



## **Advanced maintenance, lifetime extension and repowering of wind farms supported by advanced digital tools**



## Project

WindEXT is an ambitious 3-years project funded by the [ERASMUS + programme](#) of the European Union. The goal of the project is to develop and standardize specialized training integrating digital tools like Virtual Reality or 360° video tours to complete the classical theoretical methods. Furthermore, the project is an advanced integration of partners of different profiles and experiences to facilitate the exchange of knowledge between Universities, Vocational Training centers and private companies, in a model that it is now followed in different countries to facilitate the employability of students leaving both types of centres from different countries:



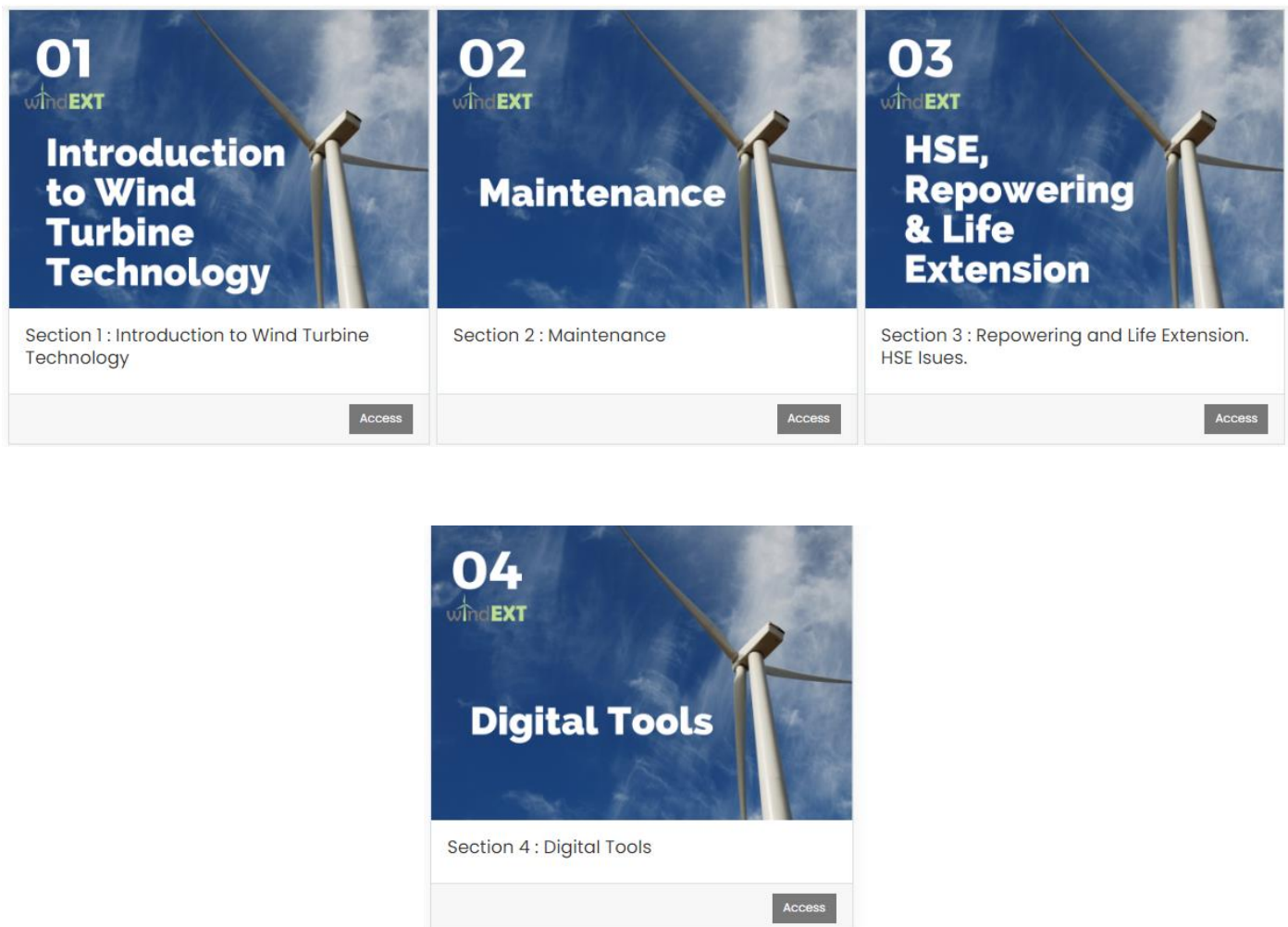
The goal of this approach is to optimize the generation costs of the windfarms in operation, either existing or new ones, by increasing the quality of O&M services and the wind farms availability while extending the lifetime of the assets and the working HSE conditions of the maintenance personnel.

### Intellectual outputs: WINDEXT MOODLE Platform

The project has produced a **standard training course based in a MOODLE platform** where all the contents are integrated as well as the different digital tools below presented. The purpose of the consortium is to promote the use of **either the course as a whole or some independent modules** or tools, serving always as practical basis of the theoretical teaching.

The course provides the training contents of the wind turbine technology (WTG) including the descriptions of the different components of a WTG and their function. It also deals with the maintenance of WTG and Wind Farms (WF) from both, general and specific point of view, as well as the main tasks for either extending the life of repowering the WF installations.

The structure of WindEXT course is based on four sections each one with their different modules:



Picture 1: overview of the course structure on Moodle

WindEXT has developed the following digital tools:

Through the WExSiM tool, various maintenance procedures have developed using a 3D simulation software.

The WExLaB shows the basic concepts and design of a wind turbine. Especially the design of wind turbines is explained with the help of MATLAB Simulink®.

From its side WExViR presents the various maintenance areas (preventive, corrective and predictive) of wind turbines through the H5P tool.

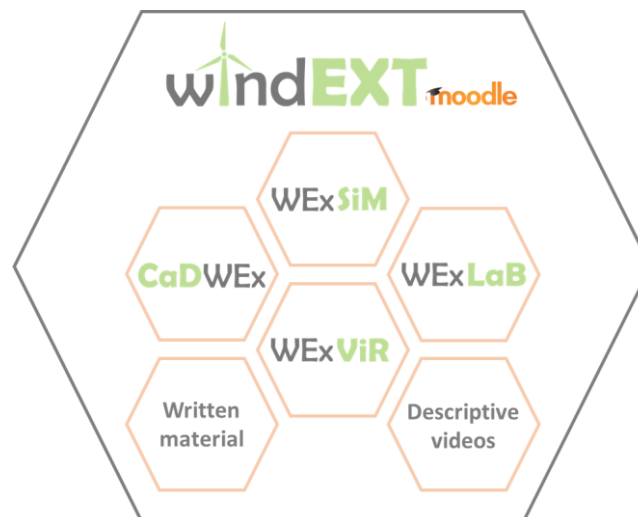
Finally, the CaDWEEx "Failure Tree" software allows, through a mathematical function, a set of data is taken as input and as output we get the evolution over time of the damage of a machine component.

A new version of SIMULWIND, developed in a previous ERASMUS project has been also completed in this project

Additionally, different interactive videos extend the use of the digital tools to give a complete overview of different maintenance and operational tasks related to repower, life extension and recycling.

### Description of the produced Digital Tools:

All the content of WindEXT project can be found in the MOODLE platform, from the theoretical content to the digital tools, with the exception of WExSiM, which is accessed externally.



Picture 2: structure of our WindEXT course

## WindEXT. Section 1: Introduction to wind turbine technology.

### Digital tool: WExLaB

Section one of MOODLE, “Introduction to Wind Turbine Technology” is divided into seven modules:

- Introduction to the Wind Turbine Components
- Design of a Wind Turbine Rotor
- Load Analysis
- Modal analysis
- Operation and Control of a Wind Turbine
- Wind Farm Component Layout and Design Criteria
- Reliability, Failures, Faults and Fault Tree Analysis

The purpose of these sections is to familiarise the course participants with different technological aspects and challenges related to the wind turbine. The course aims to answer the main questions that people are going to face when starting out in the wind turbine operations and maintenance field.

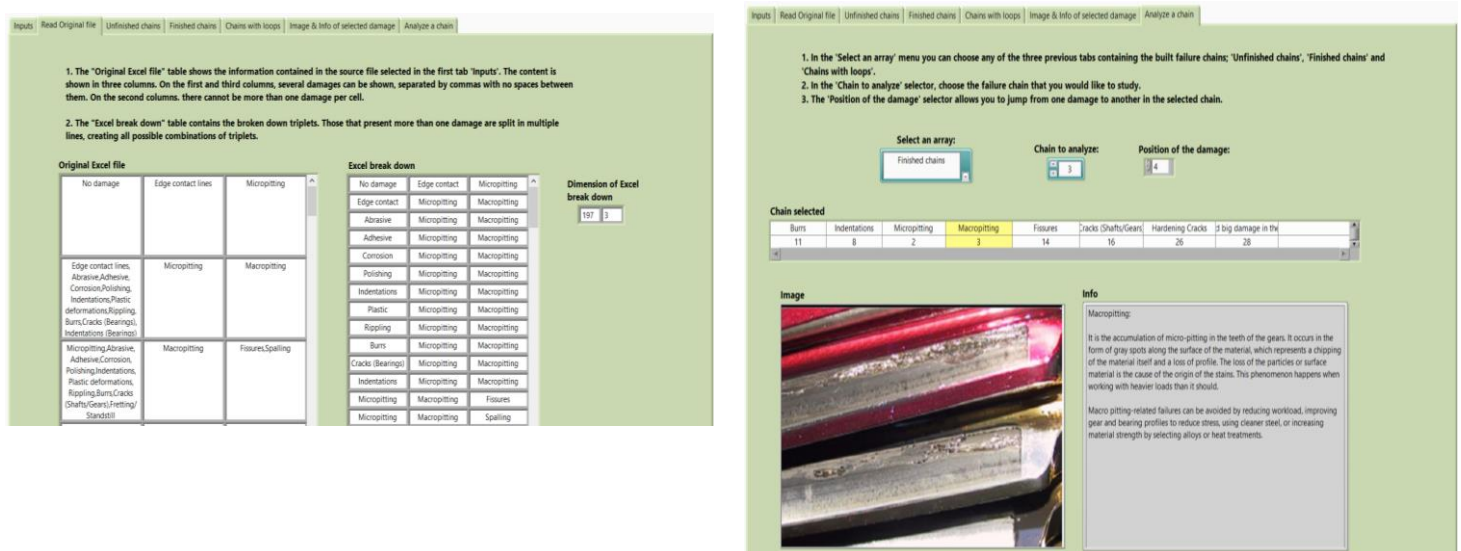
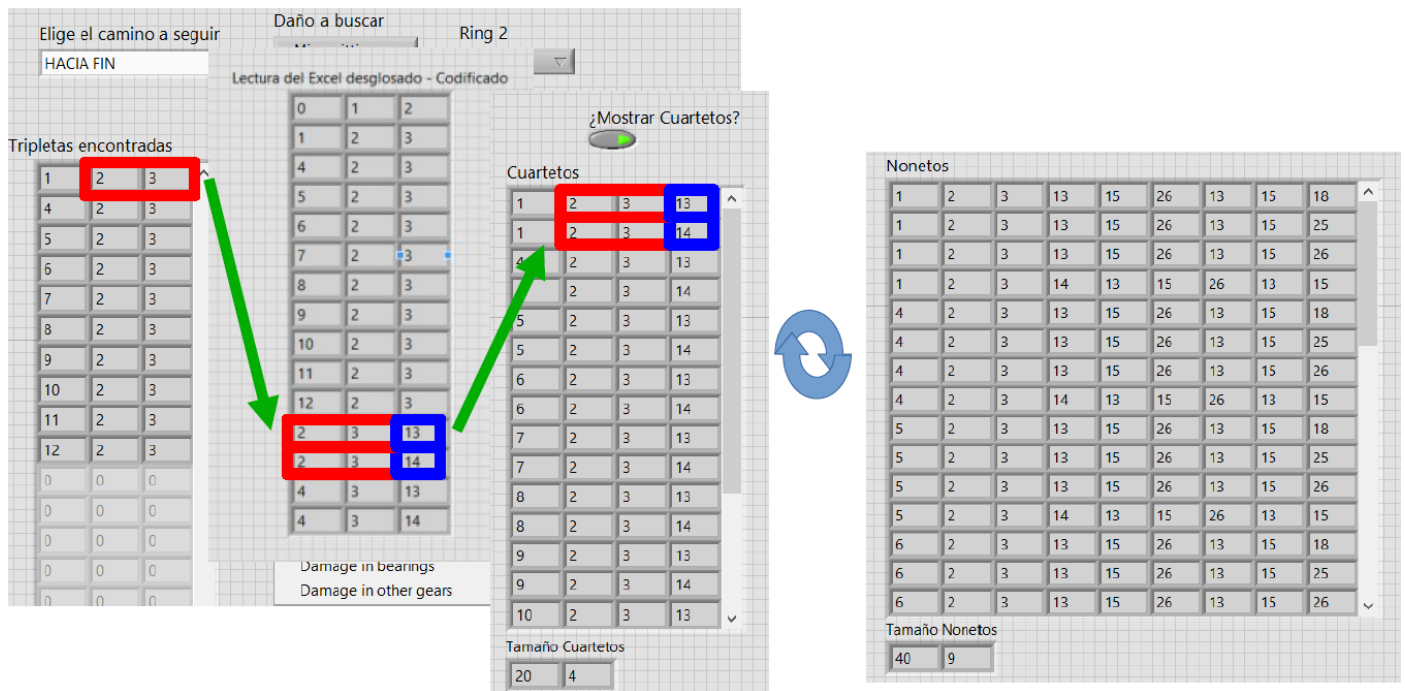
The digital tool associated with this section is WExLaB. This software integrates OpenFAST source code with a standalone MATLAB application as a graphical user interface. We have developed 4 parts of software:

- System level analysis
- Modal analysis
- Load analysis
- Operation and control of the wind turbine

### Digital tool: Failure Tree CaDWEEx

CaDWEEx (Cascade Damage Explorer) is a software that allows to explore the chains of damage of a specified component in the area of failure cascade analysis. And as example it focusses on the gearbox. With the assessment of experts, the possible faults (failure modes) were analysed and listed. The subsequent faults were defined for each individual fault as it can be observed in the tables below, so that a complete failure cascade was created. Using this failure cascade generated, the students can now learn about the faults, and how individual faults develop in the gearbox of a wind turbine along time. The learning material also shows when and how to react correctly to the respective faults. The software easily adapts to other components if the information of the fault development is provided.





Picture 3: fault tree analysis

## WindEXT. Section 2: Maintenance:

### Digital tool: Virtual Reality WExViR

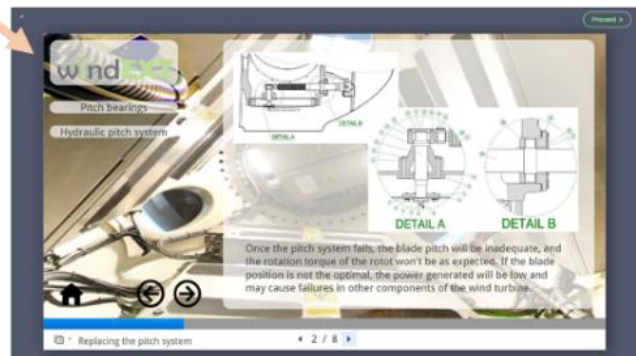
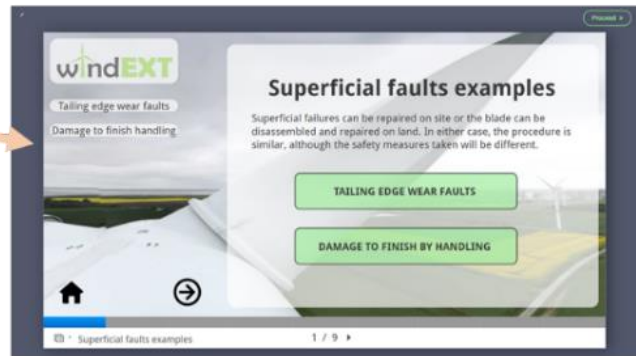
In the second section of the course, students are taught the different approaches to maintenance strategies. This includes preventive, corrective and predictive maintenance. The theoretical teaching material for each section is available on the Moodle platform.

Through the WExViR digital tool, the theoretical concepts of this section can be better assimilated using interactive contents that allow for a friendlier approach than the traditional written material, developed in H5P as a *Guided Tool*. Besides, virtual tours have been developed through a wind

turbine with 360° images using the H5P tool as well, in this case as a *Move-around Tool* that allows for a more independent use, for the students to have a complete overview of the different maintenance procedures.

# WExViR

## Guided tool



# WExViR

## 360° Move around tool



Picture 4: impressions of the WExViR tool

## WindEXT. Section 3: Repowering and LIFE Extension. HSE Issues:

### Interactive videos.

This section covers a reflexion about how the life of wind farms can be extended; it addresses the cost of repowering and presents wind turbine refitting as an alternative. The content is presented through different training videos on the subject, with the special function of interactivity. The development has been done with the collaboration of different educators and teachers.

4.1 Reusing, recycling

### Energy recovery from blade incineration

Incineration consumes polymer but leaves glass fiber behind.

### Cement co-processing

preheating  
pulverized coal  
kiln  
calcination-burning raw meal to clinker  
cooling  
pulverized coal

- Consumes polymer and E-glass
- Substitute 1000kg blade waste= 600 kg coal

Source: University of Cork

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WindEXT

Waste  
Blades  
Composites  
Recycling  
Mechanical  
Thermal  
Chemical  
Reusing  
2nd Market  
Energy rec.

Picture 5: Interactive training video

## WindEXT . Digital tool: WExSiM

In this part of our training courses, different exercises can be used in a virtual environment. The simulation runs on the Oculus Quest 2. With these 5 training procedures, which can be viewed on our homepage [www.windext.com](http://www.windext.com) and on our YouTube®-channel WindEXT. The 5 training scenarios are:

- Maintenance and replacement of a yaw drive
- Blocking High speed shaft and pad lubrication
- Evacuation from service lift
- Hydraulic torque wrench operation
- High voltage cabinet fuse replacement



## WindEXT .Digital Tool: new version of SIMULWIND

WindEXT has developed a new version of the SIMULWIND that allows the software to be used in up to four VR Googles, Vive PRO, Vive Pro 2, Oculus Rift and Oculus Quest 2. That makes possible 13 vocational training centers in Spain are using now this training tool.

### Pilot tests

After completing the WindEXT platform and the digital tools produced during the project, pilot tests were organized by some of the partners to test them. For instance;

- **UCLM** carried out the pilot tests in the Faculty of Industrial Engineers, in Albacete, part of the University of Castilla-La Mancha (UCLM). The participants were students of the Electrical Engineering Degree. The sessions were developed accessing the WindEXT Moodle platform and covered part of the WExVIR tool and part of the WExSIM tool.

In general, the students perceived the digital tools mentioned to experiment with close-to-real maintenance activities that are normally carried out at operating wind turbines.

- **TESICNOR** carried out the pilot tests in the CENIFER center (Centro de Referencia Nacional en Energías Renovables y Eficiencia Energética). in a session of three hours with 24 participants. The contents for these pilots were: Elevators: Safety use and evacuation procedures; Electrical works: Medium voltage switchgear; 360° Wind turbine tour; Identify bugs.

The WExSIM simulator had a very positive balance. The students showed great interest in the courses received and the methodology adapted very well to their needs. Enthusiasm and proactivity would be the adjectives that best capture the essence of the Pilot Test. Every student executed the practices.

- **AEE** carried out several small Pilot Tests in different events where, the WindEXT project was presented and attendees were able to test the digital tool WExSIM.

Those Pilot tests took place in Bilbao (WindEurope annual congress) and WindTalent (Madrid, event organized by AEE and the school of industrial organization (EOI). The participants had different backgrounds and profiles: workers of companies of the sector, university students, vocational training students. Many of them had never been inside a wind turbine, so the experience carried out through WExSIM was different parts of the nacelle so closely. They were happy to be able to put into practice the very rewarding for them. Among the comments they told us how real it was to be inside the elevator and see the maintenance tasks they have learned from their books in the classroom. Teachers also found it to be a perfect tool to complement their lessons.

**INESTEC** carry out its own pilot test with the assistance of **AEE's** technicians, a total of 15 students have the opportunity to test the different WindEXT tools. Similarly, a Pilot test was carried out in **TUD** facilities with a similar scheme: a total of 20 students participate in that pilot test with the involvement of **AEE's** staff too.

Finally, **AEE** tested the WExSIM with Moroccan students within the MOVE Green project addressed to extend the knowledge on RE energies to foster the creation of SME related to asset management sector in Morocco with the involvement of Spanish companies.

- **Dp2i** carried out 4 pilot tests to test the digital tools SIMULWIND/ WExSiM and CaDWEx in different cities from Spain; Valencia, Leon, Barcelona and Lleida. The professors are very enthusiastic about the possibilities, especially about WExSiM.

### Disseminations of the project

All the results of the project are presented on its own website [www.windext.com](http://www.windext.com), including the 6 [newsletters](#) developed during the project progress, which are available in English, Spanish, French and German.

More information can be also found on its own Twitter channel. Follow [@Wind\\_EXT](#)

### Conclusions and strategical recommendations

The experience in the development of the Project has allowed to draw several conclusions:

- The importance and interest of creating links between university and vocational centres, not always simple. The firsts have difficulties in lowering the contents level and the for the second ones, it is not easy to understand the theoretical background to explain the failures and root causes.
- The difficulties of coordinating teams with different professional approach and different ways to approach the foreseen tasks of the project.
- However, working with such diverse entities has been truly motivating and has allowed mutual learning among the participants. In fact, the COVID pandemic has had a positive influence because it has allowed to have a more continuous contact through the telematics meetings.
- The importance of digital tools to approach the wind maintenance network, complex due to the multitude of technologies involved and the need to do it in so demanding physical conditions: work at heights and narrowed space.
- The pilot experiences and the first simulations have been welcomed by vocational training centers and they encourage to follow for this path in the future.

In this sense and in the line pointed out above, the possibility of giving continuity to the work carried out is being considered, with the partners' own means as well as with some possible public support. In this sense, the strategic approach for the future is based on the following points:

- Follow up of the impact of using the [WindEXT](#) tools in the vocational centers at worldwide level.
- Possible extension with new maintenance procedures.
- Evaluation of the possible updating of the tools to follow the hard and software advances on VR.
- Integration of new areas, taking into consideration the experience of other national and ERASMS projects, as for instance off shore wind and PV maintenance.

## Project Consortium and contact:

A consortium of European key players in the Wind Industry (entrepreneurial associations and maintenance companies), Universities and vocational training centres come together, to create the reference training course **WindEXT**.

The presence of UTEC/CEFOMER from Uruguay is considered fundamental to adapt the contents to another sociological/legal scenario as the LATAM countries.

### **Project Leader:**

Asociación Empresarial Eólica (AEE)



### **Project partners**



For more information about the project partner's visit:

<https://www.windext.com/projectconsortium/>

### **Contact:**

*Victoria Campos: [vcampos@aeeolica.org](mailto:vcampos@aeeolica.org).*