND** Some partners **own funding**	In progress
M10	RT2: Assessment of current reliability level for support structures		*Feb 2016*	WMC, IWES, Forwind-H	**IRPWIND**	In progress
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**	**DONE** DOW2015
M13	RT3: Database on Adhesive material properties	Data submitted in web/form	*Feb 2015*	IWES, TUD, WMC	**Own funding**	
M15	RT3: Round robin of testing for core material		*Nov 2014*	IWES, WMC CENER	**Own funding**	On Hold, lack of resources
M16	RT3: Round robin on white etch cracks	R	*Dec 2016*	RWTH Aachen, DTU, BERA	**Own funding**	**In progress**
M17	RT3: Review of available	R	*Feb 2015*	WMC, CTC,	**IRPWIND**	**DONE**

Mile-stone	Objective/title	Nature[2]	Delivery	Lead partners	Comments	Status – end 2015
	composite and metallic material databases			CRES, IWES, CENER		(IRPWIND milestone)
M18	RT3: Report on material models for blades and support structures	R	*Feb 2017*	WMC, CTC, CRES,IWES, CENER	**IRPWIND** IRPWIND deliverables D73.1 and D73.2	In Progress
M20	RT4: Theoretical benchmark vs. experimental results for full-scale tower joints	R	*Jun 2016*	CTC, WMC, IWES, CENER		Cancelled
M21	RT4: Comparison of calculated results from different analysis models for pitch bearing	R	*Mar 2015*	ORE Catapult	**Own funding**	
M22	RT4: Report on validation of grouted joints	R	*May 2017*	DTU, CTC, AAU	**IRPWIND** IRPWIND deliverable D72.1	In progress
M23	RT5: Review and specifications of testing coatings for wind turbine blades and towers	R	*Dec 2014*	SINTEF, CTC, IWES, WMC	**Own funding**	Draft available
M24	RT5: Review of structural health monitoring methodologies for wind turbine Towers and Support Structures	R	*Sep 2014*	CTC, AAU, Forwind-H, IK4	**Own funding**	Draft available
M25	RT5: Review of structural health monitoring methodologies for wind turbine blades and methodology for NDT/SHM testing	R	*Apr 2016*	IWES, CRES, CENER, CNR, WMC, SINTEF	**IRPWIND** Some partners **own funding**	In Progress
M27	RT5: Review of blade repair issues	R	*Jun 2015*	IWES, CRES, WMC, DTU	**GR National** Some partners **Own funding**	DONE Paper EWEA 2015
M28	RT5: Deliverable D4.1.3 – Innovations on component level (final report)	R	*Aug2015*	FORWIND Hannover, (WMC, AAU, FhG-H, DTU, FhG-DA, UOL, FhG-KS, RAW)	Innwind.EU D4.1.3	DONE

Mile-stone	Objective/title	Nature[2]	Delivery	Lead partners	Comments	Status – end 2015
M29	RT5: Deliverable D4.1.4 – Validation of innovations by tests on component level	R	*Aug2015*	FhG-H, (FORWIND Hannover, WMC, AAU)	Innwind.EU D4.1.4	DONE

3.3 International collaboration in 2015

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 some of the international collaborations, where effort was devoted towards achievement of the goals of the SP “Structures and materials”.

<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>
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<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>
</table>

<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>
</table>

MARE-WINT	
	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).
	General Description
http://www.marewint.eu/	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.
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).	

<table>
<tr><th colspan="2">MARINET</th></tr>
<tr><td>MARINET</td><td>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.</td></tr>
<tr><td>http://www.fp7-marinet.eu/</td><td>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.</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

WINDUR

www.project-windur.eu

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.

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.

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.

[Project Acronym]	
[Project logo]	**Participants** [participants]
[project web page]	**General Description**
Contribution in Structures and Materials R&D	

3.4 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 2015 (running or completed within 2015) are presented for each country, indicating contributing partners.

3.4.1 Greece (CRES)

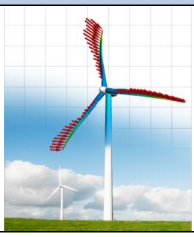
REWIND: Validated design rules for REpair of WIND turbine rotor blades	
ReWIND	**Participants** University of Patras, CRES, National Technical University of Athens, ROKAS SA, COMPBLADES SA
http://www.core.mech.upatras.gr/index.php/rw	**General Description** The project aims at validating the repair procedures 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.

3.4.2 Germany (DLR, IWES)

Smart Blades	
	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.

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.

3.4.3 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.

3.4.4 Belgium (BERA- Univ of Liege & Laborelec)

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.

3.4.5 Netherlands (WMC, ECN)

MIMIC (Micromechanics-based Modeling and condition monItoring of rotor blade Composites)	
	Participants WMC, TU Delft, TNO, Bright Composites, We4Ce/Tres4, CTC
http://tki-windopzee.nl/project/mimic	**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.

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.

3.5 Publications in 2015

The research performed in 2015 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. Publications with two or more partners of the EERA JP-Wind are shown first. Publications with a single partner from EERA JP-Wind are then ordered per country.

1. 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, in 20th International Conference on Composite Materials conf. proc., Copenhagen, 19-24th July 2015
2. Bacharoudis KC, Antoniou A, Lekou DJ. Measurement uncertainty of fatigue properties and its effect on the wind turbine blade reliability level, Scientific Proceedings of EWEA 2015, PO. 254, Paris, France, 17-20 November 2015

3.5.1 Greece

1. Makris A, Lekou DJ, Philippidis TP, Kossivas T. Verification of repair method for a damaged wind turbine blade, PO.053, in EWEA 2015 conf. proc., Paris, France, 17-20 November 2015
2. Bacharoudis KC, Lekou DJ, Philippidis TP, Probabilistic analysis of wind turbine blades considering stiffness, strength and stability under extreme and fatigue loading, in 20th International Conference on Composite Materials conf. proc., Copenhagen, 19-24th July 2015

3.5.2 [Partner country]

1. Author AB, …., 2015

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

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Wind Energy Integration

A sub-programme within the Joint Programme:
Wind Energy

Yearly reporting - 2015

4. Sub-programme on Wind Energy Integration

4.1 Report on Research Themes

RT1: Wind power plant capabilities

The Sub-Program Grid Integration of EERA JP Wind Energy organized a workshop in 09/2015 to present and discuss latest developments of frequency and voltage support by WPP as well as the requirements on system stability support by RES including new ideas for system services and dedicated grid support. The results of this workshop were integrated in the proposal preparation for H2020 LCE7-2016/2017: “Enhanced system support services for a 100% RES power system”.

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 Integration delivered input to the project. The WPP capabilities are developed from two perspectives; 1- the fulfilment of grid code obligations and 2- the provision of ancillary services including balancing reserve and primary and secondary frequency responses. The first aspect was covered in a paper that was recently presented in EERA DeepWind’16 conference[3] that investigated the performance of large offshore wind power clusters that are constructed at far distances from onshore grids and connected via HVDC corridors.

The second aspect was investigated in IRPWIND-D81.1 where the provision of balancing power and different methods of frequency support from WPPs that are connected via HVDC links were studied. Three different frequency support methods were compared; continuous de-loading, battery storage banks and a mix between the two previous methods. A simplified method was applied to estimate the de-loading ratios and battery bank rated power. Presently, further research is conducted in the frame of IRWPIND D81.3 to estimate the inertia contribution from a WPP with individual wind turbine representation (e.g. 5 to 15 wind turbines) to assess the overall contribution with turbines operating under different conditions. In addition, the role of enhanced controllers for hybrid AC-MTDC grids to provide frequency support to power system operation is being developed[4].

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. To improve the co-operation with ENTSO-E, a joint workshop with EERA JP Smart Grids, EERA JP Wind Energy and ENTSO-E is planned in 2016.

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[3] A. B. Attya, O. Anaya-Lara, P. Ledesma and H. Svendsen, Fulfilment of grid code obligations by large offshore wind farms clusters connected via HVDC corridors, in proc. of EERA 13th Deep Sea Offshore Wind R&D Conference, Trondheim, 2016 (to be published in Energy Procedia in Aug 2016).

[4] F.D. Bianchi and J.L. Domínguez-García, Coordinated frequency control using MT-HVDC grids with wind power plants, IEEE Transactions on Sustainable Energy, vol. 7, no. 1, 2016

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. Results of NSON were presented at the DeepWind Conference in Trondheim in 2015. In December 2015, the NSON core group decided to submit a proposal for the H2020 LCE 33 ECRIA call in 2016.

On the IRPWIND conference in September 2016, a NSON stakeholder workshop was organized as a side event.

RT3: Wind energy and power management

The needed improvement of forecast-tools is one focus of this RT and was elaborated and discussed in joined workshops. The adaptation for the different applications, such as new market mechanisms, new business 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 2014 and provided input for the proposal development for the H2020 2015 LCE6 Call. The proposal was submitted in April 2015. Unfortunately, the proposal was not accepted. On the workshop in September 2015, the SP decided, to work out a proposal for the H2020 LCE7 2016 Call, addressing the same aspects. This work is in progress.

This research theme, related to tools and business models (markets) to allow economic wind power utilization, is pursued as part of IRPWIND WP83, with work in 2016 centered on three related deliverables in 2016 and three in early 2017.

Additionally, a workshop, previously postponed, will be arranged in Helsinki in Q3 addressing markets and business models for ancillary services.

4.2 Reporting on Milestones and deliverables

Mile-stone	Objective/title	Delivery	Lead Partners	Comments/ project	Status – end 2015
M6	RT1-3: Joint proposal (H2020) of JP wind, JP smart grids “Ancilary Service to enable 100%RES” LCE 5 and LCE 6	*April 2015*	IWES, DTU UoS, VTT, IREC	Own Funding	Not accepted
M7	EERA DeepWind R&D Offshore Wind Conference: EERA partners will contribute in total to about 50 oral and 50 posters, and approx. 30 papers from the conference will go through peer-review and be published in Energy Procedia	*Feb 2015*	SINTEF	Part of IRP Wind WP 8 Own Funding	Report available
M8	Workshop “Control Strategies for Ancillary Services Provision and Grid Compliance”	*Sep 2015*	IWES, DTU, SINTEF, UoS, VTT,	Part of IRP Wind WP 8.1	Report

Mile-stone	Objective/title	Delivery	Lead Partners	Comments/ project	Status – end 2015
			Catapult, IREC	Own Funding	
M9	Proposal Preparation AnRES	*Oct 2015 ongoing*	DTU, SINTEF, VTT	Part of IRP Wind WP 8.1-83.3	In progress
M9	NSON Stakeholder Workshop	*Sep 2015*	IWES, ECN		Report
M10	Proposal preparation for H2020 LCE 33 ECRIA NSON	*Dec 2015 ongoing*	SINTEF, IWES, DTU, UoS, ECN		In Progress

4.3 International collaboration in 2015

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 Integration 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.

4.4 National projects (running in 2015)

4.4.1 Denmark

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)

RePlan (Ancillary services from <u>Re</u>newable power <u>Plan</u>ts)	
	Participants DTU Wind Energy
	General Description The overall objective of this project is to contribute to the integration of large share of renewable energy in the Danish power system and thus to enable a resilient power system in the future by developing technical solutions for the provision of ancillary services by renewable power plants. RePlan focuses on WP and PV plants since they are expected to jointly produce the lion's share of renewable energy generation capacity needed to reach the Danish government 2050 targets.
	Contribution in Grid Integration R&D • Definition of an hierarchical control framework including information and communication technology (ICT) for coordinated participation of ReGen in the provision of ancillary services (2015)

NSON-DK (North Sea Offshore Network – Denmark)	
	Participants DTU Wind Energy, DTU Management Engineering, EA Energyanalyses
	General Description

	The focal point of the NSON-DK project is how the future massive offshore wind power and the associated offshore grid development will affect the Danish power system in the transition towards a future sustainable energy system. NSON-DK will be the Danish part of the North Sea Offshore and Storage Network (NSON) project framework, which has emerged from the European Energy Research Alliance (EERA) as a pioneer project framework joining nationally funded research according to the European Commission's Berlin model.
	Contribution in Grid Integration R&D • How will the offshore wind power development affect the variability and uncertainty of variable renewable generation in the Danish power system and neighboring systems? (2016)

Concert (CONtrol and unCERTainties in real-time power curves of offshore wind power plants)	
	Participants DTU Wind Energy, Vattenfall, SIEMENS Wind Power
	General Description The Concert project is based on the method developed in the prior PossPOW project which developed a methodology to assess the possible power from a down regulated wind power plant. Concert project will use and evaluate the PossPOW findings in real life for power trading and will do a full uncertainty analysis of the signals and forecasts needed for such a demonstration.
	Contribution in Grid Integration R&D • Selection of relevant models for uncertainty quantification, propagation and reduction as well as preliminary application of the selected techniques to the historical data (2016)

SARPS (Security Assessment of Renewable Power Systems)	
	Participants DTU Elektro, DTU Wind Energy, Copenhagen University – Department of computer science
	General Description The overall objective of the SARP project is to push forward the envisioned technology needed for ensuring secure and stable system operation of future power systems with high share of fluctuating RES based production. The main objective of DTU Wind Energy's contribution to the project is to provide improved models of RES based generation units, controls and protection under stressed conditions and to study the RES impact on the power system stability under such conditions.
	Contribution in Grid Integration R&D • Identification of weak points of existing generic RES generation models in simulations of stressed power system conditions (2016)

NetVind (Application of wind power control to improve the operation of a distribution network)	
	Participants EnergiMidt, DTU Wind Energy, Danish Energy Association
	General Description The objective of the project is to use the wind power control capabilities and IT infrastructure to improve the operation of a distribution network. More specifically, a driving objective is to reduce the losses in a distribution system taking into account requirements such as reactive power control to ensure power system stability. Another important objective is to use the wind power control capabilities to avoid or postpone grid reinforcements.
	Contribution in Grid Integration R&D • Formulation of strategy for using wind power control capabilities to reduce losses in distribution networks (2016)

4.4.2 Finland

FLEXe – Future Flexible Energy Systems	
	Participants ABB, Dinex Ecocat, Elenia, Empower IM, Empower TN, Emtele, Fingrid, Fortum, Helen, Inno-W, MX Electrix, Indmeas Industrial Measurements, Tekla, Valmet Automation, Valmet Technologies, Wapice, Wärtsilä Finland, Aalto University, Finnish Meteorological Institute, University of Eastern Finland, Lappeenranta University of Technology, University of Oulu, Finnish Environmental Institute, Svenska Handelhögskolan, VTT Technical Research Centre of Finland, Tampere University of Technology, University of Vaasa
	General Description

	Topic 1: Systemic views on the transition to business ecosystems of a future flexible energy system – understanding future demand profiles and the role and value of different flexibility options. The topic looks at the system level – power and heat system and electricity markets – the expected changes in flexibility needs, the value of each flexibility option in different time scales and markets, and market models and business cases needed in the transition. Topic 2: Optimized and secured integration and operation of future energy networks. The key objective is to define the flexibility requirements for the planning and operation of integrated energy networks. This requires novel, high-quality, reliable and secured measurements, telecommunication, data processing and new technological platforms to be researched. Topic 3: Flexibility management of distributed resources – increasing efficiency across the whole energy system and supporting active participation of all partners of the system. The key objective is to integrate the distributed resources to the energy system and harness the flexibility at the customer and prosumer side for the improved operation of the energy system. Enabling extensive integration and maximal utilization of local and global intermittent energy sources. Topic 4: Flexible generation for future energy system – new operational modes for secure, cost-effective, clean and competitive supply. Gaining understanding in the requirements and limitations that the future energy system poses for flexible generation and how flexible power generation can overcome those limitations and meet the requirements.
	Contribution to Grid Integration R&D Adds to the understanding of the value of power system flexibility options, flexibility management of distributed energy resources (e.g. wind), and extensive integration and maximal utilization of local and global intermittent energy sources.

Transition to a resource efficient and climate neutral electricity system (EL-TRAN)	
	Participants University of Tampere, University of Eastern Finland, Tampere University of Applied Sciences, Tampere University of Technology, The Finland Futures Research Centre (University of Turku), VTT Technical Research Centre of Finland
	General Description EL-TRAN Consortium investigates what a resource efficiency means, how to implement such a system in Finland and elsewhere, what kind of policy problems are foreseeable in the process and how do we eventually resolve the problems.
	Contribution to Grid Integration R&D What policy measures are needed to implement a resource efficient and climate neutral electricity system. Wind power will be one of key options.

Neo-Carbon Energy	
	Participants VTT Technical Research Centre of Finland, Lappeenranta University of Technology, The Finland Futures Research Centre,
	General Description

	Despite all the efforts to reduce the energy-related greenhouse gas emissions, the global-scale fact is that the annual emissions have doubled since the 1970s. The proportion of fossil fuels from the global energy use is currently the same it was in the 1990s. The world needs concrete and feasible solutions. Neo-Carbon Energy's solution is an entirely new energy system based solely on solar and wind alongside hydro power and biomass. The system will produce energy that is emission-free, cost-effective and independent. The new system is based on solar and wind because they are the only sufficient and infinite energy sources. They will also be the cheapest production methods in the largest energy markets by 2020. The renewable energy system will impact all levels of society. Societally there will be a feasible renewable energy system that will allow variable electricity production and energy storages. Industry will have new technologies. There will be new industrial and economic opportunities to serve world's energy needs. Consumers will become 'prosumers' with the democratisation of energy production.
	Contribution to Grid Integration R&D How can wind power contribute towards a new emission-free, cost-effective and independent energy system?

RealValue	
	Participants VTT Technical Research Centre of Finland, Riga Technical University, SSE Airtricity, MVV Energie, Intel, Glen Dimplex, Glen Dimplex Deutschland, ESB Networks, Eirgrid, Environmental Change Institute (University of Oxford), BEEGY, DIW Berlin, Energy Energy Institute (University College Dublin)
	General Description RealValue commenced in June 2015 and is a €15.5 million European energy storage project funded by Horizon 2020. RealValue will use a combination of physical demonstrations in Ireland, Germany and Latvia along with innovative modelling techniques, in order to demonstrate how local small-scale energy storage, optimised across the whole EU energy system, with advanced ICT, could bring benefits to all market participants. The duration of the Project is 36 months.
	Contribution to Grid Integration R&D How can local small-scale energy storage help integrate large amounts of wind and solar power?

Improving the value of variable and uncertain power generation in energy systems (VaGe)	
	Participants VTT Technical Research Centre of Finland, Finnish Meteorological Institute
	General Description

	The energy sector is under transformation. The share of variable power generation, such as wind power and photovoltaic (PV), is increasing rapidly. Their output is dependent on weather and therefore much more variable and uncertain than the output from more conventional power generation. Variability and uncertainty brings challenges to power system operators and lowers the value of wind power and PV for the overall energy system and therefore also for the society at large. Variability decreases value since it causes periods with surplus electricity and periods with high net demand (demand minus the generation from wind power and PV – i.e. what other power plants need to provide for). Uncertainty decreases value since decision making under uncertainty is more difficult. Uncertainty leads to suboptimal decisions concerning e.g. when to store energy and when to start up power plants. VaGe project objective is to improve operational decision making in the power systems when considering the variability and uncertainty of wind, solar, water inflow, heat and electricity demand, their correlations and possible sources of flexibility. Decision making under weather related variability and uncertainty is improved in two different time scales: 1) short-term power plant unit commitment and dispatch decisions (look-ahead up to 36 hours) and 2) medium-term optimization of storage use, consumer resources and other slow processes (look-ahead up to two weeks). More information, i.e. better and more comprehensive forecasts, and energy system flexibility can mitigate variability and uncertainty. Due to systemic interactions, it is important to assess all relevant sources of flexibility. The general objective is split into: 1. Improve the uncertainty estimates of weather related power generation on both medium-term and short-term time scales 2. Improve the representation and modelling of weather related uncertainties within the energy system optimisation models – including a new model for the medium-term 3. Find solutions to mitigate variability and uncertainty utilizing better forecasts as well as flexibility from biomass, consumer participation and electrification of heat and transport
	Contribution to Grid Integration R&D Improving the forecasts of weather related power generation. Improving the representation of the forecasts in power system models.

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

4.4.3 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

DEA-Stabil	
	Participants IWES, DERlab e.V., Enercon GmbH, TenneT TSO GmbH
	General Description The main focus of the project DEA-Stabil is to investigate the contribution of distributed energy resources (DER, German "DEA") to the system stability. In the DEA-Stabil project the power system stability has been considered to consist of: rotor angle stability, frequency stability and voltage stability. The main goals of the project are: - the development of methods for investigating power system stability in presence of high shares of grid-connected DER - the analysis of changes in the power supply structures - the development of grid connection requirements for DER - the development and demonstration of new control structures - the transfer of results at European level.
	Contribution in Grid Integration R&D Within the DEA-Stabil project one of the performed investigations concerned the analysis of the transmission system stability in the presence of high wind power shares. For the aforementioned investigations the IEEE 39 bus test benchmark was used. Within the study conventional generation was substituted by wind power plants having different frequency supporting functionalities (like proportional primary control and synthetic inertia control). These functionalities were developed and integrated in a doubly-fed induction generator-based wind turbine (DFIG-WT). The functionalities were tested and the frequency behaviour of the 39 bus system was analysed. As result it could be shown that in the transmission system integrating 50 % share of wind power plants in case of different events the frequency can be stabilized similarly to the case of a conventional plants-dominated system. Under certain conditions (e. g. availability of active power reserve capacity from the wind turbines) it has been shown that it is possible to enhance the frequency behaviour of the system in the cases of loss of generation or load. The study will be mainly finished within quarter 1 of 2016.

NETZ:KRAFT	
	Participants
	IWES, Amprion, TenneT TSO, 50hertz Transmission, Transnet BW, Avacon, Drewag Netz, EnergieNetz Mitte, HanseWerk, MITNETZ Strom, Energiequelle, DUtrain, GridLab, ENERCON, Oekobit, SMA Solar Technology, DERlab, Friedrich-Alexander-Universität Erlangen-Nürnberg, Univerität Kassel
	General Description
	NETZ:KRAFT is investigating network restoration concepts in view of future power plant structures aiming at active contributions from renewables. Enhancement of existing restoration concepts considering the characteristics of wind and PV plants. Investigate options to build grid islands with decentralised generation to reduce downtime in distribution grids.
	Contribution in Grid Integration R&D
	Define the requirements for renewable installations and decentralized generation to actively contribute to individual steps in the network restoration process.

4.4.4 Italy

RITMARE	
	Participants
	CNR, INGV, CONISMA, OGS, ENEA, Anton Dohrn, CIFAI
	General Description
	RITMARE is the leading national marine research project for the period 2012-2016; the overall project budget amount to 250 million euros, co-funded by public and private resources. It is coordinated by the National Research Council and involves an integrated effort of most of the scientific community working on marine and maritime issues, as well as some major industrial groups.
	Contribution in Grid Integration R&D
	Integration of renewable energy on board

I-AMICA	
	Participants
	CNR
	General Description
	To develop a research infrastructure and services to territory in Southern of Italy related to climate changes and environmental observations.
	Contribution in Grid Integration R&D
	Application service for wind energy forecast

Greenports	
	Participants
	CNR, University of Reggio Calabria, CRATI, Buonafede SRL, Cooperativa Tec,

	WaveEnergy Srl
	General Description The project aim to develop environmental sustainable ports related to environmental impact and self-energy production through: wind, solar and wave energy resources in Vibo Valentia and Crotone Italian ports.
	Contribution in Grid Integration R&D renewable energy resource climatology (wave, wind and solar energy) and their integration in a possible small grid

Res Novae	
	Participants CNR, University of Calabria, University of Bari, ENEL Distribuzione, ENEA, University of Naples, General Electrics, DATASystem, Università Korè Enna
	General Description The project aim to develop an advanced and efficient management energy fluxes system at city level with the aim of develop a Smart Cities experimenting it in Bari and Cosenza.
	Contribution in Grid Integration R&D a new platform to improve the use and integration of innovative solution in ICT and Renewable Energy (wind and solar) toward a sustainable development. Optimal parametrization scheme adoption for wind and solar forecast for Bari and Cosenza energy production.

4.4.5 Netherlands

Synergies at Sea – Sub-project 1: Interconnector	
	Participants Nuon/Vattenfall, ECN, Delft University of Technology, University of Groningen, Royal HaskoningDHV and DC Offshore Energy, Executed under program TKI-WindOpZee, 2013-2016
	General Description This project studies interconnecting between two offshore wind power plants in the UK and Dutch part of the North Sea. Leads to the following synergy advantages: • There is a redundant connection from the OWF to shore. • Cross-border trade of electricity generated onshore via the same infrastructure • Electricity can be sold to the country with the highest price of electricity. In total 15 different design variants were studied, addressing economic and technical feasibility as well as regulatory aspects.
	Contribution in Grid Integration R&D The project showed that some technically feasible solutions exist already at relatively short-term (2020) that are also beneficial for both private investors and for society as a whole. For this detailed electrical models and a European-wide market model have

been coupled to accurately predict the Interconnector losses and benefits. Regulatory barriers were addressed and concrete proposals formulated to alleviate the existing regulatory barriers, which is a requirement for further cost reductions as a result of increased industrial R&D efforts. HVDC MMC-converters have been modelled to prepare for protection and dynamics simulations of the most promising systems, planned for 2016.

Wind Farm electrical system design and optimization	
	Participants ECN, Delft University of Technololgy, RWE Innogy, XEMC Darwind, 2_Energy, 2011-2015, Executed under the FLOW (Far Large Offshore Wind) proram
	General Description In this project a framework has been developed and demonstrated to integrate, automate and optimize the design of offshore wind farms. For this a state-of-the-art multi-objective optimization algorithm, was tailored to the design process of offshore wind farms and applied to optimize the wind farm electrical system for RWE Innogy.
	Contribution in Grid Integration R&D The optimized approach showed potential cost benefits for the Dutch development zones IJmuiden Ver (*Tromp Binnen*) and Borssele (4 x 350MW). Further, existing models have been extended and validated, such as thermal subsea cable models in EeFarm, which were compared to measurements from the *Gwynt-y-Môr* offshore wind farm, showing increased accuracy of the modelled losses. Further a dynamic study on voltage control and low-voltage ride through for an HVDC connected offshore wind power plant, specified by RWE Innogy, showed to fulfil the draft Dutch grid code.

4.4.6 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.

4.4.7 Portugal

MAN-REM: MAN-REM - Multi-agent Negotiation and Risk Management in Electricity Markets. PTDC/EEA-EEL/122988/2010	
	Participants
	Laboratório Nacional de Energia e Geologia, I.P. (LNEG) (Coordinator). Instituto Superior de Engenharia de Lisboa (ISEL/IPL)Instituto Superior de Engenharia do Porto (ISEP/IPP)Fundação da Faculdade de Ciências da Universidade de Lisboa (FFC/FC/UL).

	General Description
	The MAN-REM (Multi-agent negotiation and Risk management in Electricity market) project aims at developing an agent-based tool to simulate pool trading and bilateral contracting of energy. Currently, the major components of the tool (or system) include a graphical user interface, a simulation engine, and a number of domain-specific agents. The graphical user interface allows users to specify and monitor trading simulations. , which are controlled by the simulation engine. The agents are computer systems capable of flexible action and able to communicate, when appropriate, with other agents to meet their design objectives. They perform actions to achieve specific goals, notably the goal of maximizing profit during energy trading. The system supports a day-ahead market, where load-serving entities and buy energy from producers in advance of time when the energy is produced and consumed. The pricing mechanism is founded on the marginal pricing theory, both system marginal pricing and locational marginal pricing. The system also supports bilateral contracting of electricity. Buyer and seller agents are equipped with a negotiation framework that handles two-party and multi-issue negotiation. The agents interact and trade according to the rules of an alternating offers protocol, i.e., negotiation proceeds by an iterative exchange of offers and counter-offers.
	Contribution in Grid Integration R&D
	The system is being analyzed and tested by considering a case study describing the Iberian market (MIBEL). Different closure times and reserves payments structures are being tested for high wind penetration scenarios.

VRPP - Dynamic model of Virtual Power Plant able to account for Ancillary Services	
	Participants
	Leading Institution: LNEG. Partners/Institutions: Faculdade de Ciências da Universidade de Lisboa (FCUL)
	Leading Institution: LNEG. Partners/Institutions: Faculdade de Ciências da Universidade de Lisboa (FCUL)
	Characterizing the impact of renewable energy sources (RES) in the Portuguese electrical power system with special focus on relating wind parks power fluctuations to the use balancing services. The main goals of this work are: i)evaluation of the historical technical and economic impact of RES in the power system balancing needs; ii) development of a Virtual Power Plant controller able to provide power balancing services optimizing the market value of renewable energy making use RES control capabilities and ultimately, its curtailment; iii) evaluate the requisites and added value of energy storage solutions; and iv) develop a dynamic model able to test and evaluate the value and efficiency of the proposed solutions.
	Contribution in Grid Integration R&D
	To allow for a larer profit during the life-cycle of the RES installations while at the same time will reduce the costs and improve the security of the power system operation.

4.4.8 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.

4.4.9 UK

SUPERGEN -- Wind Energy Technology	
	Participants
	Academic full partners: University of Strathclyde (coordinator), University of Durham, Loughborough University, University of Manchester, STFC-RAL, University of Cranfield, **Industry partners and advisors:** AREVA, CEFAS , Clipper Wind , EA Technology, Eon Climate and Renewables, GL GarradHassan, MLS, Mott MacDonald, NaREC, Nordic Windpower, QinetiQ, Rolls Royce, Romax, Scottish Power, Siemens Wind Power, TNEI, Vestas, Wind Prospect, 3M
	General Description
	Integrates the research efforts of all the partners to address the medium term challenges of scaling up to multiple wind farms through building, operating and maintaining multi-GW arrays of wind turbine
	Contribution in Grid Integration R&D
	1. Better Understand impact of whole wind farms on AC networks 2. Integration of new technology with onshore legacy systems on UK and European scale 3. Assessment of UK economic impact

4.5 Publications in 2015

Denmark

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Kiviluoma, Juha ; Holttinen, Hannele ; Weir, David ; Scharff, Richard ; Söder, Lennart ; Menemenlis, Nickie ; Cutululis, Nicolaos Antonio ; Danti Lopez, Irene ; Lannoye, Eamonn ; Estanqueiro, Ana ; Gomez-Lazaro, Emilio ; Zhang, Qin ; Bai, Jianhua ; Wan, Yih-Huei ; Milligan, Michael. Variability in large-scale wind power generation. In journal: Wind Energy (ISSN: 1095-4244) (DOI: http://dx.doi.org/10.1002/we.1942), 2015

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The Netherlands

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4.6 Contact for the sub-programme Wind Energy Integration

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

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

A sub-programme within the Joint Programme:
Wind Energy

Yearly reporting - 2015

5. Sub-programme on Offshore Wind Energy

5.1 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 was mainly expected to being addressed through the ERA-net co-fund European wind atlas project, but as this project will not address wave and currents, other initiatives shall be pursued.	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. Closer alignment with the FP7 BestPath project and the new H2020 PROMOTioN (PROgress on Meshed HVDC Offshore Transmission Networks) should be sought.	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. The new H2020 Lifes50+ covers partly the RT, but to further 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

5.2 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
√ (green)	Goal has been reached (and maybe even exceeded).
(yellow)	Ongoing activity / prior to deadline
X (red)	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 are submitted.
M4	RT5: H2020 applications on novel concepts	Sept. 2014	SP partners		More initiatives in preparation	(√) Applications were submitted,

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	In progress
M11	RT3: Workshop on political drivers and cost-benefit sharing options	Sept. 2015	SINTEF Energy; Strathclyde, Fh IWES, ..		NSON M2	In progress
M12	RT3: Established Strategic Research Agenda for North Sea offshore grids	Dec. 2015	SINTEF Energy; Strathclyde, Fh IWES, ..	12	NSON M3	In progress

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	

5.3 International collaboration in 2015

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, expanded with DK and NL in 2015
- EERA IRPWind, kick-off 2014
- IEA Wind Task30: OC5, kick-off 2014
- LIFES 50plus, kick-off 2015

5.4 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)

5.5 Publications in 2015

John Olav Giæver Tande, Trond Kvamsdal, Michael Muskulus, Editorial, Energy Procedia, Volume 80, 2015, Page 1, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.399. (http://www.sciencedirect.com/science/article/pii/S1876610215021311)

Erin E. Bachynski, Valentin Chabaud, Thomas Sauder, Real-time Hybrid Model Testing of Floating Wind Turbines: Sensitivity to Limited Actuation, Energy Procedia, Volume 80, 2015, Pages 2-12, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.400. (http://www.sciencedirect.com/science/article/pii/S1876610215021323)
Keywords: offshore wind energy; floating wind turbines; real-time hybrid testing

Romans Kazacoks, Peter Jamieson, Evaluation of Fatigue Loads of Horizontal Up-scaled Wind Turbines, Energy Procedia, Volume 80, 2015, Pages 13-20, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.401. (http://www.sciencedirect.com/science/article/pii/S1876610215021335)
Keywords: Fatigue; Lifetime damage equivalent loads; Scaling

Madjid Karimirad, Constantine Michailides, Dynamic Analysis of a Braceless Semisubmersible Offshore Wind Turbine in Operational Conditions, Energy Procedia, Volume 80, 2015, Pages 21-29, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.402. (http://www.sciencedirect.com/science/article/pii/S1876610215021347)
Keywords: Braceless semisubmersible; Dynamic analysis; Offshore floating wind turbine

Yngve Heggelund, Chad Jarvis, Marwan Khalil, A Fast Reduced Order Method for Assessment of Wind Farm Layouts, Energy Procedia, Volume 80, 2015, Pages 30-37, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.403. (http://www.sciencedirect.com/science/article/pii/S1876610215021359)
Keywords: Wind farm layout; offshore wind; model reduction; CFD

Dariusz Dąbrowski, Anand Natarajan, Assessment of Gearbox Operational Loads and Reliability under High Mean Wind Speeds, Energy Procedia, Volume 80, 2015, Pages 38-46, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.404. (http://www.sciencedirect.com/science/article/pii/S1876610215021360)
Keywords: gearbox model; extreme gearbox loads; offshore wind energy; relaibility assassment; multibody; planetary gear

Xiaoze Pei, Alexander C. Smith, Mike Barnes, Superconducting Fault Current Limiters for HVDC Systems, Energy Procedia, Volume 80, 2015, Pages 47-55, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.405. (http://www.sciencedirect.com/science/article/pii/S1876610215021372)
Keywords: HVDC; Multi-terminal; Inductive SFCL; Resistive SFCL

N. Magnusson, J.C. Eliassen, A.B. Abrahamsen, A. Nysveen, J. Bjerkli, M. Runde, P. King, Design Aspects on Winding of an MgB2 Superconducting Generator Coil, Energy Procedia, Volume 80, 2015, Pages 56-62, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.406. (http://www.sciencedirect.com/science/article/pii/S1876610215021384)
Keywords: Superconductor generator; coil winding; electrical insulation

Yalcin Dalgic, Iraklis Lazakis, Iain Dinwoodie, David McMillan, Matthew Revie, Jayanta Majumder, Cost Benefit Analysis of Mothership Concept and Investigation of Optimum Chartering Strategy for Offshore Wind Farms, Energy Procedia, Volume 80, 2015, Pages 63-71, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.407.
(http://www.sciencedirect.com/science/article/pii/S1876610215021396)
Keywords: Mothership; Offshore Wind; Operation and Maintenance; Charter Rate; Crew Transfer Vessel; Accessibility; Simulation

Jordi Pegueroles, Mike Barnes, Oriol Gomis, Antony Beddard, Fernando D. Bianchi, Modelling and Analysis of CIGRE HVDC Offshore Multi-terminal Benchmark Grid, Energy Procedia, Volume 80, 2015, Pages 72-82, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.409.
(http://www.sciencedirect.com/science/article/pii/S1876610215021414)
Keywords: offshore HVDC; Small Signal Analysis; Multi-Terminal ;

Lars Morten Bardal, Lars Roar Sætran, Erik Wangsness, Performance Test of a 3MW Wind Turbine – Effects of Shear and Turbulence, Energy Procedia, Volume 80, 2015, Pages 83-91, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.410.
(http://www.sciencedirect.com/science/article/pii/S1876610215021426)
Keywords: Wind power; Power curve; Lidar; Wind shear; Turbulence

Magnus Stålhane, Lars Magnus Hvattum, Vidar Skaar, Optimization of Routing and Scheduling of Vessels to Perform Maintenance at Offshore Wind Farms, Energy Procedia, Volume 80, 2015, Pages 92-99, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.411.
(http://www.sciencedirect.com/science/article/pii/S1876610215021438)
Keywords: Operation and maintenance; Routing and scheduling; Offshore Wind; Vehicle routing

Kok-Hon Chew, Kang Tai, E.Y.K. Ng, Michael Muskulus, Optimization of Offshore Wind Turbine Support Structures Using an Analytical Gradient-based Method, Energy Procedia, Volume 80, 2015, Pages 100-107, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.412.
(http://www.sciencedirect.com/science/article/pii/S187661021502144X)
Keywords: Structural optimization; sensitivity analysis; gradient-based; offshore wind; support structures

Raphael Ebenhoch, Denis Matha, Sheetal Marathe, Paloma Cortes Muñoz, Climent Molins, Comparative Levelized Cost of Energy Analysis, Energy Procedia, Volume 80, 2015, Pages 108-122, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.413.
(http://www.sciencedirect.com/science/article/pii/S1876610215021451)
Keywords: Offshore wind; Floating wind turbines; Wind farm planning; AFOSP; Levelized Cost of Energy; Economics; Life Circle Assessment; Sensitivity analysis; Concrete substructure

Guang Zeng, Tobias Hennig, Kurt Rohrig, Multi-terminal HVDC Modeling in Power Flow Analysis Considering Converter Station Topologies and Losses, Energy Procedia, Volume 80, 2015, Pages 123-130, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.414.
(http://www.sciencedirect.com/science/article/pii/S1876610215021463)
Keywords: Multi-Terminal HVDC; Converter Station Loss Modelling; Load Flow Analysis

Mostafa Bakhoday Paskyabi, Offshore Wind Farm Wake Effect on Stratification and Coastal Upwelling, Energy Procedia, Volume 80, 2015, Pages 131-140, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.415.
(http://www.sciencedirect.com/science/article/pii/S1876610215021475)
Keywords: Offshore wind farm; Coastal upwelling; Vortex street; Density frons; Shallow water equation; Wake model.

Mostafa Bakhoday Paskyabi, Helge Thomas Bryhni, Joachim Reuder, Ilker Fer, Lagrangian Measurement of Waves and Near Surface Turbulence from Acoustic Instruments, Energy Procedia, Volume 80, 2015, Pages 141-150, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.416.
(http://www.sciencedirect.com/science/article/pii/S1876610215021487)
Keywords: Lagrangian drifter; ADV; ADCP; Motion compensation; Wave-induced bias; Gravity waves; Structure functions; Inertial subrange.

Sebastian Kelma, Peter Schaumann, Probabilistic Fatigue Analysis of Jacket Support Structures for Offshore Wind Turbines Exemplified on Tubular Joints, Energy Procedia, Volume 80, 2015, Pages 151-158, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.417.
(http://www.sciencedirect.com/science/article/pii/S1876610215021499)
Keywords: offshore wind energy; jacket substructure; tubular joints; fatigue design; probabilistic analysis; peak-over-threshold method; generalized Pareto distribution

Lene Eliassen, Eivind Sæta, Jørgen Krokstad, Measurement Campaign of a Large Rotor Wind Turbine, Energy Procedia, Volume 80, 2015, Pages 159-167, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.418.
(http://www.sciencedirect.com/science/article/pii/S1876610215021505)
Keywords: Measurement; Operational Modal Analysis

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Keywords: Shallow waters; Floating Offshore Wind Turbines; OC4; Semisubmersible; Quadratic Transfer Functions; Setdown.

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Keywords: Offshore wind energy; O&M; Remote inspection ;

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Keywords: HVDC; VSC – HVDC; Voltage Control; Fault Management; Wind Energy

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Keywords: Truss structures; Inverse problem; Transient finite element analysis; Slamming coefficient; Offshore wind energy.

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(http://www.sciencedirect.com/science/article/pii/S1876610215021645)
Keywords: energy storage; wind; control; capacity firming; offshore

E. Fonn, A. Rasheed, A.M. Kvarving, T. Kvamsdal, Spline Based Mesh Generator for High Fidelity Simulation of Flow around Turbine Blades, Energy Procedia, Volume 80, 2015, Pages 294-301, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.433.
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Keywords: Mesh generation; Wind turbine blades; Computational fluid dynamics; Variable turbulent intensity

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Keywords: Wind Energy; Vertical Axis Wind Turbine; Computational Fluid Dynamics; Variable Turbulence Intensity

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Keywords: floating wind turbines; vertical axis wind turbine; integrated simulations

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Keywords: Vertical–axis wind turbine; offshore floating platform; DeepWind; aerodynamics; hydrodynamics; pultrusion; structural optimization; floater; permanent magnet generator; magnetic bearings; controls; safety; cost models

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Keywords: Vortex methods; Simulation; Wind Turbines; Aeroelastic ;

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Keywords: grid model reduction; power flow analysis,

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Keywords: risk; reliability; offshore; life-cycle; maintenance; turbine; blade

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(http://www.sciencedirect.com/science/article/pii/S1876610215021736)
Keywords: non-parametric statistics; genetic algorithm; wind power integration; offshore grid design; data sampling

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(http://www.sciencedirect.com/science/article/pii/S1876610215021748)
Keywords: Floating turbine; Integrated modelling; Wind turbine modeling; Fault ride through; Motion response; Offshore Wind Introduction

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Keywords: bearings; reliability; wind turbine gearbox; electro-mechanical model

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Keywords: offshore wind power; wind energy; passive filter design; LCL filter; harmonics

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Keywords: Long-range pulsed lidar; Short-range WindScanner; Sonic anemometer; Length-scale; Coherence; Long-span bridges

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Keywords: Offshore; system costs; flexibility costs; reserve power; optimal renewable energy mix

Jakob Kristoffer Süld, Adil Rasheed, Jørn Kristiansen, Øyvind Sætra, Ana Carrasco, Trond Kvamsdal, Mesoscale Numerical Modelling of Met-ocean Interactions, Energy Procedia, Volume 80, 2015, Pages 433-441, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.447. (http://www.sciencedirect.com/science/article/pii/S1876610215021797)
Keywords: Met-Ocean interaction; Wave modeling

Timo van Opstal, Eivind Fonn, Runar Holdahl, Trond Kvamsdal, Arne Morten Kvarving, Kjell Magne Mathisen, Knut Nordanger, Knut Morten Okstad, Adil Rasheed, Mandar Tabib, Isogeometric Methods for CFD and FSI-Simulation of Flow around Turbine Blades, Energy Procedia, Volume 80, 2015, Pages 442-449, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2015.11.448. (http://www.sciencedirect.com/science/article/pii/S1876610215021803)
Keywords: Isogeometric Analysis; Finite Element method; Wind turbine blades

5.6 Contact Point for the sub-programme on offshore wind energy

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Research Infrastructures

A sub-programme within the Joint Programme:
Wind Energy

Yearly reporting - 2015

6. Sub-programme on Research Infrastructures

The background for having a dedicate programme on research infrastructures is the importance of achieving as real cooperation and enough critical mass among the EERA JP Wind partners. This will improve their ability to perform large, advanced or unique 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 partners of the EERA common research program in the field of Wind Energy.

6.1 Report on Research Themes

The following responds to a status description for each of the research themes

RT1: Networks on relevant RI

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The first task of the IRPWind WP3 Infrastructures is the creation of Networking's of Research Infrastructures. Sharing and coo-working are expected to create synergy and effectiveness or value of future results.

The first three Networks have been created for the following priority research facility types:

- ✓ Research Wind Turbines for aerodynamics and loads study: **RWT.** Coordinated by Dr. Chong Ng / Offshore Renewable Energy Catapult.
- ✓ Wind Tunnels for wind energy research: **WT.** Coordinated by Dr. Stephan Barth / ForWind - Center for Wind Energy research.
- ✓ Testing Facilities for Grid integration: **GI.** Coordinated by Dr. Jose Luis Dominguez / IREC - Catalonia Institute for Energy Research.

The procedure for the networks creation has followed these steps:

- Request of Expression of Interest, EoI, to IRPWIND and EERA members.

- Establishment of Networks: According to the EoI's received, three networks have been created.
- Appointment of the three Network Coordinators.

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

The Second task of this WP3Infrastructures, is “Experiments selection and supported access to facilities”

This task has produced the following deliverables for the second year of the project:

- Publication of the Catalogue of EERA Facilities Available to the IRPWIND project
- 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 was 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 has been given priority.
- Call for Proposal of Experiments and Granting of Support. Two calls will be made along the project. Best proposals will be granted support for merits reasons according to the rules. More experiments will be carried out as budget allows so. This year the first Call has been launched.

The first action, publication of the Catalogue of EERA test Facilities, is required 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.

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

Second action has been 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 has been created. The Technical Committee was created i during the kick-off meeting of the IRPWind project in Barcelona were Pablo Ayesa (Director of 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 has been 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 has been given priority.

Main activities of this action have been:

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

The work document "Rules & Conditions for joint experiments" has been a deliverable of this second year work.

The forth action has been accomplished; the first "Call for Proposal of Experiments and Granting of Support" has been launched.
In order to launch the first call on experiments, the previous three actions: Publication of the Catalogue of test Facilities, creation of the Technical Committee and the creation of the Rules and Conditions for joint experiments, were of critical importance.
Focussing on the first Call built up, an evaluation procedure of the applications has been set up The eligible proposals will be evaluated and scored by relevant Network Coordinator and two independent experts appointed by the Work Package Coordinator: CENER.
The evaluation will be done according to the criteria and the grading scale already publish it on the IRPWIND web, thanks to the collaboration of DTU Wind . The proposals with highest scores above threshold will be presented to the Technical Committee, for final approval.

RT3: Measuring of Windflow

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 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.

All along this second year the two actions that have been completed are the creation of the "Roadmap for the construction phase of the european Windscanner.eu" and the "Planning for the implementing of the national nodes of windscanner", both are deliverables of this second year preparatory phase. The WindScanner Preparatory Phase (PP) project has developed the governance scheme, legal model, and the final technological design and associated budget and financing models for its construction in 2016.
The WINDSCANNER PP project address coordinated European development of the facility in a joint technological and economically substantial European approach.

6.2 Reporting on Milestones and deliverables

These are the milestones and deliverables **M/D** of all the activities carried out within the research Infrastructure subprogramme.

Mile-stone	Objective	Date	Comments /project	Status - end 2015
M/D 1	RT1: Report on Networking Activities	March 2015	IRPWIND	√
M/D 2	RT2: Rules and Conditions for Joint Tests	March 2015	IRPWIND	√
M/D 3	RT2: Call for Experiments for Existing Facilities (IRP)	October 2015	IRPWIND, start 2015	(delayed to February 2016) √
M/D 4	RT2: EERA facilities catalogue	March 2015	IRPWIND	√
			Windscanner.eu	√
M/D 5	RT3: Definition of Windbench.eu work program	March 2015	IRPWIND	√
M/D 6	RT3: Roadmap for the construction phase of the european Windscanner.eu	October 2015	Winscanner PP	√
M/D 7	RT3: Planning for the implementing of the national nodes of windscanner.	April 2015	Winscanner PP	√
M/D 8	RT3: Start of operation of Windbench.eu	December 2015	IRPWIND and others	

6.3 International collaboration in 2015

Several partners in EERA JP Wind are involved in the European collaborative projects such as INNWIND, AVATAR and the IEA Annex MexNext 3. Besides basic research activities the partners cooperate with different international Research Infrastructures.

INNWIND	
	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 Research Infrastructures A specific work package focuses on innovative solutions in offshore. These studies should be coupled together with new innovative rotor concepts to reduce the cost of energy of future 10-20MW offshore turbines. 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 Research Infrastructures Aerodynamics of large (10MW+) wind turbines is investigated in the EU FP7 project AVATAR. In order to improve aerodynamic models, **air foil measurements** were carried out in the pressurized **Wind tunnel of DNW-DLR** 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. The outcome of the blind test has	

been presented on a side event of EWEA 2015 in November 2015 in Paris.

<table>
<tr><th colspan="2">IEA Mexnext</th></tr>
<tr><td rowspan="2"></td><td>Participants</td></tr>
<tr><td>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</td></tr>
<tr><td rowspan="2">http://www.mexnext.org/</td><td>General Description</td></tr>
<tr><td>The objective of IEA Wind Task MEXNEX is a thorough investigation of various aerodynamic measurements in a rotor model scaled and tested in a wind tunnel. These effects are analysed by means of different categories of solvers As such the Task provided insight on the accuracy of different types of models by comparing to the wind tunnel test of the scaled wind turbine.</td></tr>
<tr><td colspan="2">Contribution in Research Infrastructures
Unique database for code comparison and evaluation is set up to support code development as well as giving the opportunity to have comparison data for wind turbine rotor validation..
The validation of the aerodynamic modelling is 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 Wind Tunnel of DNW-DLR (9.5x9.5 m2) .</td></tr>
</table>

6.4 Contact Point

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EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

SUB-PROGRAMME: Economic and social aspects of wind integration

Yearly reporting - 2015

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

7.1 Report on Research Themes

This sub-programme explores 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 supports the other sub-programmes within the joint programme on wind energy by adding an economic and social perspective into the analysis. This includes aspects relating to society, technology, environmental and economic challenges of wind integration. Moreover, independent research activities will be undertaken within the sub-programme.
The main research themes are:

TR1	Component and system costs of wind energy
RT2	Economic incentives and support mechanisms for wind energy
RT3	Economic integration of wind into energy systems
RT4	Adapting power markets for wind energy
RT5	Environmental issues of wind energy including Life Cycle Assessment (LCA)
RT6	Public engagement options for wind energy

The subprogram started up in end 2014. Therefore some of the research themes had kick-off during 2015.

RT1 had its official kick-off in May 2015 at IREC, Barcelona, Spain.
14 partners from 4 different countries attended the kick-off meeting, presenting their research work within the economic assessment and technology development in the wind energy field. The out-come of the workshop will be a report on *State of the art of existing tools for wind energy economic assessment*. The draft report was presented at the EERA jp Wind conference in Amsterdam in September 2015. The final report will be finish in 2016.

RT2 had its official kick-off and first workshop in connection to the EERA jp Wind conference in Amsterdam in September 2015. The outcome of the workshop was a draft report on 'Future policy support options for offshore wind energy in Europe. The report will be finalised in 2016

RT3-5 have planned Kick-off meetings in 2016.

RT6 was started up in end-2014. A workshop on public acceptance issues of onshore wind energy were organised in March 2015 at DTU, Denmark. The purpose of the workshop, was to gather social scientists and wind engineers within EERA jp Wind to discuss the state of the art and science of public engagement and identify key questions relevant for the wind community in EU and beyond. 30 partners participated in the workshop.
The outcome of the workshop was a draft report of a white book on social science approaches of wind energy deployment. The draft white book was presented at the EERA jp Wind conference in Amsterdam in September 2015. The final report will be finalised in January 2016.

7.2 Reporting on Milestones and deliverables

Mile-stone	Objective/title	Nature	Delivery	Lead partners	Comments	Status – end 2015
M3	*RT1: Kick-off and workshop on component and system cost development and related research needs*		*May 2015*	IREC		done
M4	*RT6: Workshop on public acceptance issues of onshore wind energy*		*March 2015*	DTU		done
	Sub-programme: Organise session at EERA DeepWind conference		*February 2015*	DTU		done
	RT6: Draft version of white book on social science approaches of wind energy deployment		*Draft report at Amsterdam conference September 2015*	DTU		done
	RT2: Workshop on future policy support options for offshore wind energy in Europe		*Workshop at Amsterdam conference September 2015*	DTU ECN UCD		done
	RT1: Draft version of review document: State of the art of existing tools for wind energy economic assessment		*Presented at Amsterdam conference September 2015*	IREC		done
	Sub-programme: Organise SP meeting		*Amsterdam conference September 2015*	DTU		done
	Sub-programme: Input to new EAWE R&D plan		*November 2015*	TU Delft DTU		done

7.3 International collaboration in 2015

Several groups of members were formed at the different Kick-off meetings within each research themes. This in order to form collaborations for new project ideas and in order to start creating EoI's and organizing the different milestones. By the end of 2015 no concrete international projects had been funded.
Partners from the sub-programme were involved in input to the long term research and development plan for EAWE, and developed a new focus area within societal and economic aspects of wind energy.

7.4 National projects

An overall mapping of interest and ongoing projects within the sub-group members were made in connection to the Kick-off meeting in November 2014.
These have been updated at the workshops and kick-off meetings for RT1, RT2 and RT6.

7.5 Publications in 2015

Several presentation were made, e.g. at the different schematic workshops and at the EERA conference in Amsterdam in September 2015.

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

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