# EXTENDED PROGRAMME

## 11-22 OCTOBER

## TOWARDS 2030: RESHAPING THE EUROPEAN ENERGY SYSTEM

## #EUSEW2021

SUSTAINABLE ENERGY WEEK

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# ROMEO

## RELIABLE OM DECISIONS TOOLS AND STRATEGIES FOR HIGH LCOE REDUCTION ON OFFSHORE WIND

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 745625.

ROMEO

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# WHAT IS ROMEO PROJECT?

ROMEO H2020 project aims to develop advanced technological solutions enabling Offshore O&M cost reduction (up to 8%)

- 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.

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# 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.

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# WORK DESCRIPTION

## WT Condition Monitoring

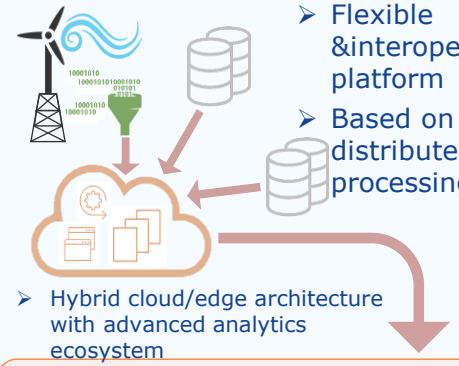
- Detect degradation patterns related to critical failure modes
- Develop innovative DIAGNOSIS and PROGNOSIS solutions

## Health Structural Monitoring

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

*WT scale*
*Components and structure*

## Data Acquisition & Analytics Ecosystem



- Flexible &interoperable IoT 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

*Wikinger* IBERDROLA
*East Anglia* IBERDROLA
*Teesside* EDF

## Impact assessment & Replication

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

*WF SCALE*
*Demonstration & Impact*

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# NEW MONITORING TECHNOLOGIES

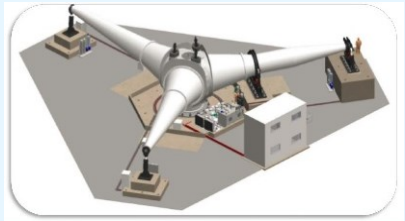
- Development of new tailored monitoring solutions for specific failure modes.
- Study of degradation and failure symptoms and how to capture/measure them at test bench scale, for testing & improvement purposes:
  - ✓ Proper sensors and configuration, suitable subsequent data analysis.

## Main Bearing & Gearbox

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

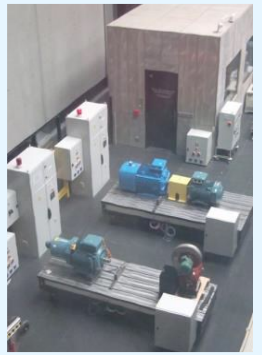
## Blade Bearing

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



## Electrical Drive Train

- Tests running @ EDF Electrical Lab (generator, transformer, capacitor)





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# PHYSICAL & MACHINE LEARNING MODELS

**Platform A: Wikinger Wind Farm – Adwen AD5-135 (operated by Iberdrola)**

**WP1**
**Failure Mode Effects & Criticality Analysis (FMECA)**

**Selection of the 13 most critical failure modes**

- ***PROGRESS:***
  - *In-Depth investigation of component real behaviour & Failure symptoms*
  - *13/13 diagnosis models running*
  - *Risk-based Diagnosis & Prognosis, implying important advances towards the State-of-the-Art*

**Development of advanced Diagnosis & Prognosis Physical Models for these 13 Failure Modes**

**NEW Physical approach based Health Indicator, covering…**
- Damage Classification Technique.
- Unbalance Detection.

**Statistical/machine learning models bootstrapped with Physical models**

# PHYSICAL & MACHINE LEARNING MODELS

| Module | Description |
|---|---|
| 1 | **Gearbox:** Sliding Bearings Wear/Blockage |
| 2 | **Converter:** DC link capacitor degradation |
| 3 | **Converter:** IGCT failure |
| 4 | **Generator:** Rotor Demagnetization |
| 5 | **Generator:** Loss of insulation in the stator winding |
| 6 | **Blade Bearing:** Fatigue and wear of raceways detection module |
| 7 | **Blade Bearing:** Loss of structural integrity detection module |
| 8 | **Gearbox:** Cracks in gears detection module |
| 9 | **Gearbox bearings:** Wear of raceways/rollers detection module |
| 10 | **Main Shaft Bearing:** Fatigue/wear of raceways detection module |
| 11 | **Main Shaft Bearing:** Wear/fatigue of rollers detection module |
| 12 | **Main transformer:** Loss of insulation in the winding detection module |
| 13 | **Main transformer:** Compromised structural integrity detection module |



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# PHYSICAL & MACHINE LEARNING MODELS

**Platform B: Teesside Wind Farm – Siemens SWT2.3 (operated by EDF)**

FMECA

P-F intervals for main failure modes

Available Data

| Module | Description |
|---|---|
| **1** | **Main bearing: failure early detection** |
| **2** | **Pitch system: failure early detection** |
| **3** | **Gearbox: failure early detection** |
| **4** | **Transformer : interturn short-circuit or Cooling System** |
| **5** | **Generator: Interturn short-circuit of windings, rotor bars** |
| 6 | Generator: Interturn short-circuit of windings, rotor bars & cooling system |

***Statistical/machine learning models bootstrapped with Physical models***

State: Normal / Abnormal

Phase of P-F interval

Temporal evolution of physical error

Time to failure prediction



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# SUPPORT STRUCTURE

## Real time intelligence to achieve operational excellence & sustainability goals - ROMEO targets -

### REDUCE EXPENDITURE

**REDUCE OFFSHORE WORK TIME**
FROM SCHEDULED TO RISK BASED INSPECTION

**OPTIMISE MAINTENANCE – REDUCE PLANNED OFFSHORE VISITS**
FROM CORRECTIVE TO PREDICTIVE

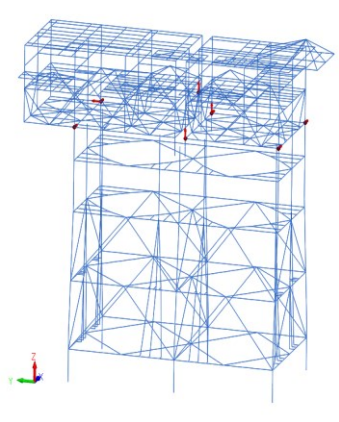
**REDUCE COST OF CONSEQUENCE**
BY EARLY REMIDATION

### INCREASE PERFORMANCE

**IMPROVE ASSET AVAILABILITY**
THROUGH FAST INCIDENT RESPONSE

**MINIMISE DOWNTIME**
BY PREVENTING FAILURES

**FULLY EXPLOIT ASSET LIFETIME –**
BY KNOWING THE CURRENT CONDITION



### IMPROVE SAFETY

**INCREASE WORKFORCE SAFETY**
BY MINIMISING DANGEROUS OPERATIONS

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# SUPPORT STRUCTURE

## Data driven decision support via low-cost monitoring methods

- Optimal sensor placement
- True Digital Twin Technology
- Relevant insights

**FE-model update:**
Establish ‘as-is‘ model by reducing uncertainty in the FE-model

- ➢ Reassessment & design validation by simulations
- ➢ Enabler for low-cost monitoring

**Fatigue monitoring:**
Indirect monitoring of fatigue damage of the entire structure

- Verified using strain gauge data
- ➢ Remaining useful lifetime estimation & Predictive maintenance

**Damage detection:**
Indirect monitoring of global and local structural integrity of the structure for damage detection and identification (optimally with localisation)

- ➢ Risk based inspection



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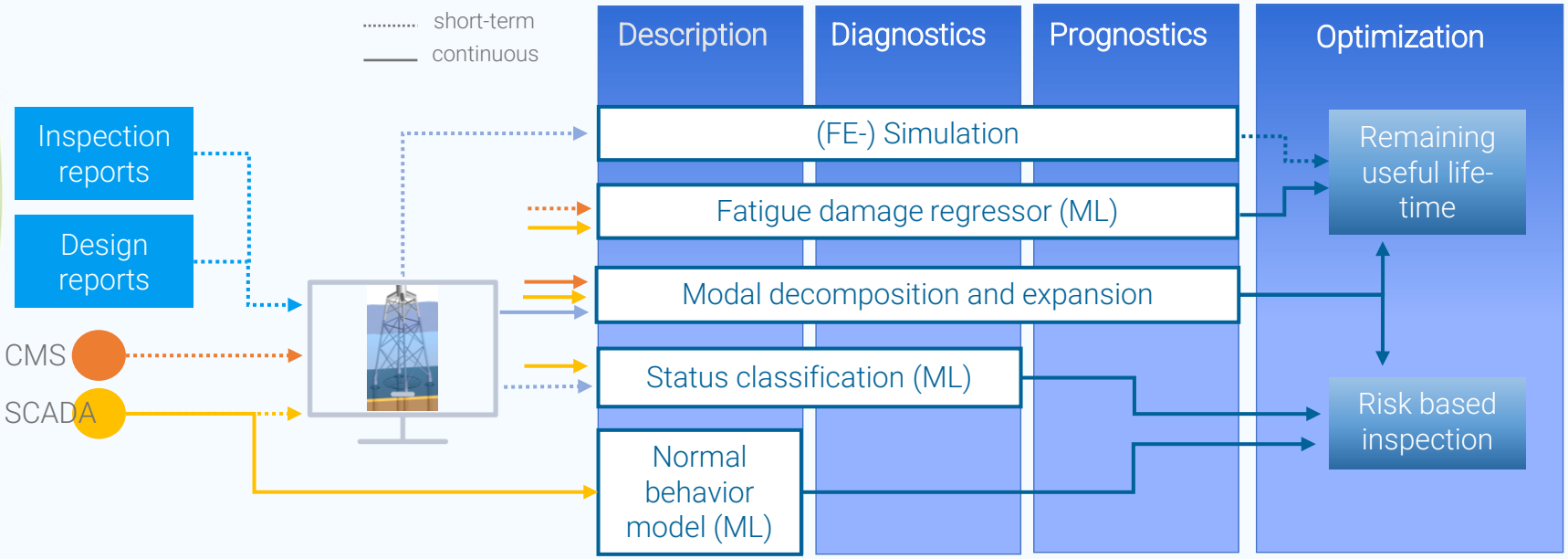
# SUPPORT STRUCTURE

## Demonstration of ROMEO analytics for low-cost monitoring

Risk assessment of critical failure mechanisms without feasibility of direct sensing:

- Fatigue
- Selection of anomalies:
  - Structural anomalies
  - Environmental conditions beyond expectation



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# DIGITALIZATION&DATA INTEGRATION

**Integration** of the different **data acquisition and processing** elements and protocols:

- Heterogeneity of **variables** to monitor and process
- Multiple **communication infrastructures**: Interfaces and protocols have to be independent of the communication infrastructures
- **Communication protocols**: 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 **IoT cloud platform**

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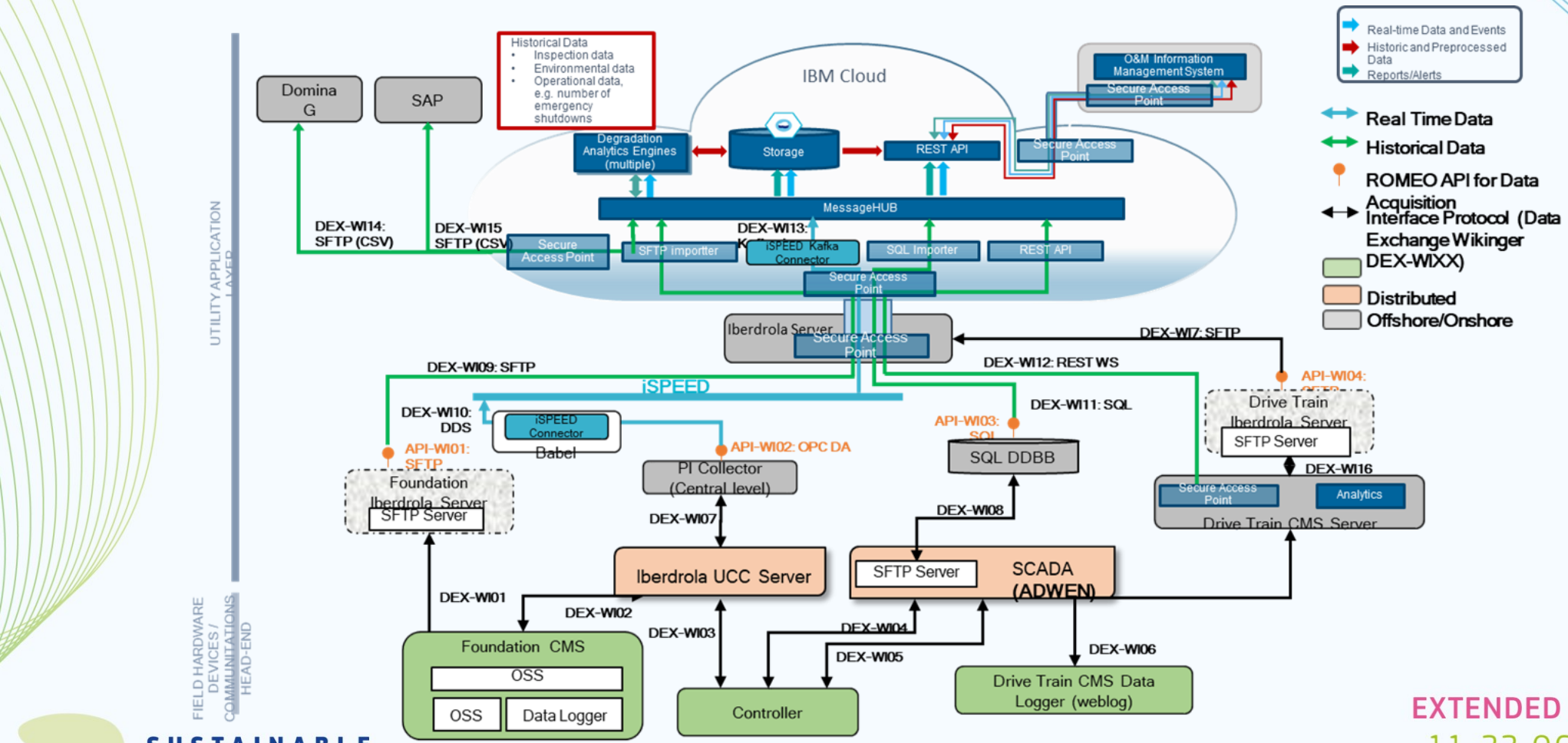
# DIGITALIZATION&DATA INTEGRATION

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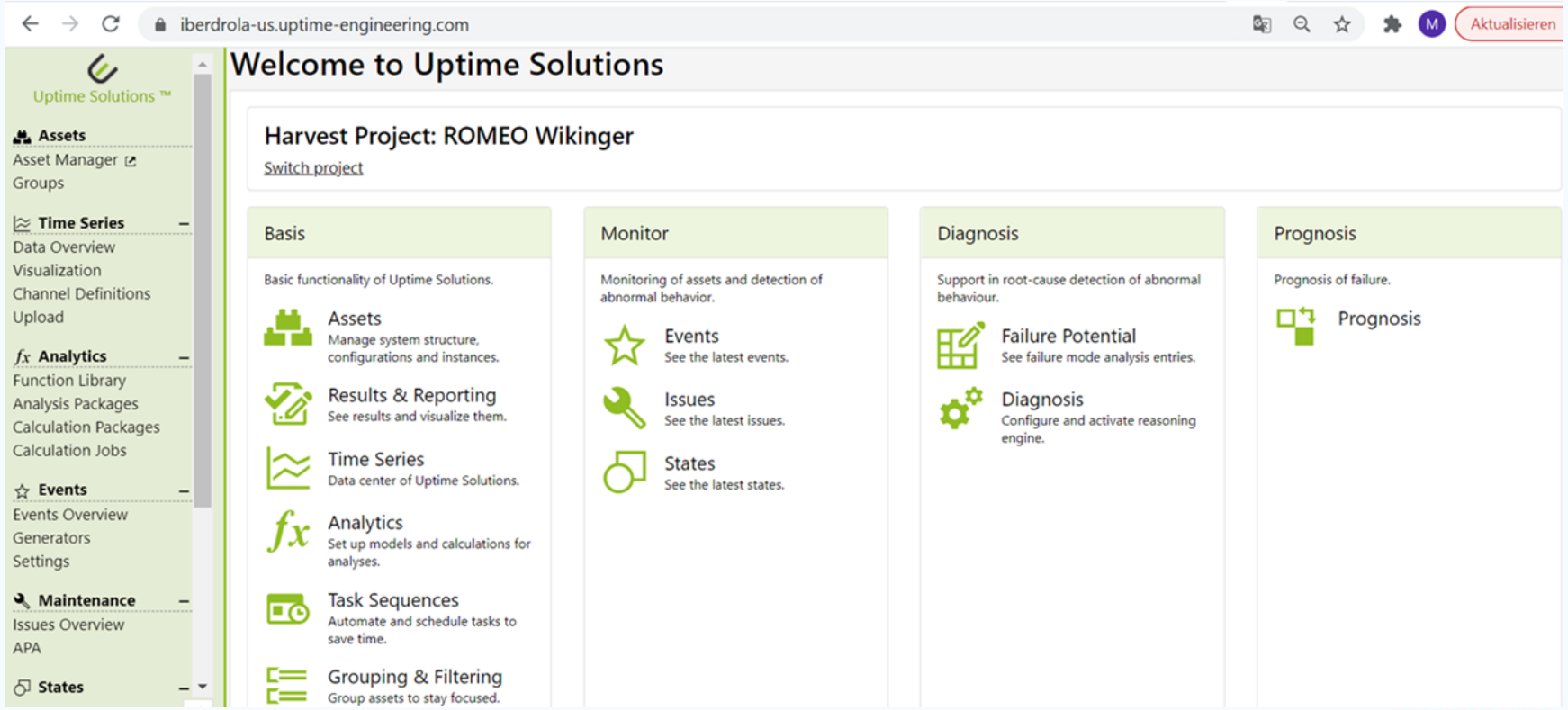
# O&M INFORMATION PLATFORM

- Integration of heterogenous data and information
- Visualization tools for analysis
- Analytics functionalities for KPI calculations and analysis
- Automated advisory generation functionalities



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# INTEGRATED ASSESSMENT TOOL

**Life cycle cost model:** (i) time domain simulations, (ii) account for stochastic inputs, (iii) provision for advanced maintenance topics, (iv) evaluate environmental impact for different scenarios, (v) a fully modular format

**Site characteristics Module**

Weather distribution, distance from port, water depth, etc.

**FinEX Module**

Weighted Average Cost of Capital, Inflation rate, Equity/debt

**CAPEX Module**

Input data during:

- Development and Consenting (D&C)
- Production and acquisition (P&A)
- Installation and commissioning (I&C)
- Decommissioning and disposal (D&D) stages of the offshore wind farm

- Temporal capital costs
- Total D&C, P&C, P&A, I&C, D&D cost

**OPEX Module**

- Latest reliability data
- Vessel and technician cost
- Number of technicians required for O&M operations

- Availability, annual repair costs
- Annual O&M cost

**Environmental Impact assessment Module**

- Processes
- Materials

→

- Unit emissions databases

→

CO2 emissions, SDGs



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# TRAINING PILLS

https://www.romeoproject.eu/1st-training-pill/

https://www.romeoproject.eu/2nd-training-pill/

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*We appreciate your feedback!*

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*César Yanes*

*Romeo Project Coordinator*

*Iberdrola Renovables*

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