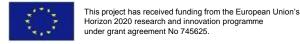
# ROMEO

# An ambitious project to reduce the cost of offshore wind energy



Wind Energy Science Conference - 18<sup>th</sup> June 2019 University College Cork, Cork

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### What is ROMEO?

ROMEO stands for Reliable OM decision tools and strategies for high LCoE reduction of Offshore wind

- H2020 Innovation Action for Societal Challenges
- 16.4 M€ Total Budget (~10M€ EU contribution)
- 5-year project (2017-2022)
- The consortium...
  - Led by Iberdrola Renovables
  - Formed by 12 partners across Europe
  - Involves some of the most important players in the offshore wind industry











# What is ROMEO?



















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# **ROMEO Project**



What are the objectives?

The Project phases

Work description & packages

The progress: ROMEO to date

**Summary & Future steps** 









### What are the objectives?

### Main objective: Reducing Offshore wind O&M costs through...

- Development and demonstration of an O&M information management and analytics platform
  - Better understanding of real-time behaviour of the main components under real operating conditions
  - Assess and maximize their lifetime
  - Facilitate the switch from corrective maintenance to condition-based maintenance strategies
  - Improve the decision making processes, such as scheduling maintenance activities or managing end-oflife scenarios.
- ⇒ All leading to a minimised OPEX and a reduced LCoE













## What are the objectives?

### **Greater reliability, less repairs, more safety**



Increase wind farm reliability and decrease the number of failures leading to downtime



Increase the life time of key turbine components



Reduce the WT O&M costs through the reduction of the resources required for annual inspections of the turbine



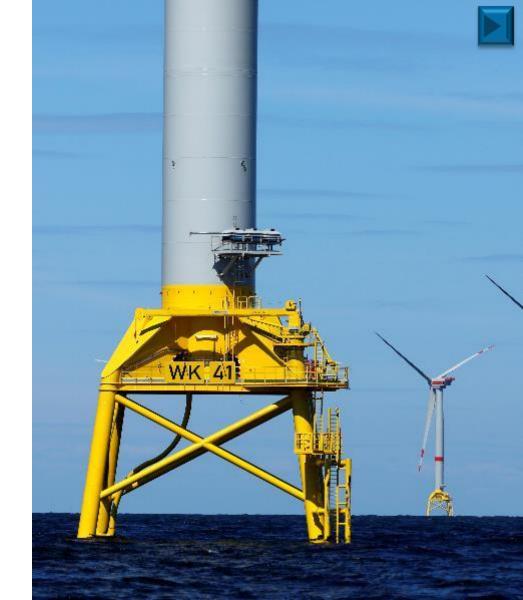
Reduce the O&M costs associated to foundation through reduction in jacket substructures inspections



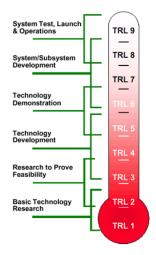




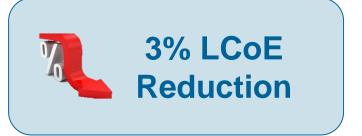




# What are the objectives?



**Technology Readiness** Level (TRL) ⇒ 7



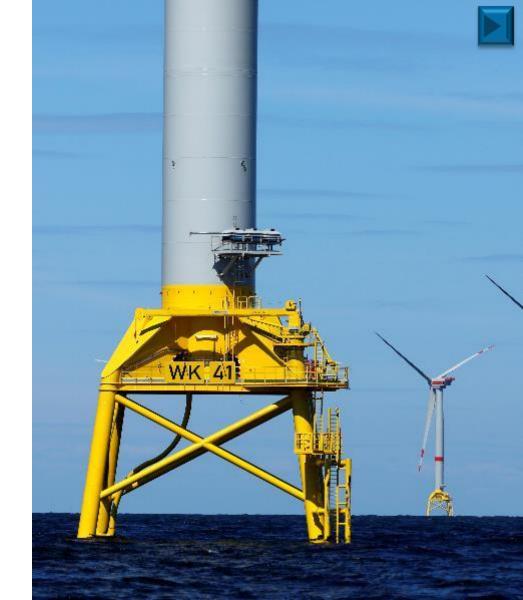










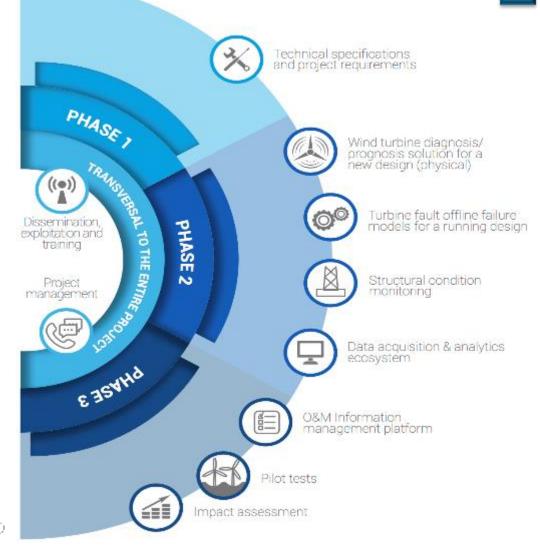


# **ROMEO Project phases**

Definition of the project technical specifications and requirements

Development of new monitoring systems as well as novel diagnosis and prognosis models for detection and prediction of failures affecting key components

Final validation of the data management platform





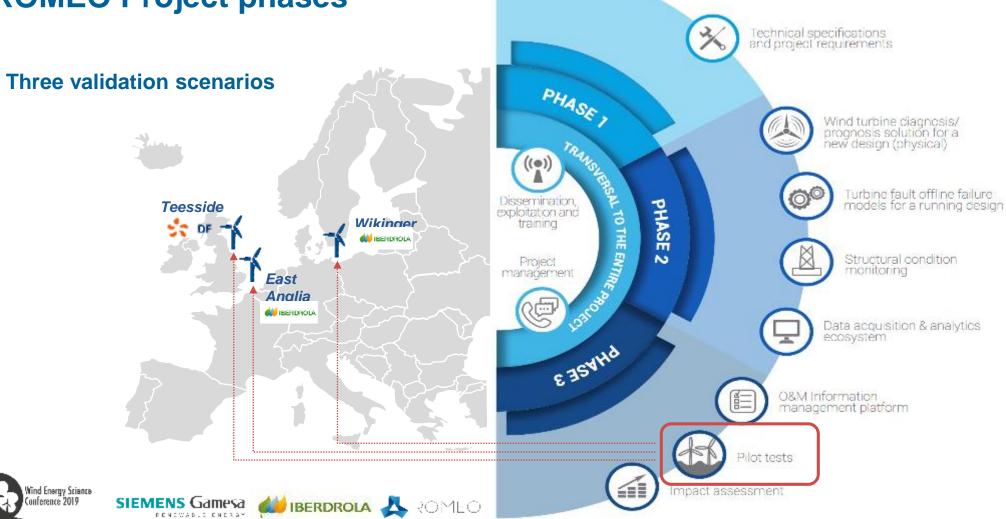








# **ROMEO Project phases**





# Work description & packages

WT SCALE Components and structure

IT SCALE Ecosystem, Platform & Environment

WF SCALE Demonstration & Impact









# Work description & packages



#### **WT Condition Monitoring**



- Detect degradation patterns related to critical failure modes
- Develop innovative DIAGNOSIS and PROGNOSIS solutions

#### Health Structural Monitoring



- Develop low-cost Structural Health Monitoring system for jackets & monopiles
- Assess RUL for lifetime extension purposes

WT SCALE
Components and structure

# Data Acquisition & Analytics Ecosystem



- Flexible &interoperable loT platform
- Based on distributed processing

Hybrid cloud/edge architecture with advanced analytics ecosystem

# O&M Information Management Platform

- Intelligent reporting & visualisation
- > Facilitate maintenance-decision making
- Asset management & advisory information

IT SCALE Ecosystem, Platform & Environment

# Pilot Tests Real scale implementation



- Real time data integration
- > On-site validation of developed solutions
- Testing Asset management tool









- Quantification of innovative O&M practices against baseline
- Assessment of impact from using the developed solutions:
  - ✓ LCOE & OPEX reduction (%)



WF SCALE
Demonstration & Impact

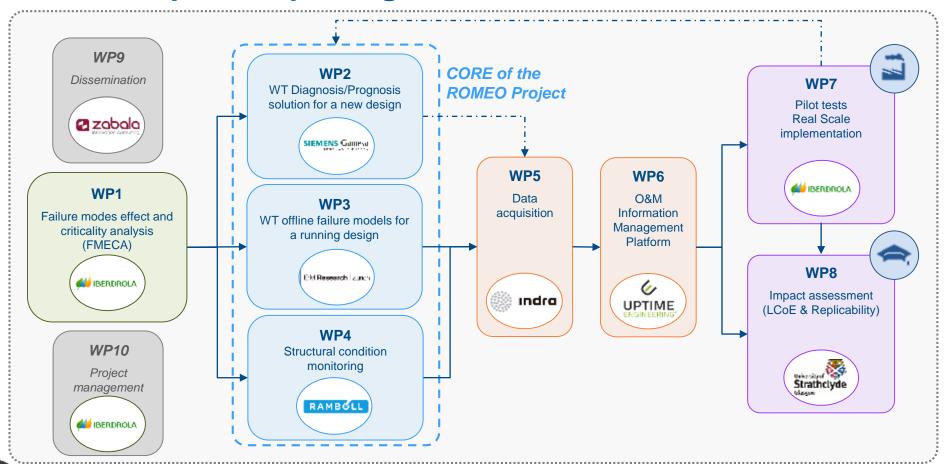








## Work description & packages













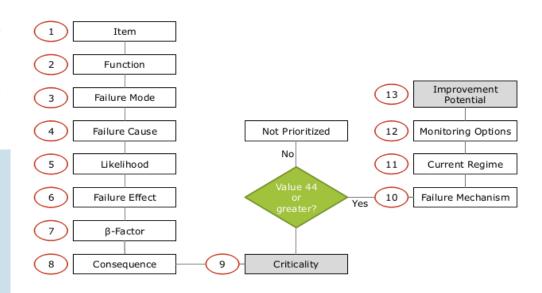
#### WP1

- Failure Modes and Effects and Criticality Analysis (FMECA) for offshore wind turbines
- Identification of the most critical components and failure modes

**337** failure modes identified for key WTG components and structure

**120** investigated towards applicability of monitoring

**60** of them with large potential benefit for monitoring systems to be further investigated





M. N. Scheu, L. Tremps, U. Smolka, A. Kolios, and F. Brennan, "A systematic Failure Mode Effects and Criticality Analysis for offshore wind turbine systems towards integrated condition based maintenance strategies," Ocean Eng., vol. 176, no. October 2018, pp. 118–133, 2019.











#### WP2

- Development of new tailored monitoring solutions for specific failure modes
- Study of degradation and failure symptoms and how to capture/measure them at test bench scale, for testing & improvement purposes.

#### **Main Bearing & Gearbox**

- New detector to account for Displacement Sensors.
  - ✓ Early detection techniques diversification.
- Damage Classification Technique.
  - ✓ Better understanding of failure mode and effects.
- Imbalance Detection using Vibration Sensors.
- RMS Vibration calculation for Gears & Bearing

#### **Blade Bearing**

- New Diagnosis & Prognosis algorithms for:
  - ✓ Rolling Contact Fatigue;
  - ✓ Structural Health Monitoring of the rings.
- Tests running @ WINDBOX



#### **Electrical Drive Train**

Forthcoming tests to be run
 @ EDF Electrical Lab













#### WP3

- > Aims at developing a full set of cost-effective diagnosis and prognosis failure mode oriented solutions
- In-Depth investigation of component real behaviour & failure symptoms as observed in SCADA data
- Risk-based Diagnosis & Prognosis (D&P), implying important advances beyond the State-of-the-Art
- > Ensure portability to contribute to enhance the understanding of failure occurrence in offshore wind farms



#### Wikinger Wind Farm – Adwen AD5-135

Adwen SIEME

SIEMENS Gamesa

- Selection of the 13 most critical failure modes
- Development of advanced D&P <u>Physical Models</u> for these 13 Failure Modes
- 5/13 diagnosis models running daily



#### **Teesside Wind Farm – Siemens SWT2.3**



- · Selection of the 9 most critical failure modes
- Development of advanced D&P <u>Physical Models</u> for these 9
   Failure Modes
- 4/9 diagnosis models running daily

Physical models to be combined with Machine & Deep Learning models

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#### WP4

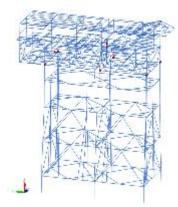
- Focus on improving structural health monitoring approaches
  - Review of monitoring technologies and specification of the support structure monitoring problem for offshore wind farms
  - Selection of the most appropriate monitoring technologies for each of the failure modes identified as part of the FMECA.
  - Optimal sensor placement study for Wikinger OSS and one foundation

Short-term measurement campaign on going Some data retrieved already from the permanent monitoring system

FEM Update and benchmark of low-cost monitoring techniques



Andalucía OSS at Wikinger site



Equivalent Digital Twin











#### WP5

#### Digitalization and data integration

- > Challenging integration of the different data acquisition and processing elements and protocols:
  - <u>Heterogeneity of variables</u> to monitor and process
  - <u>Multiple communication infrastructures</u>: interfaces and protocols have to be independent from the communication infrastructures
  - <u>Communication protocols</u>: need to cope with the variety of subsystems and strategies involved in the control of the elements participating in the WT subdomain
  - Real time data processing: allowing extreme transactions and processing characteristics based on the novel edge computing paradigm
  - New flexible and interoperable <u>IoT cloud platform</u>











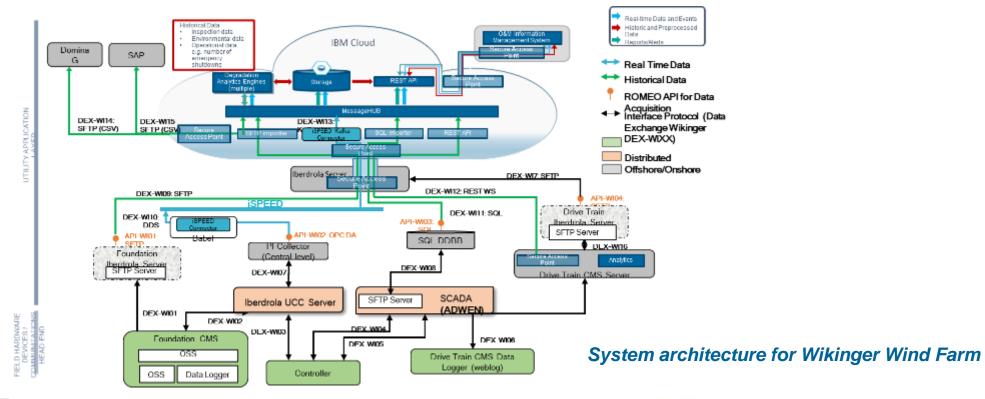








#### WP5







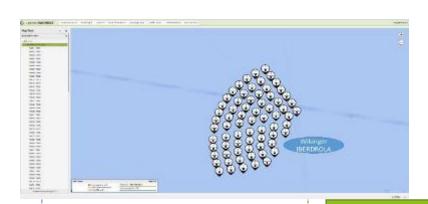






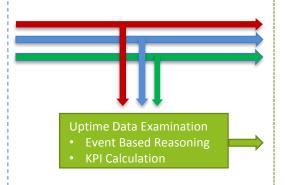
#### WP6

Development of an Information Management Platform for easing maintenance-related decision processes



**Degradation Analytics** Engines

- Operational Data



#### **O&M** Information

**Uptime Advisory Generation** 

- Failure Diagnosis













#### WP8

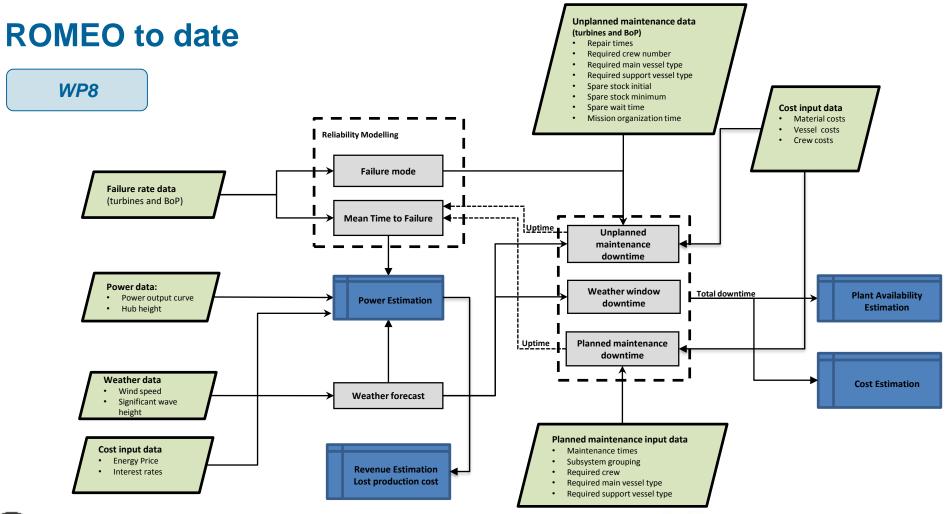
- Wide-applicability, modular, open-access tool for the simulation of O&M activities of offshore wind farms
  - Costs & revenues throughout the life cycle of the assets are considered, allowing for alternative KPIs to be considered
  - Real value of cash-flows is taken into account
  - Stochasticity of certain inputs is integrated through Monte-Carlo sampling to assign confidence levels in the assessment
  - A flexible O&M evaluation model is incorporated for a fully integrated, robust analysis.





















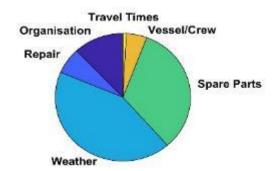
#### WP8

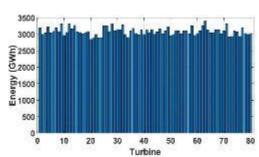
#### **Outputs**

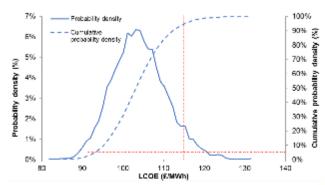
- Availability
- Downtime Breakdown
- Energy produced

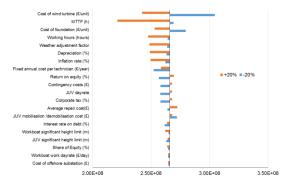
- Revenue
- Cost Breakdown
  - Direct costs
  - Indirect costs























### What makes ROMEO unique?

- Its completeness due to...
  - The holistic study of failure development and degradation at both component and structural level
  - The development of innovative solutions for failure diagnosis and prognosis and SHM filling an existing gap in both the industry and the academia
  - Their integration in a flexible interoperable IoT platform feeding an Information Management System
  - Their consideration for maintenance-related decision-making processes
  - The demonstration and validation at full scale in three different real projects
  - The stochastic assessment of the economic gain in terms of OPEX & LCoE reduction from real cases













#### Main results so far...

- FMECA workshops identifying critical failure modes both for WTG and substructure
- Physical models developed for specific failures on main turbine components
- Initial Data sets for data driven models prepared
- ICT architectures for the 3 demonstrators designed
- Backbone of O&M information platform developed
- Review of existing life cycle costing and O&M tools performed











# **Moving forward...**

- Continue developing physical and data driven models
- Updating of FEM and benchmarking of low cost monitoring techniques
- Final report on best practice guidelines for future wind farm structural condition
- Development of Cloud environment and connections including O&M platform
- Testing of models and tools
- Development of Integrated Lifecycle assessment tool













The Project phases

Work description & packages

The progress: ROMEO to date

**Summary & Future steps** 



# Go raibh maith agat!



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