Triton Knoll Offshore Wind Farm Project

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EV011: Innogy innovation case studies

Supply Chain Plan for Galloper Wind Farm for submission to Department of Energy & Climate Change

Annex 5: Evidence

Evidence reference: **EV039**

RWE Innogy research and development projects

Joint Industry R&D Programmes

Offshore Wind Accelerator

- Aim: Carbon Trust brings together nine offshore wind developers in a joint industry project to work towards reducing the cost of offshore wind by at least 10% by 2015.
- http://www.carbontrust.com/our-clients/o/offshore-wind-accelerator
- Country: UK
- Enabling Body: DECC
- RWE is participating in the following projects within the OWA:

    - **All OWA common R&D projects Year 1 –Year 6 inc. Stage I OWA.**

    - **Floating LiDAR demonstration at Gwynt y Môr (Lead partner)**

- Up to three floating LIDAR systems are to be installed in the vicinity of the Gwynt y Môr meteorological mast in the Bay of Liverpool, Irish Sea in order to collect meteorological data (primarily wind speed and turbulence) at comparable heights to the mast over a six month demonstration period.
- As the floating LIDAR units will be installed on an RWEI site, RWEI have an obligation through the CDM Regulations as well as professional and self interest to ensure that the floating LIDAR installation, operation and decommissioning is undertaken safely, the equipment and vessels are fit for purpose and the demonstration is a success.
- RWEI's has two funding agreements
- 1) The Grant Offer Letter with the Carbon Trust which provides funding for up to three LIDAR contractors who will be directly employed and managed by RWE, but through which RWEI receives no direct funding.
- 2) The Management Services Contract which provides funding for RWEI to cover their internal costs for managing the floating LIDAR project.

    - **ORJIP bird monitoring at Thanet offshore wind farm (Partner)**

- The project will require the deployment, at operating offshore wind farms, of a proven, practical and cost effective offshore monitoring system, comprising of more than one piece of monitoring equipment on a suitable number of turbines, which is capable of measuring both bird avoidance behaviour and collision impacts.
- The aims of the project are to:
    - Select suitable equipment that can be deployed in order to measure both micro and macro avoidance behaviour and, if appropriate, collision impacts.
    - Measure the level of bird avoidance and collision at one or more offshore wind farms and provide robust evidence on the rates of avoidance and collision for a number of key species identified as being most at risk from collision with offshore wind turbines.
    - Determine how data from this study can be applied to support consenting applications for other sites.
- The objective of the project is to obtain data on avoidance behaviour and collision impacts at operating offshore wind farms using proven, practical and cost-effective monitoring systems that can be used to inform the estimation of potential impacts of other offshore wind farms. The aim is to reduce the uncertainty over the prediction of the impact of new offshore wind projects on key bird species, and the degree of precaution necessary in assessments in the light of that reduction in uncertainty.

    - **Rødsands measurement campaign (Partner)**

*Project receives joint funding from OWA and FLOW

- A measurement campaign is proposed to provide the data required. It will be hosted at E.ON's Rødsand II wind farm in the Baltic Sea just off southern Denmark. Technical and logistical details of the trial are described in detail in the Method Statement. The result of a scoping desktop study has defined the measurement campaign. It will consist of:
    - 4x Nacelle-mounted LiDAR - fore and aft facing units on two turbines
    - 2x Long range scanning LiDAR - installed on the substation and met mast
    - Upgrade of met mast instrumentation to provide high frequency data
    - Upgrade of turbine SCADA data to provide high frequency data
- The project will cover all aspects of the procurement, deployment, operation and decommission of the campaign as well as data processing and analysis of the results.

    - **Universal Foundation demonstration at Dogger Bank (Lead partner through Forewind)**
- The aim of the programme is to show that the UF system, a large bucket foundation, can be used as a foundation for offshore wind structures in severe UK locations. Two Met Mast structures have been constructed and installed by F Olsen group companies including Belfast based Harland and Wolfe. Project cost largely borne by Forewind development partners (SSE, RWE, Statoil, Statkraft).

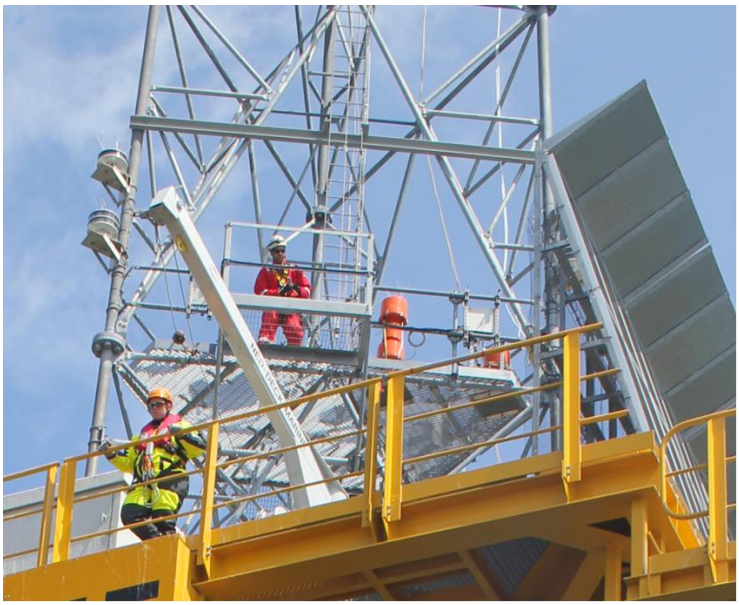

Figure 1 One of the two Installed Met-Masts on Dogger Bank, summer of 2014

- **PISA pile soil interaction (Partner)**
- How can the pile - soil interaction for offshore structures under wind turbine loading be better understood in order to reduce the design uncertainty, through lift foundation maintenance, built in design contingency and cost of offshore mono- and multipile offshore wind turbine support structures.
- Traditional design of monopole foundations is based on standards developed for the offshore oil and gas industry, which adopts the P-y curve method. The P-y curve method is a semi-empirical method based on a series of field tests conducted in the 1960s and subsequently supported by a database and calibration study in the 1980s. The original field tests which underpin this method were lateral pile load tests conducted on instrumented piles less than 1m in diameter with an aspect ratio (length/diameter) greater than 30. Typical aspect ratios (length/diameter) for the support of wind turbine generators (WTGs) have been 4-6 to date and are expected to reduce further in the future. A large aspect ratio leads to a fundamentally different failure mechanism than with the lower aspect ratio piles used for wind turbine generators.
- The aim of the programme is to gain specialist knowledge on the pile-soil interaction of laterally loaded piles.

*Project receives joint funding from OWA and FLOW

- To have access to a body of test evidence on pile-soil interaction, deformation and failure of typical structural steels used in the offshore wind turbine industry to support design decisions, structural certification and reduce insurance premiums.
- To improve the current wind industry standard pile design procedure of using P-y curves. [Knowledge to be assembled into design guidance akin to a CIRIA guide.
- Ability to extend the fatigue life of the support structure beyond its envisaged design life (20/25 years), [2-5 years potentially, dependent on maintenance and project specific factors]
- Potential slenderer design of monopiles due a to higher soil stiffness than envisaged. [Potential cost saving of £100K per monopile in steel alone]
- Potential reduced penetration depth of monopiles from an increased understanding of the long term effects of cyclic loading on soil stiffness. [Potential to reduce penetration depth by 0-5m, estimated saving up to £50K per monopile in steel alone]
- Possibility to consider the use of monopiles for projects in deeper water where monopiles were previously considered unfeasible. Benefit of existing supply chain and long experience with the foundation type reducing foundation risk in future projects. [Water depths up to 40m with 6MW WTGs may be possible which would result in savings of up to £1million per foundation by avoiding the use of jackets]
- Ability to design jacket leg piles to resist significantly larger lateral loads. Jacket piles can then have an increased upstand from the seabed before connection to the jacket. This would permit jackets for a wider range of water depths to be manufactured identically with savings to be realised in mass production and fewer different jacket designs per wind farm.

- Benefit: Improvement in the accuracy and reliability of calculations using the P-y design method leading to leaner future pile design and the use of monopile structures for WTGs in water depths, soil conditions or supporting larger WTGs which were previously not considered feasible.

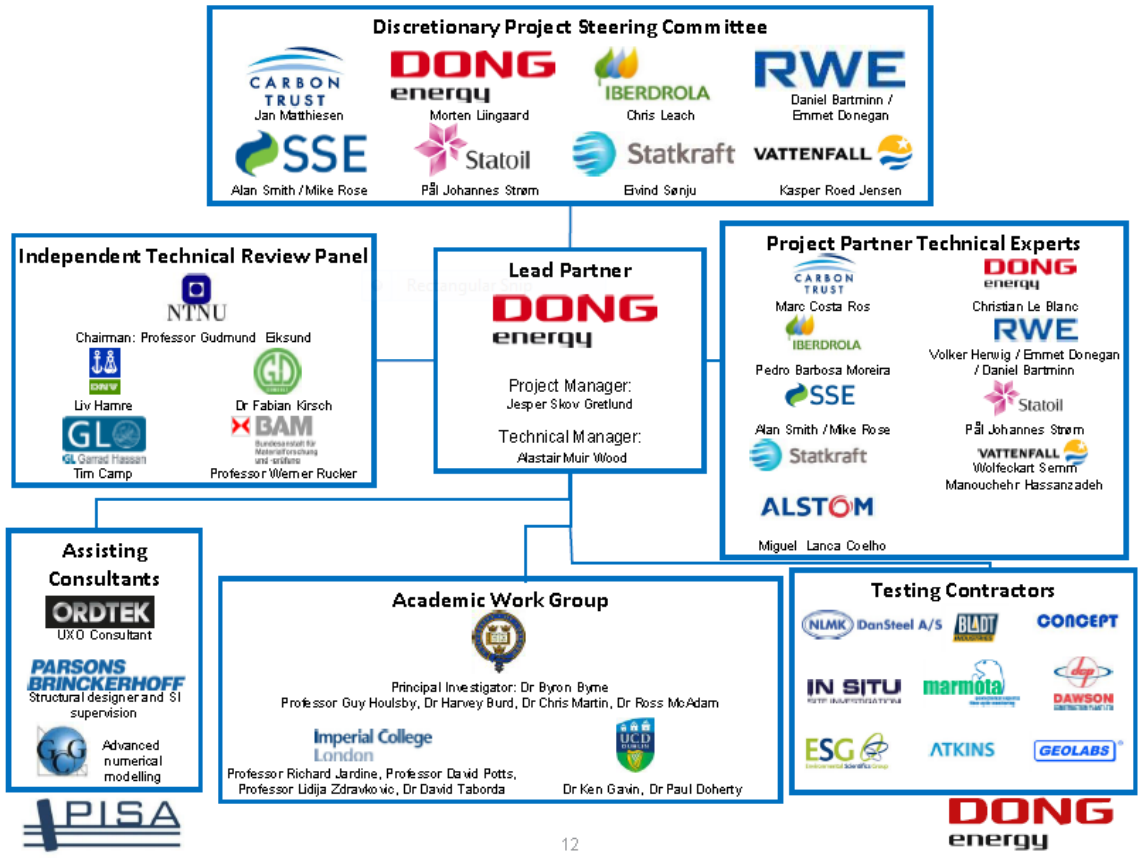

Figure 2 PISA Sponsors and Organisation

*Project receives joint funding from OWA and FLOW

- **GOAL Grouted connection (Lead partner)**

- The wind offshore industry has experienced in the past serial defects on grouted connections for monopiles, due to deficient design guidelines. These defects have resulted in multi million euro rehabilitation works, which to date are not completed. Grouted connections of pre-piled jackets for offshore wind turbines also fall outside the existing design guideline, which primarily have been derived for oil and gas platform jackets. Pre-piled grouted connection differ in the degree of cyclic loading and are further distinguished by a larger grout annulus. Therefore there is a risk that current design guidelines might not be safe.
    - To perform a series of cyclic load box tests on scale model samples and a one near full scale test of a typical pre-piled grouted connection in the following phases:
    - PHASE 1: Full scale cylindrical calibration test and box test series
    - PHASE 2: Investigation of early age cycling and effect of annulus width
    - PHASE 3: Bending tests to establish significance of bending loads
    - PHASE 4: Possible combined loading tests at a reduced scale
    - To develop design guidance for the safe and cost effective design of pre-piled large annulus grouted connections.

Figure 3 One of the proposed 20MN test rigs for GOAL Grout tests.

- **SEAT Sea vessel service trials (Lead partner)**

- The access limit for crew transfer vessels is currently subjective and the general industry accepted limit is 1.5m Hs regardless of actual vessel type and capability. To use the vessel to their full capability the actual safe transit and access limits for personnel need to be defined for all sea states.
- To provide a body of data to define the actual vessel operating limits.
- To allow crew transfer vessels to be used to their full capability.

*Project receives joint funding from OWA and FLOW

- The data collected will be fed into a further Offshore Wind Accelerator project to validate tank testing and numerical computer models of vessel performance allowing cheaper and faster vessel performance evaluation.
- Instrumentation to be fitted to three different crew transfer vessels - Discovery (19m CAT) ICENE Victory (24m CAT) Cymyran Bay (24m Semi-SWATH) during their normal operations activities to measure vessel motion in a range of sea states. A wave buoy will also be deployed near to vessel during landing operations to collect the actual wave condition data. The data will be analysed and a monthly report produced to determine the capability of the vessels.

    - **Farshore Floating LiDAR demonstration at Ijmuiden met mast (Lead partner)***

- Inexpensive floating LiDAR units offer the potential to be used instead of expensive fixed met masts in the collection of metocean data. In order for floating LiDAR units to become accepted by banks as sufficiently reliable data sources for wind resource assessment and project financing their operational performance in terms of data accuracy and availability needs to be validated. In addition, the design aspects of the floating LIDAR buoys which relate to deployment, operations, maintenance and recovery, particularly those aspects pertaining to personnel safety, require scrutiny from the operating utility.
- Aims are to:
    - To test the accuracy of floating LiDAR collected wind speed, directional and turbulence data in comparison with a fixed metmast.
    - To test the complete system availability of the floating LiDAR units including LiDAR availability, weather downtime from excessive motion, spray or fog, auxiliary system availability (incl. Power systems, washers etc.) and communication availability.
    - To test the robustness of the floating LiDAR units under farshore metocean conditions to demonstrate robustness, redundancy and survivability.
    - To gain experience of the safety aspects of the floating LiDAR units in terms of deployment, gaining access offshore, carrying out maintenance and recovery.
    - To evaluate the marine safety of the floating LiDAR units in terms of markings and identification, collision avoidance protection, compliance with MCA requirements and aids to navigation.
    - Test additional data collection instrumentation measuring parameters such as wave heights, wave periods, wave steepness, water and air temperature.
- Until now such testing and validation campaigns for floating LIDAR buoys have only been conducted for a limited number of floating LiDAR devices and only under mild wind and wave conditions (eg. Gwynt y Môr) which are not representative of farshore offshore wind farm sites where they will be required in the near future.
- The FFLIDAR project is a discretionary project of the OWA II.
- RWE will make its Ijmuiden met mast available for up to two designers of floating LiDAR units for testing and validation of measurement data each over a 6 month period. RWE will manage the project consisting of applications for permits (for installation, maintenance visits and retrieval), data collection, data evaluation and reporting. RWE will facilitate the campaign but will not take any responsibility for the floating LiDAR units themselves. No funding is proposed to be provided to the floating LiDAR suppliers, but they will receive the site location, data from the Ijmuiden metmast and analysis and validation of the floating LiDAR captured data in comparison to the metmast by an independent third party at no cost to themselves. An independent data analyst will be contracted by RWE in order to perform the data analysis and validation of the floating LiDAR measurement data against the measurements of the fixed met mast according to the GLGH floating LIDAR Roadmap to Bankability.

    - **VIBRO vibration and impact driven pile installation demonstration (Lead Partner)**

- Piles for offshore constructions are traditionally installed by heavy impact hammers. This technique creates high sound pressure levels, which are required to be mitigated to protect the marine environment. The vibration of offshore piles is an alternative installation technique that could reduce noise emissions at the source. This technique is already significantly developed and shows benefits in installation time, logistics, pile fatigue & noise reduction.
- The effect of vibropiling on the soil bearing capacity is insufficiently understood (stiffening or softening in non cohesive soils). This is particularly relevant for the lateral load bearing capacity of new generation of monopiles. Due to this lack of knowledge, the technique of vibropiling is not considered as state-of-the-art. The proposed test programme intends to fill this knowledge gap through a full-scale onshore test

*Project receives joint funding from OWA and FLOW

programme. A methodology for determining the stability of axially and laterally loaded piles installed through vibropiling shall be developed and verified. This would allow the relevant standards to be developed to allow for the installation of offshore piles solely through vibropiling.

- Potential gains:
    - noise reduction and potential cost reduction due eliminating other noise mitigation measures
    - reduced installation time
    - reduction of fatigue damage from driving

Far and Large Offshore Wind (FLOW): Phase 1 (2009-ongoing)

- Aim: reduce cost of energy, accelerate development and reduce risk in far and large offshore wind farms
- http://flow-offshore.nl/
- Country: NL
- Enabling body: Ministry of Economic Affairs
- RWE is participating in the following projects within FLOW:
    - Metocean buoy with LiDAR at Ijmuiden (Lead partner)*
    - Operations and maintenance cost estimator (Partner)
    - Electrical system stability impacts – grid trade off analysis (Partner)
    - Dynamic power management (Partner)
    - Smart regulation of far and large offshore wind farms (Partner)
    - Electrical system design and optimisation (Partner)
    - Optimized blade installation (Partner)
    - Wind farm wake modelling fatigue loads and control (Partner)
    - Meteo Dashboard weather forecasting (Lead partner)
    - Cost reduction evaluation (Partner)
    - Noise mitigation (Partner)

*Project receives joint funding from OWA and FLOW

Joint Industry R&D Projects

RWE is participating in the following joint industry R&D projects:

- **SLIC - Structural Lifecycle Industry Collaboration**

- https://www.gov.uk/government/publications/offshore-wind-structural-lifecycle-industry-collaboration
- Aim: Demonstrate and develop a contemporary set of Fatigue S-N curves to enable recent advances in welding technology to be realised in offshore structural design. Targets mainly monopile design, considers thickness effects and weld improvement, corrosion in seawater. Many UK and European partners, £2,464M budget managed by Centrica with University of Cranfield, local workshops in Northamptonshire and Berkshire, plus AMEC test houses benefitting from the program. A total of 120 large welded samples each weighing one tonne have been made by EEW, SIF and Bladt industries. The program is recognised and supported by DNV and Lloyds Wind Industry Divisions.
- Country: UK
- Enabling body: DECC with The Crown Estate

Figure 4 SLIC Large Samples

- **Cluster Design - multivariable optimised design of clusters of offshore wind farms (2011-2016)**

- https://www.cluster-design.eu/
- Aim: develop toolbox for an integrated offshore wind farm clusters design
- Development and test of a toolbox for wind farm cluster design, including novel improved control concepts which enable the wind farm to provide improved grid services and decrease loads on single turbines at constant overall output. Models for wake effects, loads as well as improved controls concepts will be tested in an offshore wind farm.

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- Partners: 3E, Repower, ECN, ForWind Oldenburg, Imperial College.
- Country: Europe
- Enabling body: European Commission

- **KiZO - Concept for intelligent condition monitoring of offshore wind farms**

- http://www.kizo-offshore.de/web/guest/ebcot-gmbh;jsessionid=A7A9CBA08A5F9541314802B007BDA187
- Offshore Windparks benötigen intensives Monitoring und Fernüberwachung. Dies ist die Basis für die Betriebsführung und angepasste Wartungsstrategien.

Die hier vorgestellte Forschungsidee greift aktuelle Herausforderungen im Bereich der Betriebsführung auf. Der Fokus des Forschungsvorhabens liegt in der Entwicklung strukturierten Auswertung und Inter-pretation der gemessenen Daten und eine weitergehende Analyse und Umsetzung in Handlungsanwei-sungen für den Betreiber. Ein wesentlicher Bestandteil der Analyse ist die konzentrierte Darstellung von KPIs (key performance indicators). Nicht zuletzt muss eine zusammenfassende Dokumentation in Form eines Reporting Systems erstellt werden, das einen schnellen Überblick über den aktuellen Zustand, so-wie eine Sicht auf die historischen Daten erlaubt.

Eine Grundlage für die Datenauswertung sind die Zusammenführung und Integration verschiedener Monitoring Systeme (Condition Monitoring Systems, meteorologische Daten, Betriebsdaten usw. Dies ist wichtig, um den Zustand der einzelnen Anlagen zu jedem Zeitpunkt bewerten zu können und stellt einen wesentlichen Punkt in einem ganzheitlichen Betriebsführungssystems dar. Zudem wird das Ergebnis des Projektes Hinweise einer Remote-Betriebsführung liefern, so dass Offshore-Windparks landgestützt überwacht werden können.

Die entwickelten Algorithmen und Darstellungen werden in eine Software implementiert, die zukünftig ein Bestandteil der Betriebsführungssysteme von Offshore Windparks bilden wird.

- **Offshore WMEP - performance monitoring and data evaluation of offshore wind farms**
- **Sparta - performance monitoring and data evaluation of offshore wind farms**

- http://offshorewmep.iwes.fraunhofer.de/index.html
- http://www.thecrownestate.co.uk/news-and-media/news/2014/sparta-project-to-drive-offshore-wind-cost-reduction/
- Aim: creation of a database of failure rates for offshore wind farms to be made available to academic and research institutions
- Extension of the WMEP database. Aims:
  - Draw general conclusions related to use of wind energy offshore
  - Monitoring of farms, high level
  - Optimise operation and maintenance effort, improve availability
  - analyse operational experience of a number of wind farms in the North Sea (anonymised)
- Country: DK
- Enabling body: BMU

- **SWINE - Study into the impacts of offshore wind farm construction on harbour porpoise**

German environmental protection agencies and authorities (BSH) lack studies about the impact of offshore wind park construction on harbour porpoise. The result of this lack of data is over-precautious guidelines for acceptable noise levels and requirements for the use of noise mitigation equipment during construction. OWP developers have collected a huge amount of relevant data in the course of permit applications, during construction and operation - in line with the guidelines for the environmental impact assessments and the general permit requirements. To date nobody has compiled the data from all developers and conducted a rigorous assessment of the impact of noise emissions on the harbour porpoise population.

*Project receives joint funding from OWA and FLOW