



WHOLISTIC AND INTEGRATED DIGITAL TOOLS  
FOR EXTENDED LIFETIME AND PROFITABILITY  
OF OFFSHORE WIND FARMS



NEWSLETTER II  
February 2025



Funded by  
the European Union



WILLOW project EU  
[www.willow-project.eu](http://www.willow-project.eu)



# WHOLISTIC AND INTEGRATED DIGITAL TOOLS FOR EXTENDED LIFETIME AND PROFITABILITY OF OFFSHORE WIND FARMS

**5**  
countries

**5.8M€**  
budget

**12**  
partners

**36**  
months

## WILLOW FACTS

**Acronym / WILLOW**

**Program /** The European Union’s Research and Innovation Program HORIZON-CL5-2022-D3-03-04 Integrated wind farm control

**Duration /** October 2023 – September 2026

**Main objective:** WILLOW project aims to achieve an integrated system that provides an open-source, data-driven health aware curtailment strategy to the wind farm operators. This integrated wind farm control system in offshore environments will look for a trade-off between the power production and the lifetime consumption.

**Partner countries /** Belgium, Germany, The Netherlands, Norway and Spain.

## EDITORIAL

Dear WILLOWers,  
Welcome back to the WILLOW project! We are delighted to share with you the second issue of the WILLOW Newsletter, in which we continue to update you on the latest progress and insights from the project.

This edition highlights a significant milestone in the project: our recent meeting with the WILLOW Advisory Board. This gathering proved to be a pivotal moment, offering invaluable insights and fostering fruitful discussions. The conclusions drawn from this meeting will shape the direction of our next steps, and you can read more about them in this issue.

If you missed the first edition of the newsletter, we encourage you to take a look to discover an introduction to the WILLOW project, its objectives, and the activities undertaken during the initial stages. Newsletter 1. For regular updates, feel free to visit our website and follow us on LinkedIn (@WILLOW Project EU).

We hope you enjoy reading this issue of the WILLOW Newsletter. As always, your feedback and comments are highly appreciated!

## UPCOMING EVENTS

  
**8-10 April 2025**  
Presence at WindEurope  
Copenhagen

  
**8 April -5 May 2025**  
Presence at IPF  
Virginia Beach



Funded by  
the European Union



The consortium





## ADVISORY BOARD

In our previous newsletter, we shared that we were in the process of establishing the Advisory Board of the project. We are pleased to announce that it has now been finalized, and the following companies have officially joined as members.

### Certification companies



### Wind farm developers

### Engineering and service providers



### Manufacturer

### Association



So far, two meetings have been held with the Advisory Board. The first was an introductory online meeting, which took place on June 19, 2024. The second was an onsite meeting, held on November 22, 2024, at the SIRRIS facilities.



To ensure the most productive discussions, the in-person meeting included three separate technical sessions:

- 1 / **Coating condition** continuous monitoring, prediction and standardization for Offshore Wind Farms (OFW); and **uniform corrosion** and pitting monitoring, prediction and standardization for OFW.
- 2 / **Cybersecurity** strategy and standardization for OFW.
- 3 / Fleet lifetime assessment, standardization and windfarm control for OFW in **curtailed conditions**.

Additionally, participants had the opportunity to tour the SIRRIS facilities.





## CONCLUSIONS OF THE ADVISORY BOARD MEETING

### First technical meeting

The first technical meeting focused on Work Package 2 (WP2) of the project, titled "Novel Structural Health Monitoring System Combined with Drone-Based Inspections,". The discussion focused on two main topics:

- **Coating condition continuous monitoring, prediction and standardization for OWF**
- **Uniform corrosion and pitting monitoring, prediction and standardization for OWF**

The companies from the Advisory Board (AB) that attended this technical meeting were:



### Conclusions on the progress of the project

**Development of Ultrasound Sensor Nodes:** Creation of small, affordable ultrasound sensors designed to detect coating defects, pitting, and quantify the size and shape of pits.

**Continuous Ultrasound Monitoring for Corrosion:** The use of ultrasound has been made to monitor corrosion rates continuously, capable of detecting thickness losses of 1µm on 5mm thick samples. This level of precision is not achievable with continuous monitoring methods.

#### Field and Laboratory Work:

- **Field work:** Sensors for monitoring of uniform corrosion, coating degradation and environmental parameters will be installed in January 2025 on specific parts of a test monopile (submerged, tidal and splash zone). Mudline monitoring is intended for Q2/2025

- **Laboratory Work:** The detection of pitting through electrochemical tests, as is possible for stainless steel, is being investigated for low carbon steel. First results indicate that this is possible under controlled circumstances. Further work is needed to expand the proof-of-concept.

**First Results from Pitting Sensor:** Presentation of a concept for a sensor that measures the potential difference between pit bottom and sample surface.





## Key insights from the discussion

### Corrosion Monitoring

- **Correlation with operation:** Establishing a link between ultrasound measurements and operational conditions (such as typical loads around 4-50 MPa) is essential for understanding the performance and durability of the system under real-world conditions.

### Sensor Placement and Data Use

- **Challenges in placement:** Initial sensor locations may miss the most aggressive corrosion spots. To address this, complementary techniques, such as thermography, can be used to identify and target critical areas more accurately
- **Data preferences:** The focus is on generating actionable alerts while ensuring broader coverage with less frequent data collection, balancing costs and benefits.

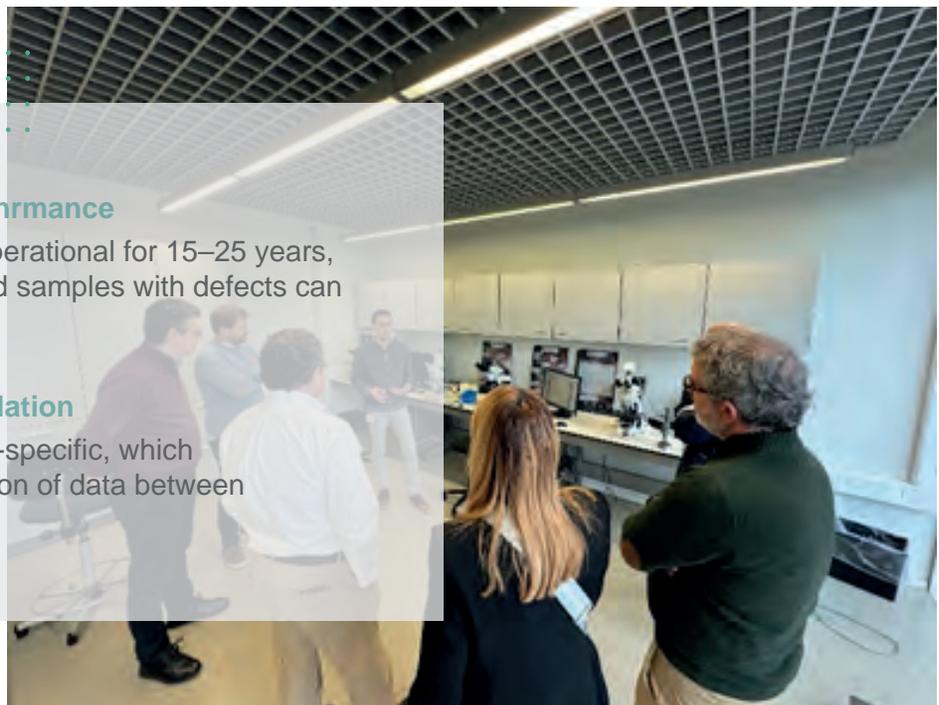


### Long-Term Sensor Performance

Sensors need to remain operational for 15–25 years, and options such as coated samples with defects can help study corrosion onset.

### Design and Data Extrapolation

Turbines are often location-specific, which complicates the extrapolation of data between different installations





## Second technical meeting

The second technical meeting focused on the first work package of the project: “Specifications, use case definition, cybersecurity guidelines & environmental and economical assessment”. addressed within the topic “**Cybersecurity strategy and standardization for OWF**”.

The companies from the Advisory Board (AB) that attended this technical meeting were:



### Conclusions on the progress of the project

#### Cybersecurity Risks in Wind Farms

The focus has been on the growing cybersecurity risks in wind farm environments due to the increased use of Industrial Control Systems (ICS) and IoT devices. Four main risks were highlighted:

**Ransomware**

**Botnets**

**Worms**

**Supply chain compromise**

Concerns were raised about the potential for external control of turbines, emphasizing the need to separate IT and OT systems for better security.

#### European Cybersecurity Standards and Directives

Various European directives and standards, such as GDPR, NIS2, Cyber Resilience Act (CRA), and ISO/IEC-62443, aim to improve cybersecurity. However, it was noted that only Belgium and Croatia had fully implemented NIS2 at the moment of the meeting. The discussion stressed the importance of **combining preventive measures with corrective plans** to address cyberattacks effectively.

#### Cybersecurity Approaches for Wind Farms

The meeting covered cybersecurity in wind farms, focusing on ICS, **IoT** devices, and the software development lifecycle (SDLC). It was clarified that IoT in this context **refers to low-resource devices using IT protocols**, not internet-connected devices.

### Key insights from the discussion

#### Data Sensitivity and Classification

A WindEurope working group has addressed data sensitivity in wind energy, recommending a classification system based on the **criticality of the data**.





### Digital Twin and Third-Party Security

- **Digital Twin:** The Advisory Board agreed that a simple digital twin could be tested for cybersecurity research, but complex digital twins are not viable due to manufacturer restrictions.
- **Third-Party Security:** It was recognized as a challenge, with the proposed solution being contractual requirements and compliance checks for suppliers.

### Physical Security

The importance of physical security was also highlighted, with some members considering it as part of their **cybersecurity strategy**.



## Third technical meeting

The third technical meeting focused on the third and fourth work packages of the project: WP3 “Data driven farm-wide corrosion and load prognosis, lifetime assessment & novelty detection” and WP4 “Fleet Life Assessment and Integrated Wind Farm Control”, both WP are addressed within the topic “**Fleet lifetime assessment, standardization and windfarm control for OWF in curtailed conditions**”.

The companies from the Advisory Board (AB) that attended this technical meeting were:



### Conclusions on the progress of the project

- The primary focus is on enhancing fleetwide load predictions, including curtailment scenarios, through the use of **advanced models** such as **Bayesian** and **Graph neural networks**. These models will enable reliable lifetime assessments and provide damage indicators to inform data-driven control strategies. Additionally, insights on curtailment, corrosion, coating, and virtual sensing from other project work packages will be integrated to further improve data-driven lifetime assessments.





- The objectives emphasise **collaboration** among **wind farm operators, grid operators, and balance responsible parties through PPAs**. Control strategies incorporate damage-aware inputs, considering lifetime consumption, operating conditions, load history, and future predictions, while addressing constraints from PPAs, energy markets, and turbine controllers.

- **Three control strategies** had been discussed: damage-aware selective curtailment (current), hierarchical active power dispatch (near-future), and load-mitigating turbine downregulation (far-future).

### Key insights from the discussion

#### Impact of Curtailment in Offshore Wind

It was noted that under current conditions, around **10%** of potential energy is curtailed annually.

#### Consideration of Curtailment in Design

Currently, curtailment is not considered in the design process. The focus is on **quantifying the acceptable downtime** turbines should experience.

#### Turbine Downregulation and OEM Negotiations

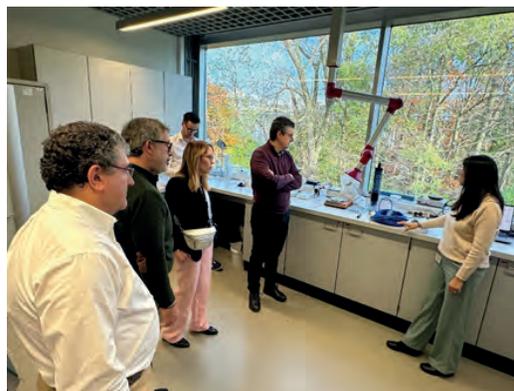
The proposal for load-mitigating turbine downregulation, is seen as a **long-term solution**. However, OEMs are unwilling to negotiate new turbine control strategies under current contracts. Any control changes must be included in the turbine certification and considered during the design phase. Research could help inform future contract negotiations, though power setpoints can already be directed to individual turbines.

#### Standstill Loads in Design vs. Real-World Data

It was highlighted that standstill loads in some plots are **higher than design values** due to the methodology used in comparing global standstill design loads with one-month periods of standstill. Over the long term, most wind farms typically operate below the design loads.

#### Wind Turbine Controller Changes in Willow

The potential for changes to wind turbine controllers in Willow depends on agreements with OEMs. While historically, OEMs have been reluctant to change wind farms, small progress has been made, such as **the removal of a single turbine from the curtailment scheme**. Additionally, the type of curtailment (sudden or not) is relevant in these discussions.





## PROJECTS NEWS

### WILLOW Co-Hosts Webinar on Next-Generation Wind Farm Control

/ 10 September 2024

WILLOW co-hosted a webinar with three European projects, focusing on "The Next Generation Wind Farm Control." Over 80 participants joined to explore advancements in wind farm control technologies. The webinar featured Horizon Europe projects IconicWind, SUDOCO, TWAIN, and WILLOW, presenting innovative approaches to integrated wind farm control.



### WILLOW in ENLIT Europe Milan

/ 22-24 October 2024

Ainhoa Cortes represented WILLOW in a panel at the EU Projects Zone Hub, discussing innovative grid technologies to support renewable energy integration, with a focus on microgrids, especially on islands. The session also highlighted projects such as SUBLIME, SHIFT2DC, and FILSUN, sharing valuable insights.

### Successful Testing of Ultrasound Sensors

/ 28-29 October 2024

Ceit and TSI tested ultrasound sensors on a prototype tower at TSI's Madrid facilities. The tests, which included static loads and vibrations, assessed structural health and response under various conditions.



### UPCOMING EVENTS



### WindEurope Annual Event - Copenhagen

/ 8 - 10 April

The WindEurope Annual Event is a key gathering for the wind energy industry, uniting global leaders and professionals to discuss the future of wind energy, and the WILLOW project will be represented there.

*Check these and more WILLOW stories in <https://willow-project.eu/news/>*



Funded by  
the European Union





## PROJECT PARTNERS



### Advancing Structural Health Monitoring in Wind Turbines with Virtual Sensing

As part of the Willow project, Wölfel Wind Systems focuses on developing a cutting-edge vibration- and strain-based Structural Health Monitoring (SHM) system for wind turbine towers and foundations. The primary targets of this initiative include increasing the operational safety and efficiency of wind turbines, reducing maintenance costs, and extending the service life of these critical renewable energy assets. By leveraging advanced monitoring and analytical techniques, Wölfel aims to provide wind farm operators with actionable insights into the health and performance of their assets.

#### Wölfel's Role in the Willow Project

Wölfel's role centers on developing innovative methods for reconstructing load components caused by aerodynamic and wave-induced forces. A significant aspect of this work is the estimation of strain values at structural points where no physical sensors are present. This is achieved through Virtual Sensing, which integrates real-time measurement data from existing sensor locations with advanced numerical models. By applying these techniques, Wölfel enables more precise load monitoring and structural analysis, contributing to the project's overarching goal of enhancing the resilience and sustainability of wind energy systems.

#### Leveraging OpenFAST for Virtual Sensing

In the project's Work Package 2, Wölfel employed OpenFAST—an open-source software from NREL—to model wind turbine support structures. OpenFAST enables the simulation of the coupled dynamic response of wind turbines by combining aerodynamic, hydrodynamic, control, and structural dynamic models. While the ElastoDyn module typically models the structural dynamics of turbine towers, it faces limitations when addressing specific design nuances. To overcome these challenges, the SubDyn module was utilized, enabling finite element (FE) modeling of the entire support structure.

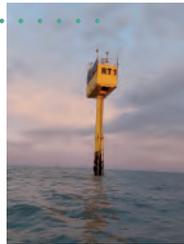
Initial comparisons of mode shapes derived from SubDyn with those from alternative FE models demonstrated good agreement. Building on this foundation, Wölfel extended OpenFAST's source code to extract mass-normalized mode shapes, which are crucial for virtual sensing of strains along the turbine structure.

By advancing Virtual Sensing techniques and contributing expertise in numerical modeling and load reconstruction, **Wölfel aims to enhance the accuracy and reliability of Structural Health Monitoring, paving the way for more efficient and sustainable wind energy systems.**





**sirris** innovation forward



Blue Accelerator test site with pictures of sensor frame before and after exposure

**Sirris is The Collective centre for the Belgian technology industry, an industrial research centre specializing in helping companies innovate across various sectors.**

Within its metal group, one focus is developing a reliable, data-driven corrosion management system for offshore renewable energies. In previous projects, in-situ sensor systems to monitor corrosion and environmental parameters were already studied and deployed, such as at the Blue Accelerator and at a wind turbine operator.



One of the sensors for uniform corrosion from MetriCorr that will be used in the measurement campaign.

These efforts provided insights into the conditions within the submerged zone of a monopile and included the selection, configuration, maintenance, and evaluation of sensors from different suppliers to assess their performance and suitability in challenging environments. Advanced statistical methods and models, exemplified by the SOCORRO App, were developed to analyse environmental data and calculate corrosion risk, integrating with predictive maintenance and risk management strategies.

These achievements mark substantial advancements in proactive corrosion monitoring and management. However, significant gaps in both technology and business case development were also identified. One of the important technology gaps is a lack of robust methods for long term monitoring of pitting corrosion rather than uniform corrosion, as pitting corrosion has the biggest impact on reducing the fatigue life of offshore structures through the introduction of stress concentrators (corrosion pits).

### Sirri's Role in the Willow Project

Within WILLOW Sirris will continue to develop this data-driven corrosion management approach. A new offshore monitoring campaign will be setup at the Blue Accelerator test site studying both uniform corrosion and coating degradation. Complementary water parameter monitoring will provide a detailed understanding of the actual conditions in the marine environment. The obtained data will be use as input for the development of prognosis models for uniform corrosion (together with FMAKE and C-Cube), and coating degradation models (together with C-Cube). The study will look at the various zones of the structure from the splash zone, of the tidal and submerged zones to the mudline. For the latter, a dedicated experiment is being developed to expose carbon steel pipes across the mud-water interface at a depth of 7m below the mean water line.

At the laboratory scale, Sirris will also focus on detecting pitting corrosion using electrochemical techniques and quantifying coating degradation as a function of temperature and time-of-wetness. This data will support updates to the current physics-based models for coating degradation, improving their accuracy and reliability. Additionally, the application of these electrochemical techniques will contribute to a proof-of-concept technology for in situ pitting detection, setting the stage for practical applications in the future.

**Finally, the goal is to reduce uncertainty on lifetime prediction and lifetime extension decisions by providing actionable data for decision makers.**



Funded by the European Union



# WILLOW



We hope that you enjoyed the WILLOW Newsletter and already look forward to the next editions.

The consortium

