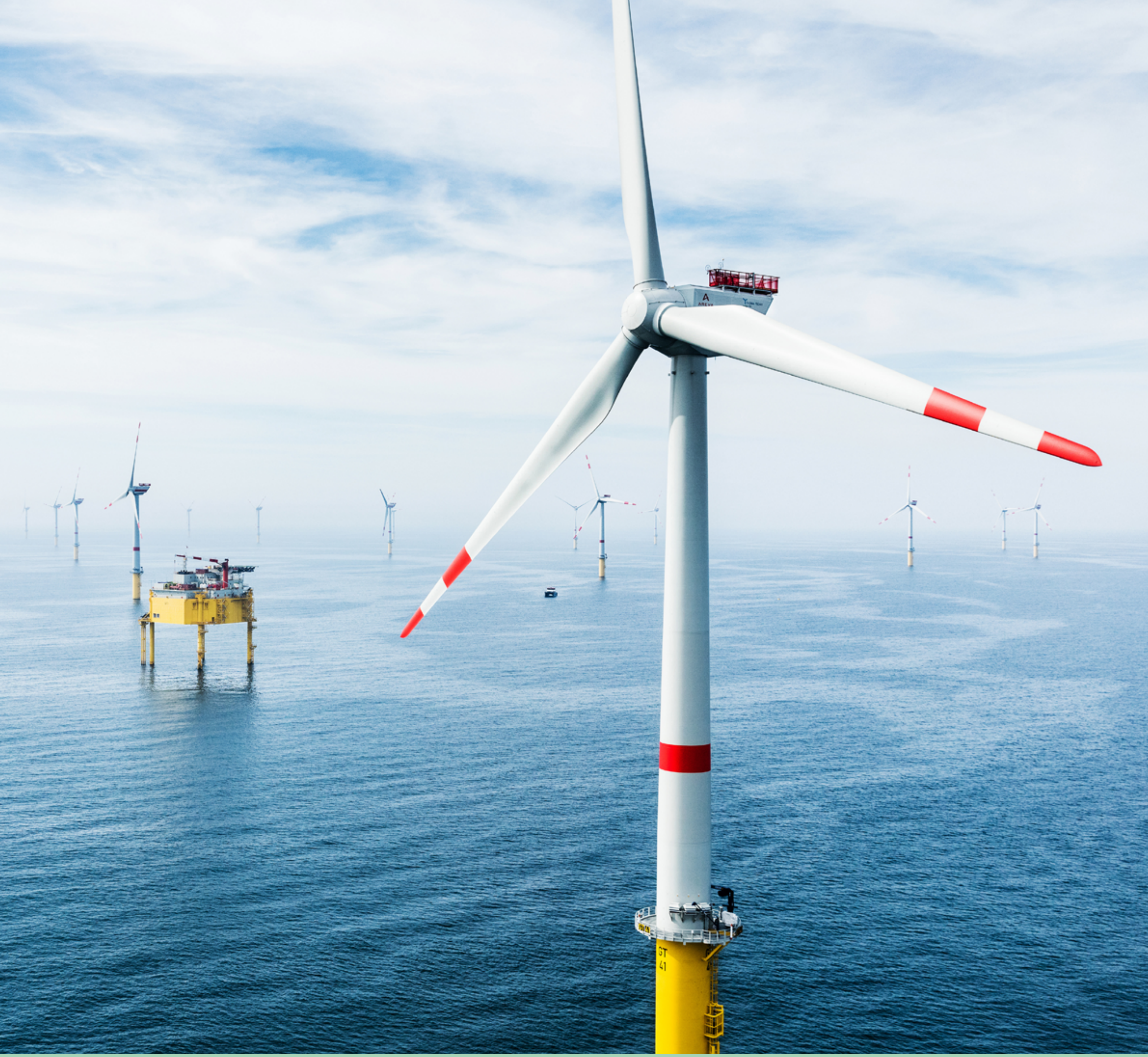

Driving Cost Reductions in Offshore Wind

THE LEANWIND PROJECT FINAL PUBLICATION

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EXECUTIVE SUMMARY

PROJECT SUMMARY

LEANWIND was awarded to a consortium of 31 participants (52% from industry) from 11 countries and is led by University College Cork, Ireland. The diverse team brings together experts from multiple sectors including oil and gas, maritime, shipping and offshore wind industries with representatives across the supply-chain including developers, utilities, turbine suppliers, vessel owners, shipbuilding, classification societies, academics, and other industry representatives. The project received funding of almost €10million from the European Commission and has a total value of €14.8million. LEANWIND commenced in December 2013 and ran for 4 years.

BACKGROUND AND CONTEXT

The European Union has a long-term commitment to reduce greenhouse gas emissions by 80-95% compared to 1990 levels by 2050. This has important implications for the current energy system. Wind power plays a crucial role in reaching the EU's renewable goals. The offshore wind industry in Europe is, in fact, moving fast to a mainstream supplier of low-carbon electricity[1]. It has grown exponentially in recent years and is expected to cover up to 23% of EU's electricity demand to 2030[2]. Today, wind energy already meets 11% of the EU's power demand, with high penetration levels in several countries (e.g. Denmark (42%), Spain (20%), Germany (13%) and UK (11%)). The wind energy sector represents over 300,000 jobs and generates €72 billion in annual turnover[3]. This unprecedented growth is due to an increased competitiveness of the sector due to several factors, such as the reduction in the cost of capital, industrial expansion and technological developments[3].

The LEANWIND project began in December of 2013, at which time the Levelised Cost Of Energy (LCOE) for offshore wind energy was €140/MWh. Over the lifetime of the project, this cost has plummeted, surpassing 2020 targets of €100/MWh. Vattenfall's offshore wind price bid of €49.9/MWh in 2016 for the Kriegers Flak project set a

1 BVG Associates and WindEurope, (2017). Unleashing Europe's offshore wind potential: A new resource assessment.
2 EEA, (2009). Europe's onshore and offshore wind energy potential.
3 WindEurope, (2017). Wind energy today.

record LCOE forecast of €40/MWh[4]. While LEANWIND is not responsible for the massive shift in energy cost expectations, innovations, novel design and LEAN construction have played a massive role in the quest for subsidy free offshore wind energy. This report outlines many of the areas in which cost reductions have been promoted and implemented throughout the life-cycle of an Offshore Wind Farm (OWF). It also presents the research undertaken by the project to address future industry challenges.

There is still work to be done to actually achieve and maintain the expected cost reductions and ensure the cost-competitiveness of offshore wind in the energy sector. The anticipated fall in LCOE has and will increase price competition as developers are under pressure to match these forecasts. New markets in East Asia and North America still need to achieve these targets using the lessons learned by the existing industry. In addition, challenges are presented by future sites located further from shore, in harsher conditions and deeper waters. Larger turbines and projects also mean larger equipment requirements and new logistics and maintenance issues. It is expected that LEANWIND results will contribute similar optimisation for future farms and, alongside applied research in years to come, guarantee the future of offshore wind within our energy mix.

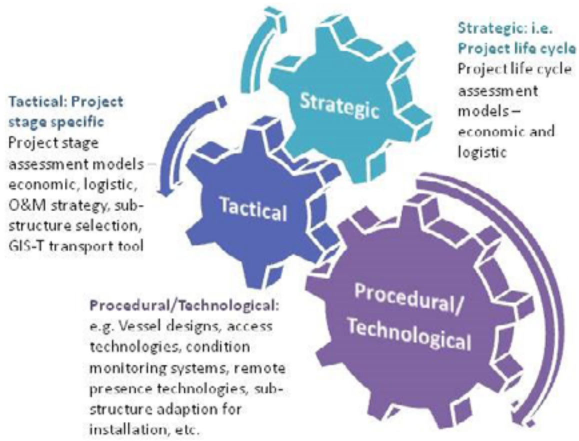
LEANWIND OBJECTIVES AND METHODOLOGY

The primary LEANWIND objective is to provide cost reductions across the OWF life-cycle and supply-chain through the application of lean principles and the development of state of the art technologies and tools. "Lean thinking" is the dynamic, knowledge driven, and end-user focused process through which people in a defined enterprise continuously eliminate wasteful stages and streamline processes with the goal of creating value[5]. Key principles include:

1. Identify what the customer needs
2. Track, reduce or eliminate wasteful stages in and between processes
3. Seek continuous improvement
4. Approach improvements from a whole system perspective

The "Lean" principles were originally developed by Toyota to optimize the processes of manufacturing industries; these principles of optimization and efficiency have subsequently been adopted by many other industries to remove wasteful stages and streamline processes. The application of lean principles is a novel development in the offshore wind industry.

FIGURE 1
Levels of process optimisation in LEANWIND



Source: UCC

4 WindEnergyUpdate, (2016). Europe's new record offshore LCOE forecast at 40 euros/MWh. Retrieved July 28, 2017, from http://newenergyupdate.com/wind-energy-update/europes-new-record-offshore-lcoe-forecast-40-eurosmwh
5 Shili Sun, (2011). The Strategic Role of Lean Production in SOE's Development. International Journal of Business and Management, Vol. 6, No. 2; February 2011, p 160.

Taking a whole system perspective, the lean paradigm is applied in LEANWIND to each of the critical project stages from Installation, Operation and Maintenance (O&M) to Decommissioning, supporting efficient holistic strategies for the development of an OWF. As illustrated in Figure 1, efficiencies have been sought at 3 levels to consider the needs of different industry stakeholders: 1) strategic project planning and management level, 2) tactical project operations level and 3) specific technological or procedural level.

LEANWIND specifically addresses the logistical challenges of deploying, installing and operating large scale wind turbines (WT) (in the range 5-10MW) in transitional water depths using fixed foundations as well as floating structures more relevant to longer term wind farm prospects. The transport, logistical and maintenance operations associated with these structures are addressed through novel approaches to vessel design, vessel management, sub-structure alterations and O&M strategies in order to reduce both the CAPEX and OPEX cost. The innovations have been rigorously tested and validated where possible and assessed for their cost benefit to industry. The project has also evaluated the applicability of the innovations to industry in order to facilitate market uptake of developed innovations and ensure there are immediate cost reductions seen by industry, thereby contributing to the competitiveness of the sector and to the creation of new jobs.

RESULTS AND FINDINGS

The following are some key results and impacts of the LEANWIND project :

- Supplied **comprehensive analysis of the industry challenges**, facilitating effective development of relevant solutions;
- Designed **novel adaptations for fixed and floating substructures** and a substructure selection framework to minimise costs and installation time;
- Streamlined the deployment and installation of large-scale turbines and both fixed and floating substructures with **improved installation processes** e.g. optimising vessel deck usage and developing efficient processes for turbine erection and technology that facilitates quicker and/or safer loading, transport or ballasting operations for substructures;
- Developed a **holistic supply-chain logistics model** to optimise scenarios, increasing efficiency and reducing bottlenecks. This includes individual modules applicable to port logistics, transport, vessel chartering etc.; a Geographical Information System (GIS) transport model; and a decision-making model for port layout/configuration to improve planning of on-land logistics;
- Constructed a **full life-cycle financial model** considering CAPEX and installation, OPEX, decommissioning, risk and life-cycle assessment;
- Developed a range of models and provided recommendations for **optimised O&M strategies** for representative existing and planned farms, which will help reduce costs and improve efficiency. This includes a strategic decision-support tool; a dynamic-scheduling model; and a risk-based framework model;
- Assessed **Reliability, Availability and Maintenance (RAM) methodologies,** existing software tools and suitable modelling approaches to identify WT's critical components and develop selected **failure/degradation models** to provide input to the O&M tools, facilitating strategy optimisation and the cost-time benefits of reliability-centred maintenance.
- Fabricated and tested a **remote presence** device and Condition Monitoring Software (CMS) to reduce the need for human intervention and maintenance costs;
- Delivered purpose-built **installation and servicing vessel concepts,** meeting the increased demand;
- undertook **tank and field testing activities** to validate and assess the benefits of selected project innovations and procedures e.g. remote presence device, gravity based substructure, floating substructure and offshore operations;
- developed and showcased **vessel simulation technologies** to assess novel design concepts and

replicate deployment and O&M activities, mitigating the risks associated with new strategies;

- identified industry specific **safety and training procedures** for installation and O&M;
- assessed **business models** at European level for large offshore systems to encourage existing and new sources of investment;
- **evaluated the benefits of optimised procedures and technical solutions** with a combined financial and logistics OWF model, resulting in recommendations for wind farm development;
- assessed the **non-technical positive and adverse impacts of project innovations** from environmental, societal and economic perspectives;
- provided **recommendations for future growth and development in the business and policy landscape** to adequately support the industry.

As the above illustrates, the project has successfully provided a large range of novel solutions that can improve existing practices and set standards in order to help industry meet their LCOE aspirations and maintain cost reductions as the industry develops. The full report presents the key outputs of the LEANWIND project including procedures, tools and technologies developed.

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