Deliverable 8.1

Deployment plan for pilots

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Prepared by: BAPE and CIRCE

SWIP – New innovative solutions, components and tools for the integration of wind energy in urban and peri-urban areas

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Executive Summary

The present document describes the deployment plan for each of the three demo sites that are part of the SWIP project, as well as the monitoring and evaluation programme that is going to be run during the demonstration stage of the project.

The Deployment Plan describes construction of three pilot micro wind turbines in three locations characterized with different orographic, wind and urban conditions. The following WT solutions developed under the SWIP project will be tested:

1. V2 WT placed on the roof of the building in Choczewo (Northern Poland)
2. H4 WT on the mast attached to the building in Zaragoza (Spain)
3. H20 WT on the stand alone mast in Kokoszki (Northern Poland)

The objective of the document is to ensure that necessary actions are executed in planned manner in order to achieve project goals and to reduce the risk of failure for each of the pilot sites.

The planning of the three demo sites follows the same paths, being some aspects of the planning different between them (i.e. due to the size of the WT in Choczewo, it is exempted of planning permissions) due to the different type of WT characteristics, land ownership and local sites regulations.

In addition, in all three pilots is necessary to notify to the corresponding DSO and an agreement needs to be signed by the DSO.

The manufacturing of the different parts of the wind turbines are going to be done depending on the different restrictions such us material availability, transportation costs, possible assistance of the manufacturer in case of any issue (local providers will be considered) and price. Once all these aspects will be evaluated, those options that best suit these requirements will be chosen.

Also, the civil works for the conditioning of the surface (roof for Choczewo, foundation slab plus roof conditioning for Zaragoza and foundation for Kokoszki) and the assembly and installation of the wind turbines are tasks that due to its nature, none of the SWIP partners have the required experience, so to perform this work with the best quality, subcontracting companies will be selected and monitored by the SWIP partners in order to have the wind turbines installed. For this task, the participation of local companies will be highly valuable since they can provide quicker response, this also allow involving stakeholders not only for the lifetime of the project but for the future exploitation after the project end.

BAPE (for Choczewo and Kokoszki) and CIRCE (for Zaragoza) as pilot coordinators will be in charge of supervising and coordinating all activities related to its demo site. Gantt chart for WT development, installation and commissioning have been developed and agreed between involved parties.

Also, there are some institutions/organizations that are needed to succeed with the installation of the Wind Turbines in the demo sites, this stakeholders are identified in the document as external

and facilitating stakeholders, which have been consulted and already engaged and should be involved in the deployment of the WT.

Risks identification and mitigation approaches for the three demo sites have been developed. This will enable assessing progress on site preparation, WT installation, and performance over the monitoring period. Identification of risks in advance shall minimize or mitigate their impact. The key risks are linked with the external factors, like bad weather conditions during WT installation and delays in notification procedures, including requirements for the local grid connection, with operator of power distribution system as well as technical aspects of civil works and WT assembly and commissioning. Necessary steps are planned to overcome these problems.

Monitoring and evaluation programme

The planned monitoring and evaluation programme shall ensure acquiring all necessary important parameters of WTs operation, especially their productivity and noise generation against measured wind conditions. The presented methodology provides adequate level of accuracy and consistency of measurements, and wind turbines and components performance evaluation. The individual approach for each site will be employed in order to meet local conditions. Final reports will include all important factors, including performance of a given WT in different wind conditions as well as correlations between deviations from the expected values and incidents in the wind turbine.

This shall ensure verification if the project objectives are achieved.

Table of Contents

Index of Figures

Index of Tables

1 Introduction

The project comprises installation of three small wind turbines achieved by the collaboration of the teams at the different sites under the SWIP projects. Two SWTs are located in Poland, Pomerania region (Pilot 1: Choczewo Commune and Pilot 3: Gdansk-Kokoszki) and one in Spain (Pilot 2: Zaragoza).

Following, a description of each pilot site is performed.

Pilot 1

Choczewo is a village situated on a hill, circa 8 km from the shore line. The district is 190 km2 in area and has a population of 6.000 inhabitants. It is suitable site for SWTs location due to its favourable wind conditions and clean environment. There are two schools, a public library, health centre, bank, petrol station and some businesses located in the town. Due to its favourable wind conditions quite a few wind farms are situated there and more than 100 MWs are planned to be installed in the municipality.

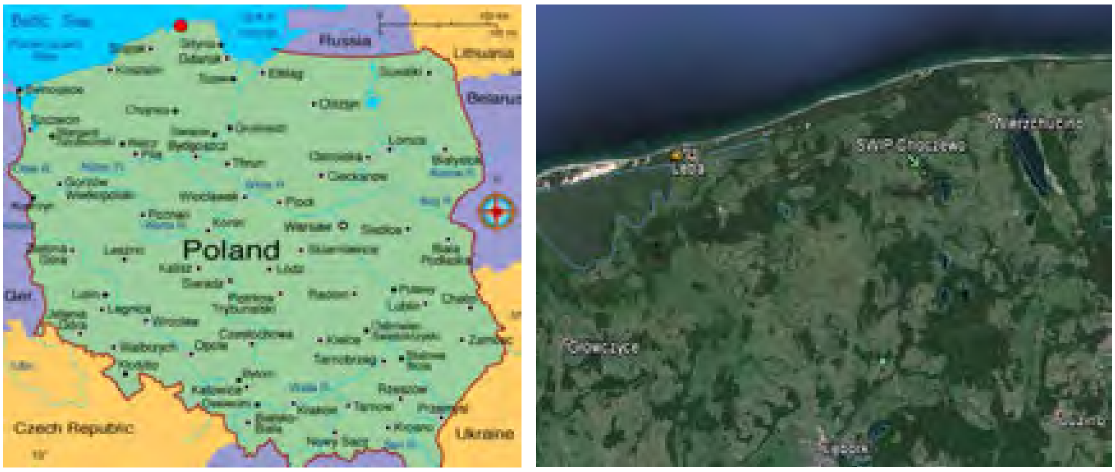


Figure 1. Choczewo pilot location in Poland

Under the framework of the SWIP project a 2 kW vertical axis WT will be installed in the middle of the village, on the roof of the local authority building.

Pilot 2

The second pilot is located in the Spanish city of Zaragoza. The climate here is typical of many parts of north and central Europe so that, this site has the benefit of being highly representative in terms of wind patterns and potential energy resources. Furthermore, locating the WT within a university campus is a good way to begin gradual integration of SWTs in urban areas and preparing them for adaptation to more urban contexts as a next step. Replicability is at the core of the SWIP project with the aim of enhancing the uptake potential for implementing reliable wind generation in Europe urban areas.

Zaragoza itself is very suitable for wind generation from both the wind resource and exploitability points of view. The wind patterns are both intensely and relatively constant here, with an annual

average speed of 19 km/h at 20 meters height. Spring and summer are the most windy seasons but it is also interesting to highlight that in summer the wind resource remains strong as well (for instance 19,4 km/h in July) illustrating the continuous availability of the resource.

The SWIP demonstrator located in Zaragoza comprises installation of a 3-4 kW horizontal axis wind turbine in a zero-emissions-building located in a university campus. The aim of this pilot is to demonstrate the integration of SWTs in buildings, and so counter presumptions of negative visual impacts on the receiving environment for such situations.

Figure 2. Zaragoza demo site location

Pilot 3

The third pilot is a 20 kW horizontal axis WT placed in Kokoszki – an industrial district in the city of Gdansk in the Polish region of Pomerania. The pilot is located in an environment of factories and warehouses with heights ranging from 10 to 20m. The topography is flat, situated approx. 130-140 meters above sea level. The spatial development plan of Kokoszki allows constructions of up to 30 m. At the same time, due to proximity to neighbouring Gdansk International Airport and its associated radar installation, the height restrictions apply to the erection of any structures.

The SWT will be installed on the plot owned by a construction company - Przedsiębiorstwo Budowlane Kokoszki SA. Due to its location, the pilot will be visible from the surrounding areas and nearby roads.

Figure 3. Kokoszki pilot location in Poland

2 Pilot Site 1: Choczewo District (Poland)

2.1 Elements, Solutions and Technologies

- Vertical axis blades design

The blades were designed from scratch specifically for this wind turbine. The blade consists of two half that are joined. Because the blade is small only 6 layers of fiberglass will be laid per half, 12 layers with epoxy resin will be used to manufacture the blade. 6 blades will be assembled to create this wind turbine.

Blade length: 2,4 meters

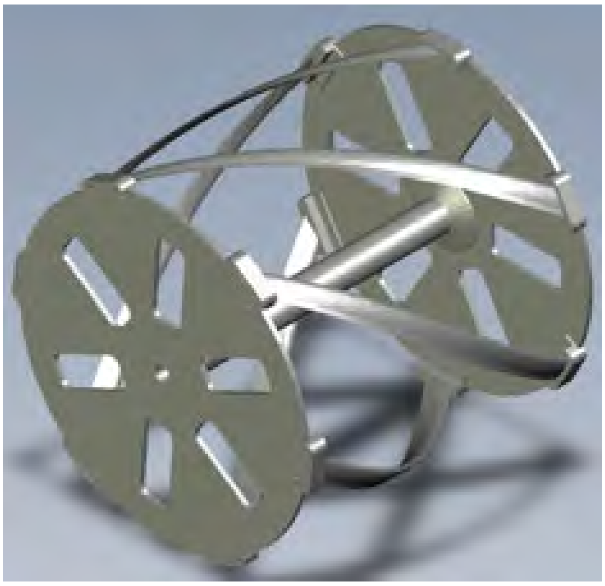


Figure 4. Blades for WT 2 in Choczewo

- Generator

The 1.6 kW generator for Choczewo demo is a permanent magnet generator specifically designed to operate optimally when coupled to the converter and blades developed within SWIP project. The generator axle is coupled directly to blades at one side by means of a key, and to the speed sensor at the opposite axle side. The mounting of the 2 kW generator is B5 type, using a mounting flange that will be bolted to the SWT blade supporting structure.

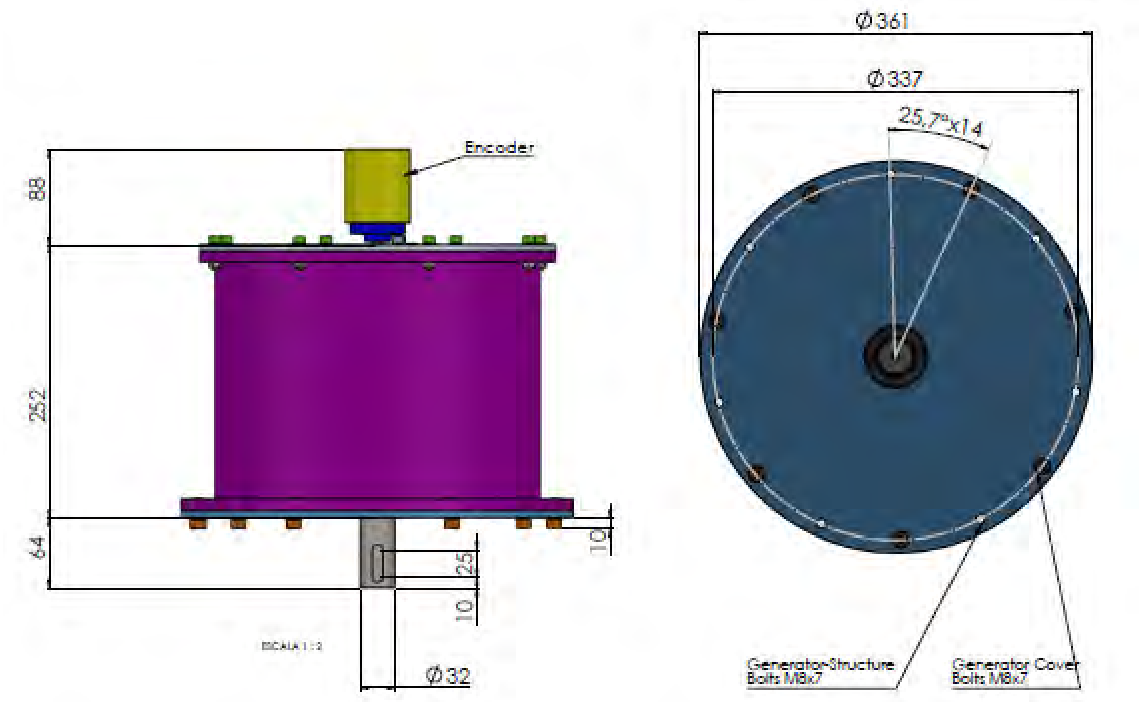


Figure 5. 2 kW generator dimensions.

The generator has been designed to output the 1.6 kW when rotating at 180 rpm, has a superior efficiency of the generator when compared to similar commercial products, and design has been optimized to find a solution as light and compact as possible. Outer dimensions are 316x361x361 mm (LxWxH) and its weight is approximately 50 kg. The connection to the converter cabinet or both signal and power cables will be performed through wiring with adequate characteristics.

- Frame and anchorages

The question of how to locate and connect the wind turbine to the fabric of the mayor´s office building in Choczewo posed quite a challenge for the consortium. The size of the turbine did not easily fit within the bays of the building nor align to the possible load paths of structure. Coupled with this there were many obstructions in the form of vents and chimneys that couldn’t be interfered with. The bespoke cranked steel structure comprising legs and angled frame platform was created to support the WT. It spans between two structural walls of a stairwell and ‘mediates’ between its span and the width of the turbine.

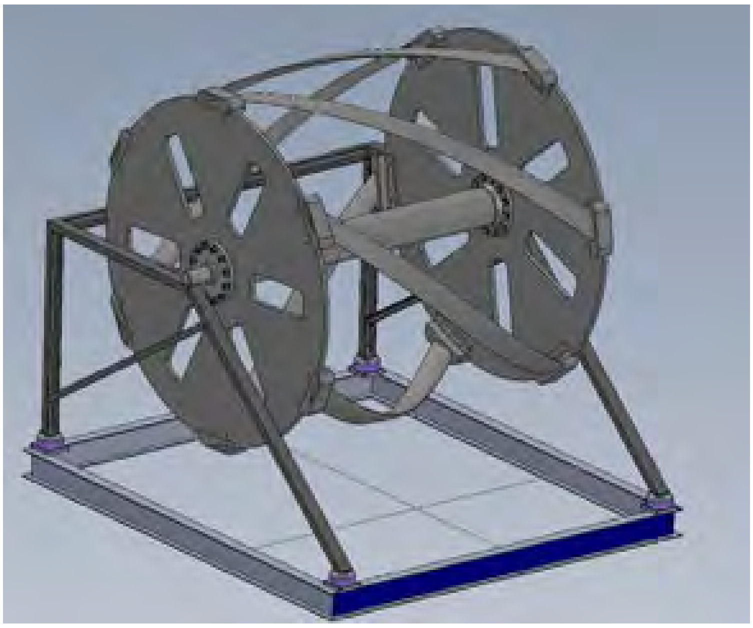


Figure 6. Frame for the WT structure

The wind turbine is supported by a four-leg structure in order to distribute the total weight of the wind turbine over the auxiliary frame built to share that weight on the load bearing walls of the building.

Figure 7. Auxiliary frame

- Converter

The 2kW converter for Choczewo has been developed using a passive rectifier + inverter topology, which is installed inside a protective cabinet with dimensions 800x1200x400 mm (WxHxL). The cabinet has a 3P+N+G 16A male connector for coupling to the grid, and a 3P+G 16 A male connector to the generator, and comprises power supplies, safety measures, signal acquisition and control boards to manage the power stage of the converter, including connection and disconnection to the grid.

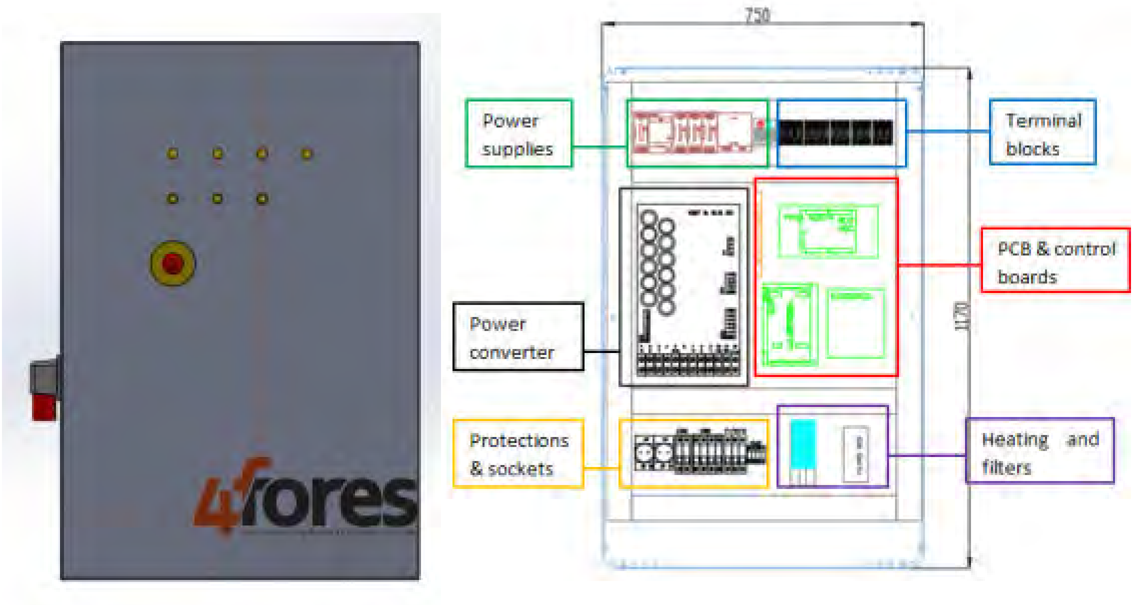


Figure 8. 2 kW converter.

During operation, the converter monitors grid voltage and frequency levels to make sure grid conditions are within tolerable ranges according to "Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators". In case either the grid levels are outside tolerable ranges or no grid is detected, the power flow into the grid is be stopped and disabled, and the converter is be electrically isolated from the grid by actuation of a contactor installed between grid and power converter. Power flow between grid and converter is enabled again after it is made sure the grid voltage and/or frequency are within the adequate levels, being the converter reconnected to the active grid to deliver power only when wind is available.

The cabinet is locked with a key lock, and is operated through three pushbuttons in the front panel; the current status of the converter and SWT is shown by 4 light pilots in the front panel of the converter. In case of emergency, an emergency stop can be manually triggered operating the emergency pushbutton in the front of the cabinet.

The cabinet must remain at all times tight to a firm solid body, by means of adequate supporting/anchorage equipment.

2.2 Schedule for the installation

2.2.1 Pre-Construction

2.2.1.1 Building permit

The WT in Choczewo is exempt from the need for planning permission as installing small wind energy devices on buildings do not require a building permit. However, in the case of the

installation exceeding 3 meters, a notification to the appropriate authority is required and the authority has 30 days to either accept or object (Act of 7 July 1994 on Building Law).

The notification has to specify the type, scope, manner of execution of works and the date of their commencement. The notification has to include a statement of the title to the property and relevant sketches or drawings, as well as permits, agreements and opinions required by separate regulations.

The competent authority (in this case Starost of Wejherowo County) may request supplemental, documentation, within a specified period and if these are not submitted, the authority would withhold permission and the installation is not allowed.

Once properly notified, construction may start after 30 days from the date of submitting the notification unless the authority objects. It is then permissible to integrate WT devices either onto a building or to install them on a roof.

If the construction is not larger than 3 meters, neither notification nor a planning permit is required.

2.2.1.2 Notification to the power distributor

Connection of a micro-installation (i.e. RES ≤ 40 kW) to the grid has to be filed to the DSO in a form of a formal notification. This should contain information on the end user, descriptions of the RES's receiving structure and technical details of the installation (including declaration of compliance in terms of fulfilling current standards for low voltage installations and electromagnetic compatibility as well as schematic diagrams of micro-source connection to the receiving installation, all executed by the installer). The energy company must be notified at least 30 days before the anticipated start of operation of the micro-installation.

The next step is the creation of an agreement with the DSO that covers grid connection of micro-generators to the grid itself. Thereafter the energy utility will install safety and measuring systems clearing the way for the export of the electricity onto the grid itself. In order to sell the electricity, a sales agreement must also be created.

There is no obligation to acquire a license in order to generate electricity at the micro-installation (i.e. RES ≤ 40 kW) scale.

2.2.1.3 Subcontracted Installation Company

Within the SWIP consortium there is no partner with the technical skills to perform the construction and installation works, so there is a need to subcontract this works. This service will consist of the civil works related to the adaptation of the building roof, as well as the installation of the supporting structure for the wind turbine and the wind turbine itself.

2.2.1.4 Land for use

As BAPE is not the owner of the building, the lease document had to be signed by the both parties.

2.2.2 Transportation

In order to optimize the costs of transportation of the different WT elements and structure to the pilot site, it is intended to select from a list of providers close to the pilot site (if they meet the technical and economic requirements). The objectives will then be to procure the various elements as follows:

- Auxiliary frame will be manufactured in Poland.
- The frame will be manufactured by SOLUTE and will be shipped to Poland.
- Blades; to be built in Lithuania by PPL Partner and will be shipped to Poland.
- Generator and power train; to be built in Zaragoza by FORES and will be shipped to Poland.
- Converter; to be built in Zaragoza by FORES.

2.2.3 Co-ordination and supervision of, assembly, civil works and installation.

BAPE as the demonstration coordinator will be in charge of supervising and coordinating all activities related to the demo site, namely:

- To ensure designs conform with/adapt to Polish requirements.
- To ensure the proper transportation of the different elements (this is responsibility of BAPE and those from other partners) to the demo-site.
- To supervise the assembly of the WT by the installation company.
- To supervise and coordinate the civil works.
- To supervise the installation of the supporting structure, the wind turbine and the power connection by the installation company.
- To perform the commissioning of the WT.

2.2.4 Gantt Chart

See "Annex I.I Gantt Chart for Pilot 1 in Choczewo".

2.3 Stakeholders involved

The design, manufacturing and installation of the WT can itself be considered as a (sub) project within the SWIP project and to achieve success a large number of parties are involved. The different stakeholder involvements with associated responsibilities within the project are presented in the following sub sections.

2.3.1 Defined responsibilities

Table 1. Responsibilities of the project partners for the 2WT

	Responsibility	Partners and stakeholders
1	vertical axis blades design	PPL
2	PM generator and converter design and electrical installation	FORES
3	Auxiliary frame, supportive frame and design and manufacturing	SOLUTE
4	Expertise on the building construction in Choczewo	BAPE
5	Re-design (adaptation of the construction design) to Polish regulations	BAPE
6	Electrical installation design	FORES
7	Power connection design based on Polish regulations	BAPE
8	Civil works on the roof (adaptation of the building construction for the installation of the WT)	BAPE
9	Notification on civil engineering works on the roof	BAPE
10	Notification on energy connection	BAPE
11	Transport of the WT elements to the pilot site	PPL, FORES, SOLUTE
12	WT installation on the roof	BAPE, FORES
13	WT certification	FORES
14	WT connection to the electrical installation	BAPE, FORES
15	Noise and vibration mitigation solutions	KTH
16	Wind resource software validation	METEODYN
17	Co-ordination and supervision	BAPE
18	Safety tests	FORES

Parties involved (SOLUTE, FORES, PPL) will prepare a document explaining how the different part of the wind turbine match each other. This document will be delivered to BAPE.
SOLUTE and FORES will assist during assembly process.

2.3.2 Project partners

Table 2. Project partners involved in the development of the 2WT

	Responsibility	Partners
1	IT system	CIRCE
2	Construction of the PM prototype and testing, converter design, converter and PCB assembling and testing	FORES
3		METEODYN
4	Blades design and manufacturing	PPL, SOLUTE
5	Platform and anchorages design and manufacturing, WT frame	SOLUTE, CIRCE
6	Noise assessment	KTH
7	Tests of the scaled blades model	USFD
8	Safety tests	FORES

2.3.3 External stakeholders

Table 3. External stakeholders in Choczewo

	Responsibility	Stakeholders
1	The building owner, consent to install the SWT	Mayor of the Choczewo commune
2	Building documentation, electrical schemes	Administrative staff: Department of investments and energy
3	Notification on WT installation	
4	Electrical connection permission	DSO energy company

2.3.4 Facilitating stakeholders

Professional partners to facilitate the stakeholders at Choczewo have been selected based on competence and experience in wind energy. At least three candidates were considered and evaluated for each specific task. These are:

Table 4. Facilitating stakeholders in Choczewo

	Responsibility	Stakeholders
1	Expertise on building construction - assessment of technical condition of the building elements Calculation f permissible load on walls Concept of mounting of VA WT on the roof Calculations, design and drawings of the platform located on the roof, base for the WT construction. Assembly drawing, drawings of elements with details of connections and requirements for manufacturing of elements Calculation of weight and costs Supervision of civil works: - Modification of roofing - Installation of base platform - Installation of WT	Civil engineers
2	Inventory of electrical supply and distribution in Choczewo commune administration building. Scheme of connection Connection point to the distribution grid. Design of connection Supervision of electrical works: - Modification of electrical circuits - Connection of WT to power supply box	Power engineer
3	Modification of the roof Installation of the supportive structure for the WT	Construction company
4	Electrical connection	Electrical engineer
5	Data collection and processing issues	IT specialist

2.3.5 Local citizens

Table 5. Local citizens in Choczewo

	Responsibility	Stakeholders
1	Participation in meetings	Local community
2	Participation in meetings	Local press

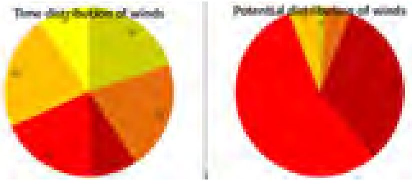
2.4 Demo Site Context

2.4.1 Climate Conditions

Choczewo is situated in a temperate warm climate zone. The region is characterized by comfortable temperatures (below 20°C) and short mild winters and summers. The average temperature on the coast in January is -1°C and in July +18°C. Annual precipitation amounts to approx. 550 mm and is concentrated in the warm half of the year (May-October). Due to its location on the Baltic Sea and in the path of low Atlantic air pressure, the whole region is is subject to atmospheric pressure and high weather variability. The coastal area has the highest wind speeds in Poland.

The prevailing wind in Choczewo is south-west turbulence intensity is 25%.

The next table (Figure 9) classifies the wind conditions among two three regimes: small winds, medium winds, and high winds. The wind characteristics of the last two regimes are detailed. 88% of the potential energy comes from the high winds regimes.



	Medium winds	High winds
Speed limit	2 to 4 m/s	above 4m/s
% of time	43%	28%
% of potential	11%	88%
Mainly during...	equal	day
Direction	E-E-N-E W-W-S-W	W-W-S-W
Turbulence	30%	25%
Mean Shear α	1.4	3.5
Up-flow angle	0°	+9°
Twist	0° to 3° /m	Variable +/- 6°/m
Turbulent Length scale	25m/50m	10m/90m Detached flow
Inst. Shear amp.	0.7σ	1.σ
Inst. Shear freq.	0.2 Hz	0.2Hz

Figure 9. Choczewo - wind resources assessment

2.4.2 Orography

The municipality of Choczewo has the Baltic Sea as its northern boundary (with a coastline of 17 km). The SWT is location a distance of circa 8km from the coast.

The mayoral building, where the SWT will be installed, is situated in the centre of Choczewo town amidst municipal, commercial and residential buildings. The west side of the pilot building is exposed to local winds with lands to this side having mainly agricultural uses.

Figure 10. Choczewo view (W – left photo, E – right photo)

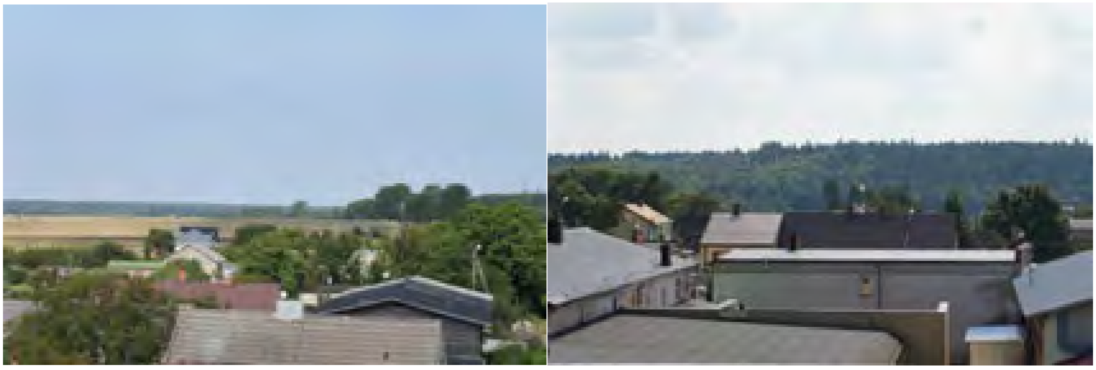


Figure 11. Choczewo view (N – left photo, S – right photo)

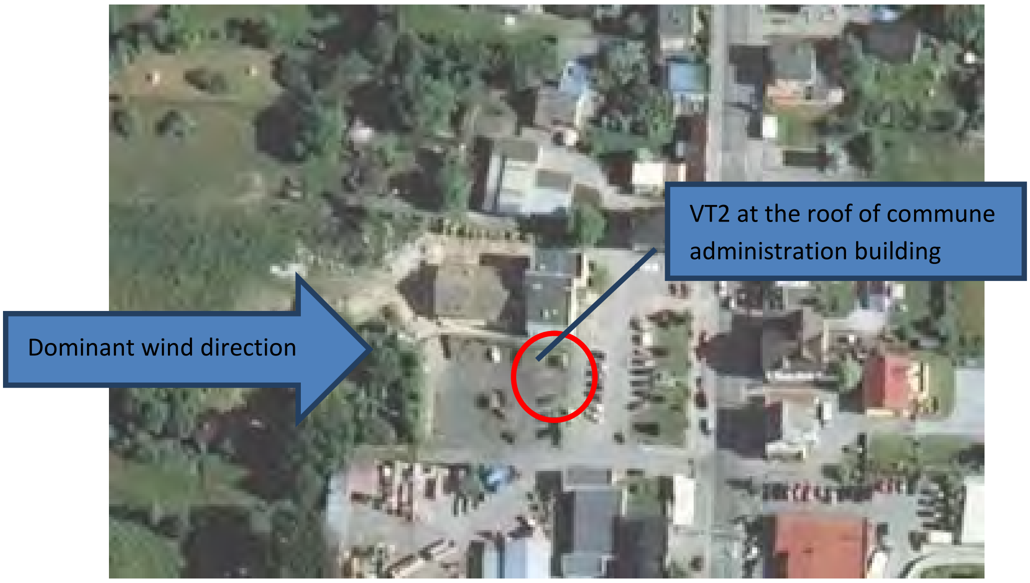


Figure 12. Pilot location in Choczewo

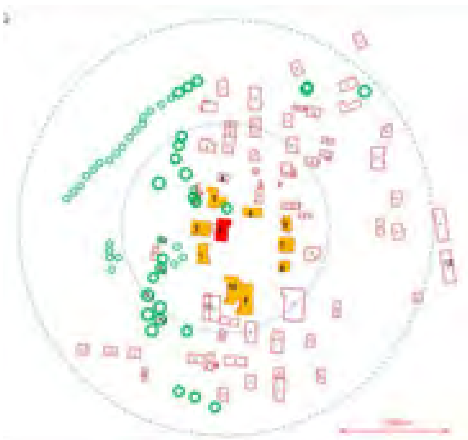


Figure 13. Orography of the pilot location in Choczewo

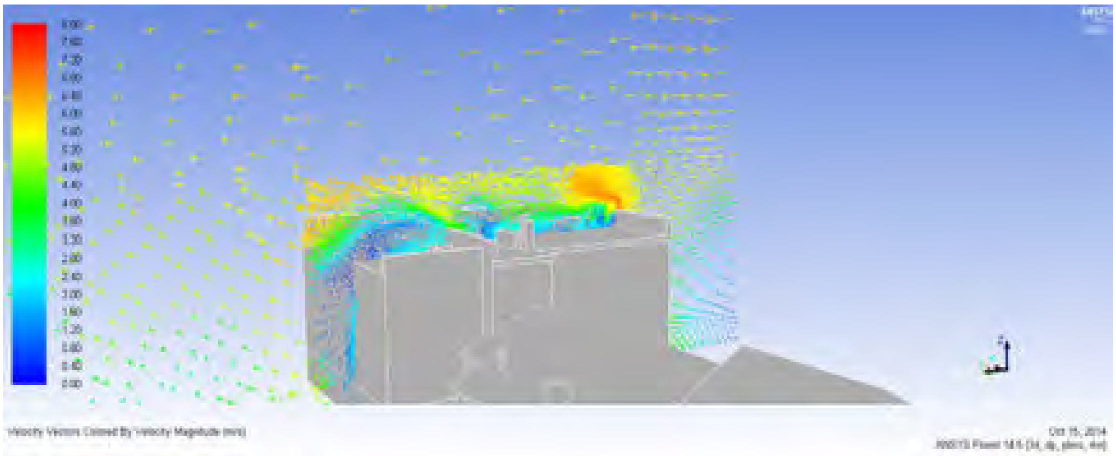


Figure 14. Choczewo - velocity vectors around the central building

2.4.3 Type of WT to be installed

The SWT be installed in Choczewo is 2 kW vertical axis wind turbine with a new design and an innovative integration approach. The competitive advantage of this wind turbine is the possibility to install it in a vertical or in a horizontal position making few changes in the supportive structure and the generator location. The total height of the WT's support structure and the WT itself will not extend more than 3.0 m above the building level (to conform to abovementioned regulations).

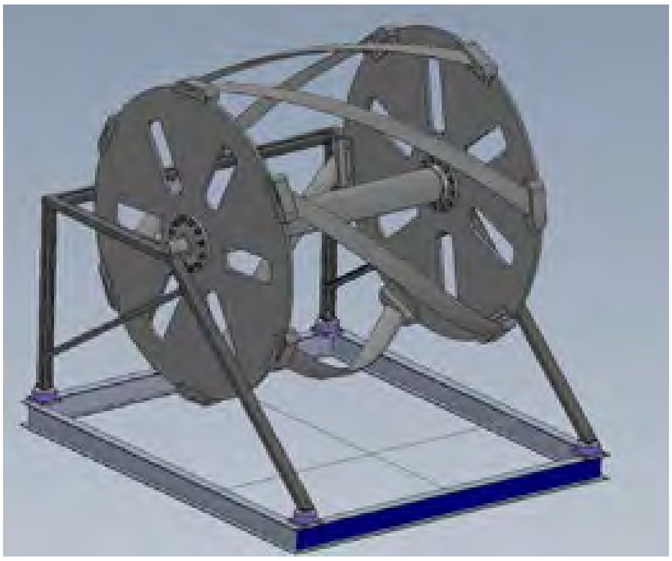


Figure 15. WT 2 kW scheme

Technical parameters of the WT:

- Installed power ; 2 kW
- Dimension of the generator (with the supporting structure) - 2,75 m x 2,45m x 2,13 m
- Max. rotation speed – 200 rpm
- Cut off wind speed – 15 m/s

2.4.4 Objectives to Be Met In the Demo Site

Each demonstration site has specific objectives depending on the type of wind turbine to be installed, the building characteristics, the surrounding area and the specific improvements being developed in the wind turbine or situation. The SWIP projects SWT demonstrations at Choczewo will represent the integration of a 2 kW vertical axis wind turbine onto a public building in the village. The aim of this pilot is to demonstrate that building integration of SWTs need not be visually negative. This is to be achieved by testing the following innovations in a real scenario:

- New vertical axis blades design.
- New costless PM generator.
- Aesthetic solutions for the integration of SWTs into urban buildings
- Noise and vibration reduction solutions and elimination of vibration transmission into the building structure.
- Wind resource assessment software validation.

2.5 Risk and mitigation plans

Installation at each demo site combines many tasks components and actors and as such carries risks of various kinds and intensities. Our aim with risk mitigation is to characterise the unknowns and hazards in such a way that can be individually reduced and managed. This will enable us assess progress on site preparation, WT installation, and performance over the monitoring period. The risks to success are identified in advance leaving room to minimize or mitigate their impact and a risk contingency plan has been developed to reduce likelihood and impact. These contingency provisions include prototyping, creating redundancy in task allocation, allowing programme and resource contingency on the project schedule and budgets etc.

The identified risks for the Choczewo pilot site are posted within next table.

Table 6. Risks contingency plans (Choczewo commune)

Risk	Risk description	Mitigation approach / Contingency plan
1	Objections of the energy company regarding the project (e.g. inverter, safety, power quality)	Project/design amendment
2	Objections of the energy company at the stage of installation acceptance	Exchange of inverter and/or metering equipment
3	Not enough (at least 3) quotes/bids for supporting structure of the WT – lack of professionals engaged in small WT installations	Carry out another tender - to collect 3 bids
4	Bad weather conditions preventing works on the roof - interference in the construction of the building (wind, rain)	Rescheduling works - good weather conditions
5	Mayors office refuses WT installation on the roof of the commune building	Negotiations with Mayor, looking for other location (either on the roof of other building or on ground location)
6	Bad weather conditions on the day of turbine installation (with crane)	Rescheduling of works
7	Non-compliance of the platform parameters with the generator frame dimensions	Adjusting both elements (drilling new holes, replacement of screws, removing construction from the roof in order to perform adjustments)

8	Lack of power supply and transfer of electricity	Checking electrical installation, removing defects
9	Objection to the notification for the WT installation by the County Authority	Delivery of additional information and documentation (delay of 2-3 months)
10	Delay in signing the agreement between the municipality and the DSO	Negotiations with DSO to speed-up the process
11	Generator failure during operational phase	Each partner responsible for the specific part development; BAPE identifies the problem, then communicates it to the partner who develop the damaged part and that partner should fix the problem
12	Local grid connection requirements are not meet	An isolate configuration for testing the WT performance under real conditions.
13	WT components could be damaged during the transportation to the demo site and or during the assembling process	The delivered time is set taking as reference the Milestones schedule stablished by the SWIP project and the time cost to manufacture and deliver a replacement for the damaged or inadequate component

3 Pilot Site 2: Zaragoza (Spain)

3.1 Elements, solutions and technologies

The SWT being deployed at Zaragoza is a horizontal axis turbine specifically designed to meet the requirements of low noise and vibration without affecting the energy yield, in comparison with commercial wind turbines, in order to get social acceptance of this technology by society and overcome the barriers this technology has.

Different technologies and solutions developed during the SWIP project will be installed and tested following, a description of each component is performed:

- New horizontal axis blade design.

These blades have been specifically designed to spin at lower speeds in order to reduce the noise level which is a crucial restriction of the small wind turbine once installed in a populated areas where meeting the comfort standards of the population is key for the acceptance and success of this technology by society. Below the sketch of the designed blade can be seen.

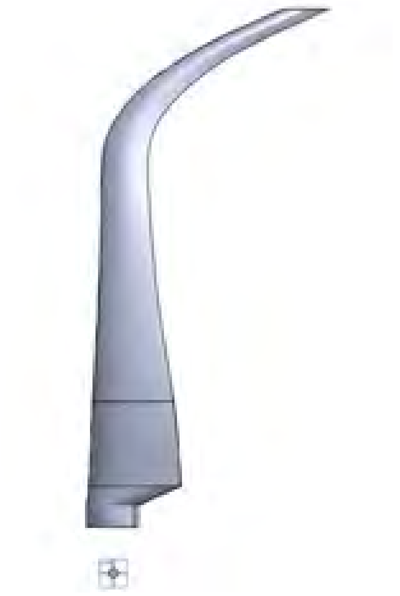


Figure 16. H4 blade

- Hub

Hub is the element used to connect the blades to the generator shaft. A novel passive pitch, which it is implemented in the hub, is developed with the aim to protect to the wind turbine against high wind speed values.

Figure 17. Hub for the 4 kW WT.

- New costless PM generator

4 kW PM generator is designed in order to maximize its efficiency and production in all wind speed range. Furthermore, the designed PM generator starts to rotate at low cutting-speed.

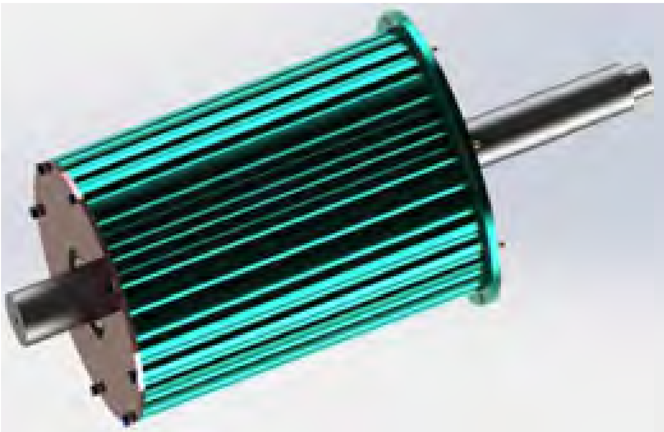


Figure 18. PM generator of the 4 kW WT

- Nacelle

The nacelle has been designed optimizing the assembly weight. This element is used to connect the blades to the yaw.

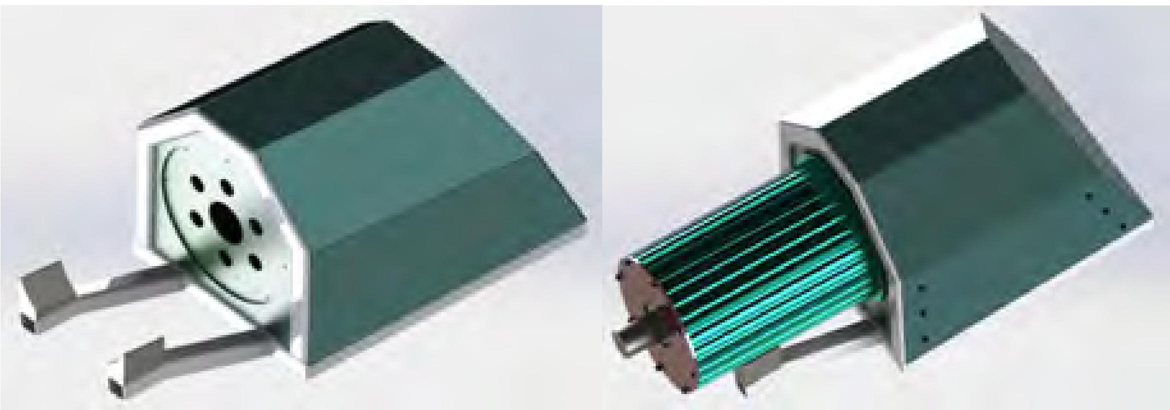


Figure 19. Nacelle for the 4kW WT

- Vane

This prototype uses a passive orientation system (vane) to adjust the orientation of the wind turbine rotor. This system is assembled in the nacelle.

Figure 20. Vane of the 4kW WT

- Slip ring

H4 small wind turbine uses a passive yaw system. In order to avoid the torsion of power and control conductors, a slip ring is needed. Slip ring provides a reliable transmission from stationary cables in the nacelle to rotating equipment in the mast.

Figure 21. Slip ring of the 4 kW WT

- Wind turbine supporting structure

The turbine structure is composed by the supportive structure itself which is joined to the mast through a bolted flange. This system has been selected due to the particular conditions of the CIRCE´s building (no flat roofs, grass-covered roofs, load bearing walls without intermediate waffle slabs). The supporting structure goes from the foundation slab to the roof, and is then bolted to the mast of the wind turbine. For replication purposes, only the mast of the wind turbine would be part of the WT.

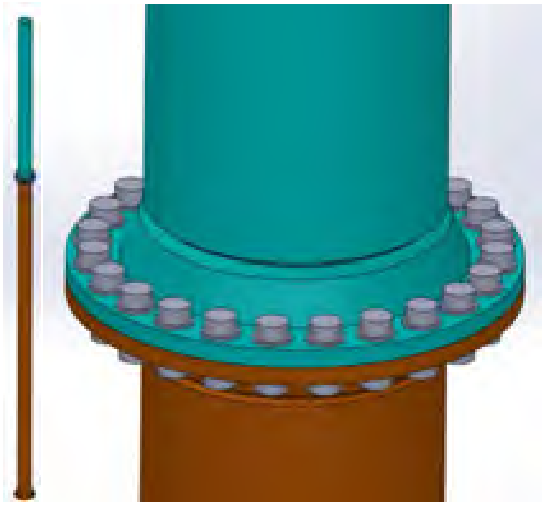


Figure 22. Wind turbine supportive structure.

- Aesthetic solutions for the integration of SWTs into urban buildings

Figure 23. Sketch of the wind turbine and CIRCE´s building

- SCADA system

The SCADA system aims not only to be used as a monitor system of the SWIP small wind turbines (SWT) but also to reduce their maintenance costs. If a proper preventive maintenance is performed, those costs can be lowered. Thus, the SCADA system monitors the SWT power performance in order to detect any deviations from the standard behaviour. Whenever a persistent power deviation is detected, the SCADA system will send an e-mail to the SWT owner informing about the issue. Therefore, any events producing losses in power generation will be detected almost immediately. As a result, a better preventive maintenance can be performed.

Several meteorological signals and also the active power must be measured to calculate the SWT power performance. Hence, the SCADA system needs to obtain data from the meteorological mast and from the converter. The converter has its own sensors to measure different parameters and to obtain a feedback regarding its performance. Thus, the SCADA system takes advantage of these measurements communicating with the converter via Modbus and reading all the measured parameters. Additionally, a self-made data-logger acquires all meteorological data and sends

them to the SCADA using also Modbus. These data allow calculating the SWT power performance and checking for any deviations.

The SCADA system not only calculates the SWT power performance, but also records several signals from the power electronic of the SWT and the meteorological mast. So it is possible to monitor each parameter and to study its behaviour. The SCADA system has an "alarm daemon" which produces a warning when some signal reaches values beyond fixed thresholds. These thresholds are defined using the historical behaviour of the corresponding signals.

Table 1 lists the available signals in different SCADA models.

Table 7. List of signals

Signal	Definition	H4
Vs_R	Converter Output Voltage Phase R	✓
Vs_S	Converter Output Voltage Phase S	✓
Vs_T	Converter Output Voltage Phase T	✓
Is_R	Converter Output Current Phase R	✓
Is_S	Converter Output Current Phase S	✓
Is_T	Converter Output Current Phase T	✓
Idc	DC Bus Current	✓
Vdc	DC Bus Voltage	✓
Ich	Converter Chopper Current	×
Vsg_R	Generator Output Voltage Phase R	×
Vsg_S	Generator Output Voltage Phase S	×
Vsg_T	Generator Output Voltage Phase T	×
Isg_R	Generator Output Current Phase R	×
Isg_S	Generator Output Current Phase S	×
Isg_T	Generator Output Current Phase T	×
P	Active Power	✓
Q	Reactive Power	✓
S	Apparent Power	✓
E	Energy	✓
F	Frequency	×
Ech	Chopper Energy	×
PF	Power Factor	✓
THD	Total Harmonic Distortion	✓
W1	Rotation Frequency of Turbine	✓
W2	Rotation Frequency Multiplier	×
Vx	Vibration in the x-axis	×
Vy	Vibrations in the y-axis	×
Vz	Vibrations in the z-axis	×
Tg	Generator Temperature	✓
Tc	Converter Temperature	×
Ws	Nacelle Wind Speed	×
Pc	Active Power Consign	✓
Qc	Reactive Power Consign	✓
Ds	Slow Disconnection Signal	✓
De	Emergency Disconnection Signal	✓
Ready	The wind turbine is ready	✓
Working	The wind turbine is working	✓

In H4 demo site, the SCADA system uses a wired network because of the SWT is near to the building. The SCADA system has three different electronic devices. All of them are plug-and-play, so the installation is very simple.

The human interface is web-based, so it is possible to connect to the interface using mobile devices, as smartphones and tablets, and also laptops and desktop computers. Online charts, historical trends and several setting can be managed and viewed using the interface. Obviously, the access is restricted by a login screen prompting for username and password, so only allowed people can have access to the interface.

3.2 Schedule for the installation

3.2.1 Pre-Construction

3.2.1.1 Building permit

In order to get the required building permits, the procedure to get all permits is the following:

- To develop the project of the installation of the WT according to the national standards for project endorsement.
- Project endorsement by the competent body ("Colegio oficial de Ingenieros Técnicos de Aragón")
- Due to the building where the demonstrator will be placed is a building within the University of Zaragoza campus, permits from the University is required. An official authorisation from the Rector´s office has been obtained.
- Finally and in order to have the final permits from the city council, an authorisation from the city council has been requested.
- In addition, the consumption installation must be registered within the Self-consumption Administrative Registry and generation installation must be registered within its corresponding Power Generation Registry.

3.2.1.2 Notification to the power distributor

Any connection of self-generation to the grid has to be filed to the DSO in a form of a formal notification. This should contain information on the end user, descriptions of the RES's receiving structure and technical details of the installation (including declaration of compliance in terms of fulfilling current standards for low voltage installations and electromagnetic compatibility as well as schematic diagrams of micro-source connection to the receiving installation, all executed by the installer).

The owner of the installation must cover the regular fees for the regular power consumption as well as those fees associated to system costs and charges to other system services (fees for self-power consumption).

3.2.1.3 Subcontract Installation Company

Within the SWIP consortium there is no partner with the technical skills to perform the construction and installation works, doing so, there is a need to subcontract this works. This service will consist on the civil works related to the shallow foundation and roof conditioning, as well as the installation of the wind turbine supportive structure and the wind turbine itself.

3.2.1.4 Land for use

As CIRCE is not the owner of the building, land for use document has to be signed by the both parties.

3.2.2 Transportation

In order to optimize costs of transportation of the different elements of the WT and the structure to the pilot site, it is intended to select those providers as closer as possible to the pilot site (if they meet the technical and economic requirements). That way, the objective is to build the following structures:

- Supporting structure.
- Blades; to be built in Lithuania. Partner PPL is in charge of the manufacturing.
- SCADA system; is built in Zaragoza by CIRCE
- Hub and yaw system; to be built in Zaragoza
- Vane; to be built in Zaragoza
- Generator and power train; to be built in Zaragoza by CIRCE.
- Converters; to be built in Zaragoza by CIRCE.

3.2.3 Co-ordination and supervision of assembly, civil works and installation.

CIRCE as pilot coordinator at the H4 pilot is in charge of supervising and coordinating all activities related to the demonstration, which are:

- To ensure the proper manufacturing of those parts of the WT. CIRCE is responsible for designing and coordinating manufacture.
- To ensure the proper transportation of the different elements (those which are manufactured/procured by CIRCE and those from other partners) to the demo-site.
- To plan the assembly of the WT
- To supervise and coordinate the civil works.
- To supervise the assembly of the WT by the installation company.
- To supervise the installation of the supporting structure, the wind turbine and the power connection by the installation company.
- To perform the commissioning of the WT.

3.2.4 Gantt Chart

See “Annex I.II Gantt Chart for Pilot 2 in Zaragoza”.

3.3 Stakeholders involved

For each pilot the stakeholder mix is different. At Zaragoza, the stakeholders associated with the project and the partners or entity with responsibility for liaising with them are set out below.

3.3.1 Defined responsibilities

Table 8. Responsibilities of the project partners for the 4WT

	Responsibility	Partners and stakeholders
1	Horizontal axis blades design	PPL, SOLUTE
2	PM generator and converter design and electrical installation	CIRCE
3	Vane, mast, hub and yaw design	SOLUTE
4	Expertise on the building construction in Zaragoza	CIRCE
5	Transport of the WT elements to the pilot site	PPL, CIRCE, SOLUTE, USFD
6	WT installation	CIRCE
7	WT connection to the electrical installation	CIRCE
8	Noise and vibration mitigation solutions	KTH
9	Wind resource software validation	METEODYN
10	Co-ordination and supervision	CIRCE

3.3.2 Project partners

Table 9. Project partners involved in the development of the 4WT

	Responsibility	Partners
1	SCADA system	CIRCE
2	Construction of the PM prototype and testing, converter design, converter and PCB assembling and testing	CIRCE
3	Wind assessment	METEODYN
4	Blades design and manufacturing	PPL, SOLUTE
5	Vane, mast, hub and yaw design	SOLUTE
6	Structure and foundation design	SOLUTE,CIRCE
7	Noise assessment	KTH
8	Tests of the scaled blades model	USFD

3.3.3 External stakeholders

Table 10. External stakeholders in Zaragoza

	Responsibility	Stakeholders
1	Consent to install the WT	University of Zaragoza
2	Consent to install the WT	Zaragoza City Hall

3.3.4 Facilitating stakeholders

At Zaragoza, the facilitation duties will be organised as illustrated in the table below.

Table 11. Facilitating stakeholders in Zaragoza

	Responsibility	Stakeholders
1	Preparation of the project for project endorsement	Civil engineers
2	Modification of the roof and construction of the shallow foundation Installation of the supportive structure and the WT	Construction company
3	Manufacturing yaw, system, hub, structure, vane	Manufacturing companies

3.3.5 Local citizens

Table 12. Local citizens in Zaragoza

	Responsibility	Stakeholders
1	Participation in meetings	Local community
2	Participation in meetings	Local press

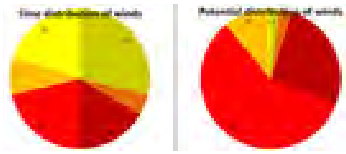
3.4 Demo Site Context

3.4.1 Climate conditions

Zaragoza is situated in the dry warm climate zone, in a windy valley. The temperatures stay between 2°C and 32°C, with a mean precipitation level of 26mm/month. The prevailing wind in Zaragoza is west and turbulence intensity is 23%.

The next table classifies the wind conditions among two three regimes: small winds, east winds, and west winds. The wind characteristics of the last two regimes are detailed. 84% of the potential energy comes from the west winds regime.

Figure 24. Wind rose in Zaragoza pilot site



	east winds	west winds
Speed limit	Above 3 m/s	Above 3m/s
% of time	14%	38%
% of potential	13%	84%
Mainly during…	day	day
Direction	E-E-S-E	W-W-N-W
Turbulence	23%	23%
Mean Shear α	5.0	0.8
Up-flow angle	+0.3°	+0.6°
Twist	0°	+2.5 °/m
Turbulent Length scale	25m/130m Detached flow	75m/100m
Inst. Shear amp.	0.6σ	0.3σ
Inst. Shear freq.	0.1 Hz	0.3Hz

Figure 25. Zaragoza - wind resources assessment

3.4.2 Orography

The region is quite flat even if Zaragoza is located in the confluent of two valleys (Ebro and Gállego).


Figure 26. Zaragoza surrounding

Figure 27. Zaragoza – top view

Figure 28. Zaragoza – top view

Figure 29. Zaragoza – CIRCE's building

3.4.3 Type of WT to be installed

Figure 30. Render of the Wind turbine and CIRCE´s building

3.4.4 Objectives to meet in the Demo site

As referenced above the SWIP is attempting to develop new design and approaches to address the various obstacles that have challenged SWT uptake across Europe. Each pilot site represents a particular blend of individual challenges and conditions which in combination across all 3 pilots show the improvement potential that exists.

Thus each demo site has specific challenges to be met, these objectives depend on the type of turbine being installed, the particularities of receiving structure/ and context and the individual objectives set out in the DoW for each site. The demonstration pilot at Zaragoza is a representative of small horizontal turbines. It will be a 3-4 kW horizontal axis wind turbine and is to be hosted in a zero emissions building in an area of a university campus. The aim of this demonstration was to show a designed approach to the integration of SWT and within a building architecture and, as with other pilots improve the reception of SWTs so as increase SWT uptake potential. More specifically it will trial and monitor how the following technical approaches perform in real world conditions:

- New horizontal axis blades design
- New costless PM generator
- Aesthetic solutions for the integration of SWTs into urban buildings
- Noise and vibration reduction solutions / elimination of vibration transmission to host building structure.
- Integration of SCADA system and control when integrated into buildings
- Wind resource assessment software validation

3.5 Risk and mitigation plans

As discussed above risk management at pilots includes bespoke risks identification and development of a risk contingency plan particular to the demonstration site and its objectives. The specific risks we have identified for the for the Zaragoza pilot site are described in the following table.

Table 13. Risks contingency plans (Zaragoza)

Risk	Risk description	Mitigation approach / Contingency plan
1	Loads induced by the WT tower exceed building structure strength or do not meet enough safety factor to satisfy standards	A complementary structural elements designs for loading distribution is prepared to be introduced to the original design. This complementary design is thought to use the lateral wall structure to support a fraction of the total load
2	Foundation design modifications	The project responsible will act as intermediate to ensure a fluid communication. A general meeting with the technical team involved of the progress will be complete at the half period of the task to review and evaluate existing problems and quality of the solution
3	Local grid connection requirements are not meet	An isolate configuration for testing the WT performance under real conditions.
4	Building and installation permission	To advance the subcontracting company hiring process in order to start the works once all permits are received
5	WT components could be damaged during the transportation to the demo site and or during the assembling process	The delivered time is set taking as reference the Milestones schedule stablished by the SWIP project and the time cost to manufacture and deliver a replacement for the damaged or inadequate component
6	Problems that may arise due to an unexpected error in the components fitting due to misunderstanding between partners	To redesign and modify the inadequate component, to do so, demo site responsible owns a number of laboratories and machining centres where the modifications can be done with minimal impact to the time schedule and budget of the project

4 Pilot site 3: Kokoszki District (Poland)

4.1 Elements, solutions and technologies

The Kokoszki pilot (H20) is a large horizontal shaft generator on it own free standing mast within an industrial area in northern Poland. It is a 20 kW installation.

- Horizontal axis blades design

The blades were designed from scratch specifically for this wind turbine. The blade consists of three pieces that are joined. The blade will be created from two sides and the centre. The sides will form the shape and the centre will support the sides. One side will be laminated from 26 layers and the centre 53 layers. Special epoxy resin will be used for lamination. 3 blades will use for this demo site.

Blade length: 3,65 meters

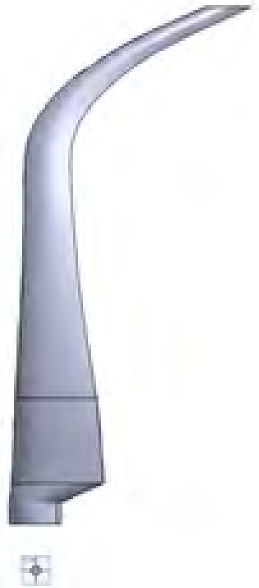


Figure 31. H20 blade sketch

- Hub

The hub is made by 7 steel plates of 20mm of thickness and a 20mm steel frame to prevent bending. The back plate will be connected to the shaft by a bolted joint. The material used for these plates is S355JR steel. The plates are joined by a welding joint.

Figure 32. H20 hub sketch

- Yaw system

The yaw system is composed by the next parts: a tower connection flange, an exterior housing, a friction plate, a connection to the nacelle and an inner disc. This system will allow the wind turbine to locate the rotor against the wind direction as soon as it receives the order to change the position.

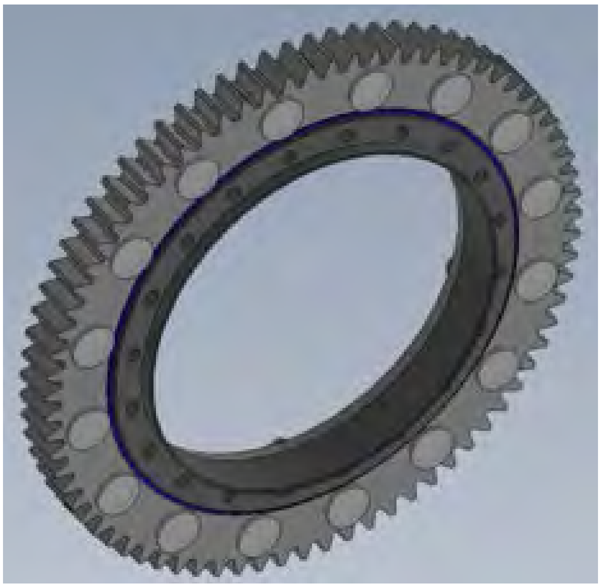


Figure 33. Schematic of the yaw system for the H20 wind turbine

- Generator

The 20 kW generator for Kokozski demo is a permanent magnet generator specifically designed to operate optimally when coupled to the converter and blades developed within SWIP project. The

generator axle is coupled to the gearbox at one side by means of a key and flexible coupling, and to the speed sensor at the opposite axle side.

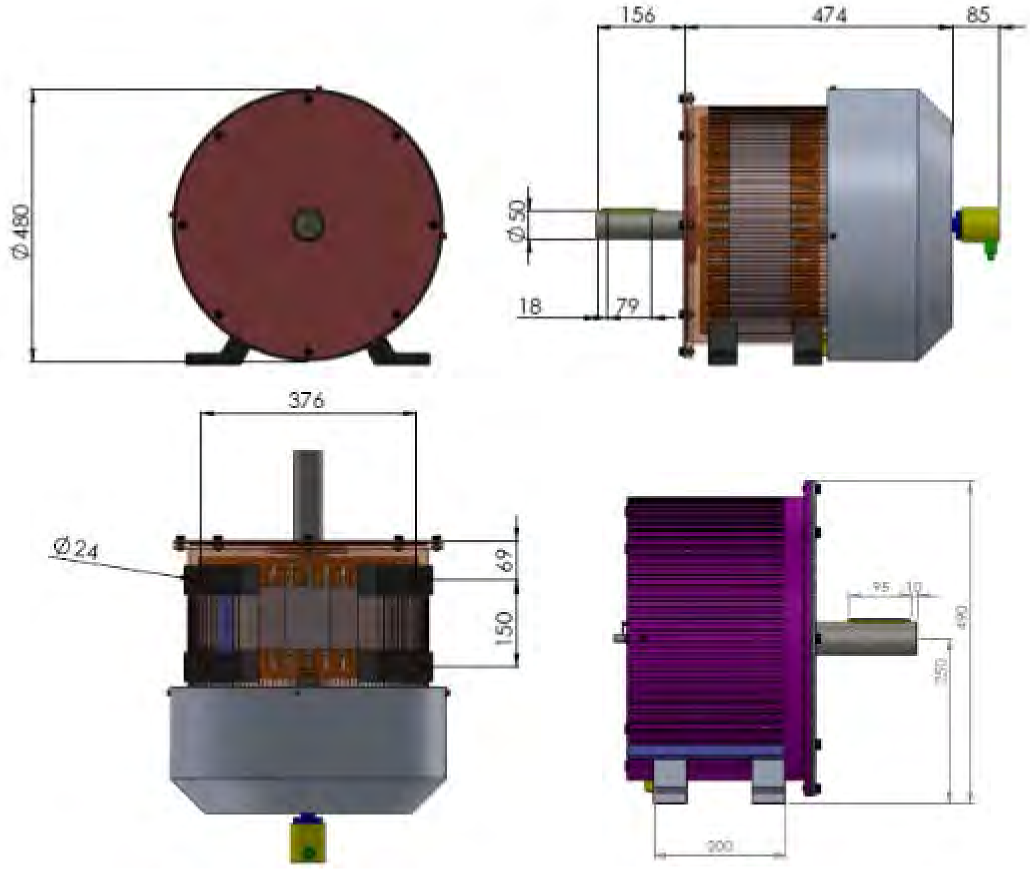


Figure 34. 20 kW generator dimensions.

The generator has been designed to output the 20 kW when rotating at 480 rpm, and to be as light and compact as possible. Despite of the superior efficiency of the generator when compared to similar commercial products, the compactness level achieved reduces the self-cooling capabilities of the generator, thus a forced ventilation system has been designed allowing helping in the generator heat dissipation. This ventilation system is removable, and will be installed depending on the heat dissipation capabilities of the nacelle cover.

The mounting of the 20 kW generator is B3 type, as it stands in 4 legs which shall be bolted to the nacelle structure, outer dimensions are 930 x480x490 mm (LxWxH) and it weights approximately 125 kg. The connection to the converter cabinet or both signal and power cables will be performed through wiring with adequate characteristics.

- Mast and anchorages

A free-standing, 15 m high, steel mast with a steel frame was designed as the support for the WT at Kokoszki. The mast will be mounted on a reinforced concrete foundation.

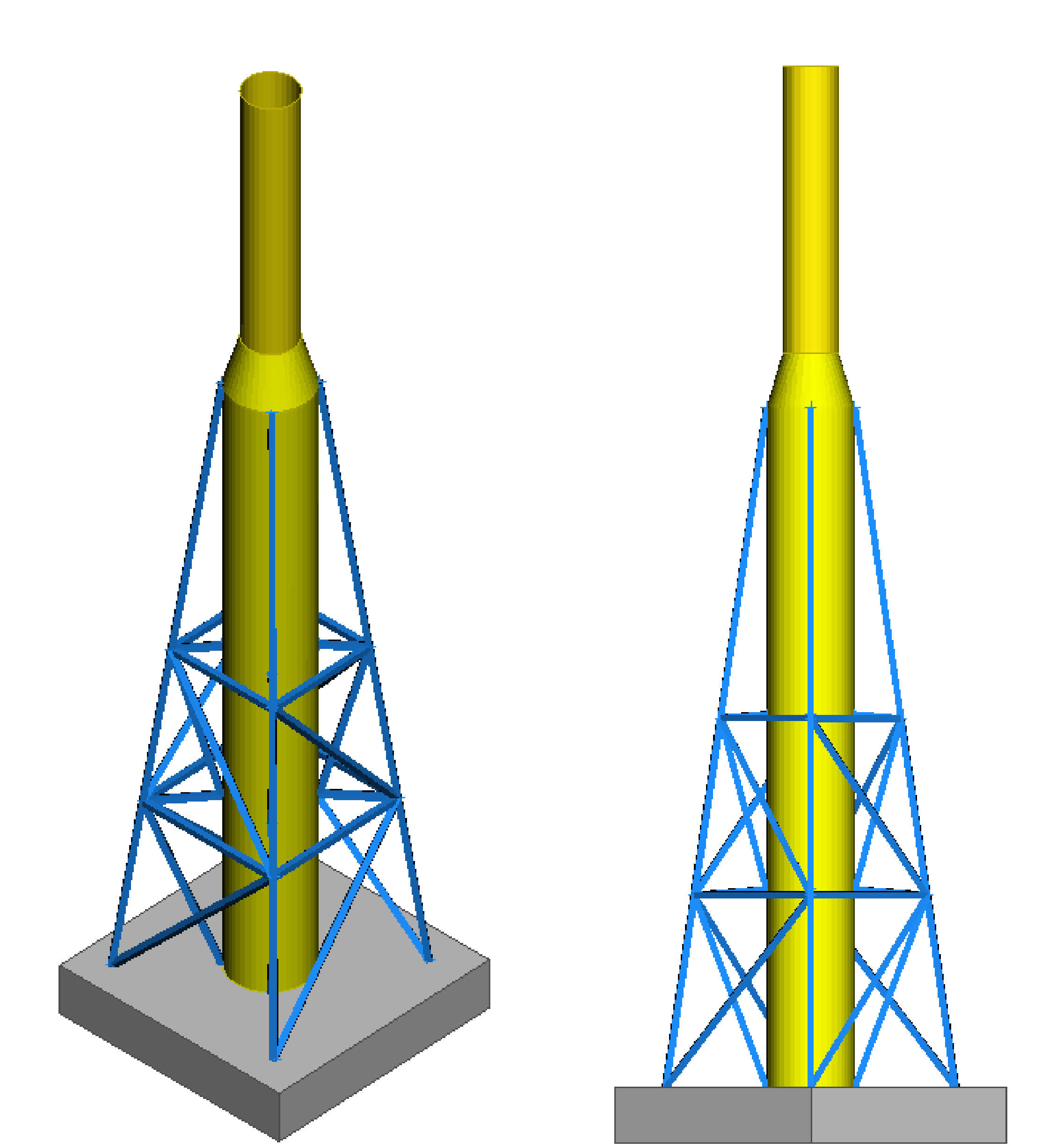


Figure 35. Mast for the WT structure

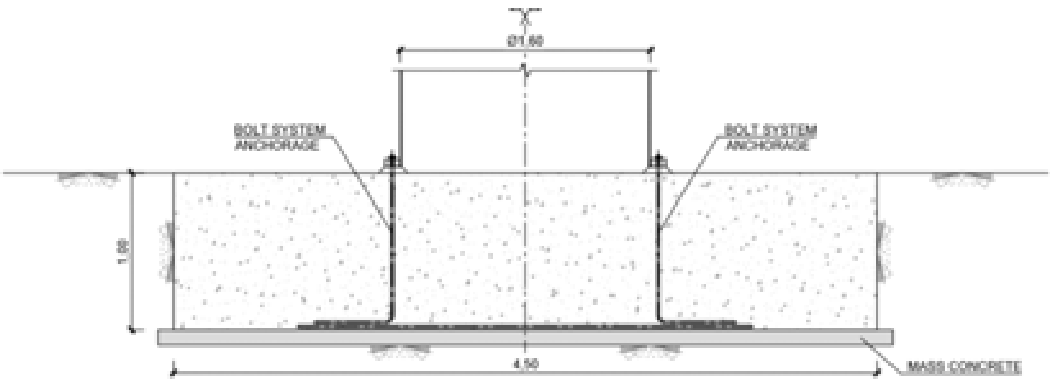


Figure 36. Foundations for the H20 WT

- Nacelle

The nacelle is composed by the drive train components (rotor axis, bearings, generator, mechanical break, gearbox) the yaw system, a supportive structure where all the components are fixed and the frame to protect the components from external weather conditions.

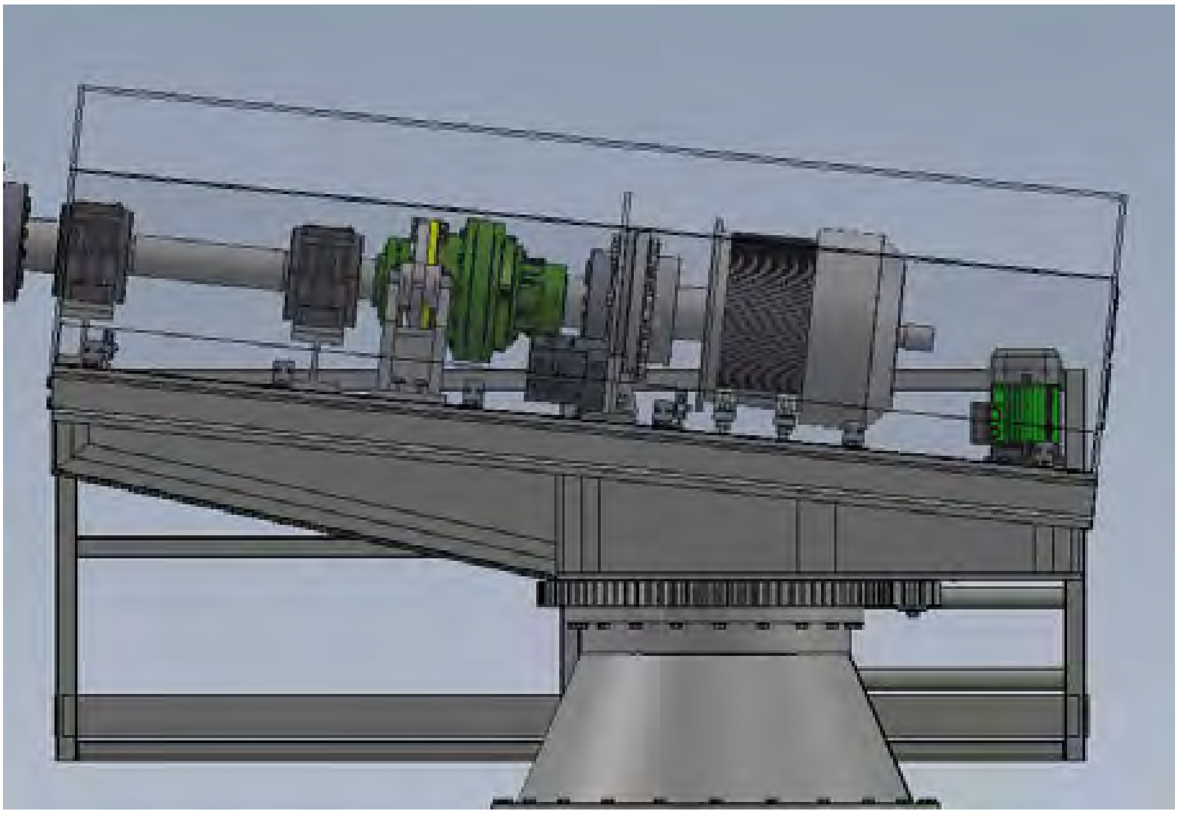


Figure 37. Nacelle of the H20 WT

- Nacelle cover

The nacelle cover will be manufactured from two parts: bottom and top. The bottom will be made from metal, it will support the weight of all components of the wind turbine and the yaw system. The top will be made from fiberglass, the main purpose will be to protect the inside components from the weather.

The top part for nacelle cover will be made from resin with higher mechanical and physical properties, as the cover will not have steel structure to support and not to deform from the weather and heat. Also the cover will have two ventilation ports from each end to reduce heat inside.

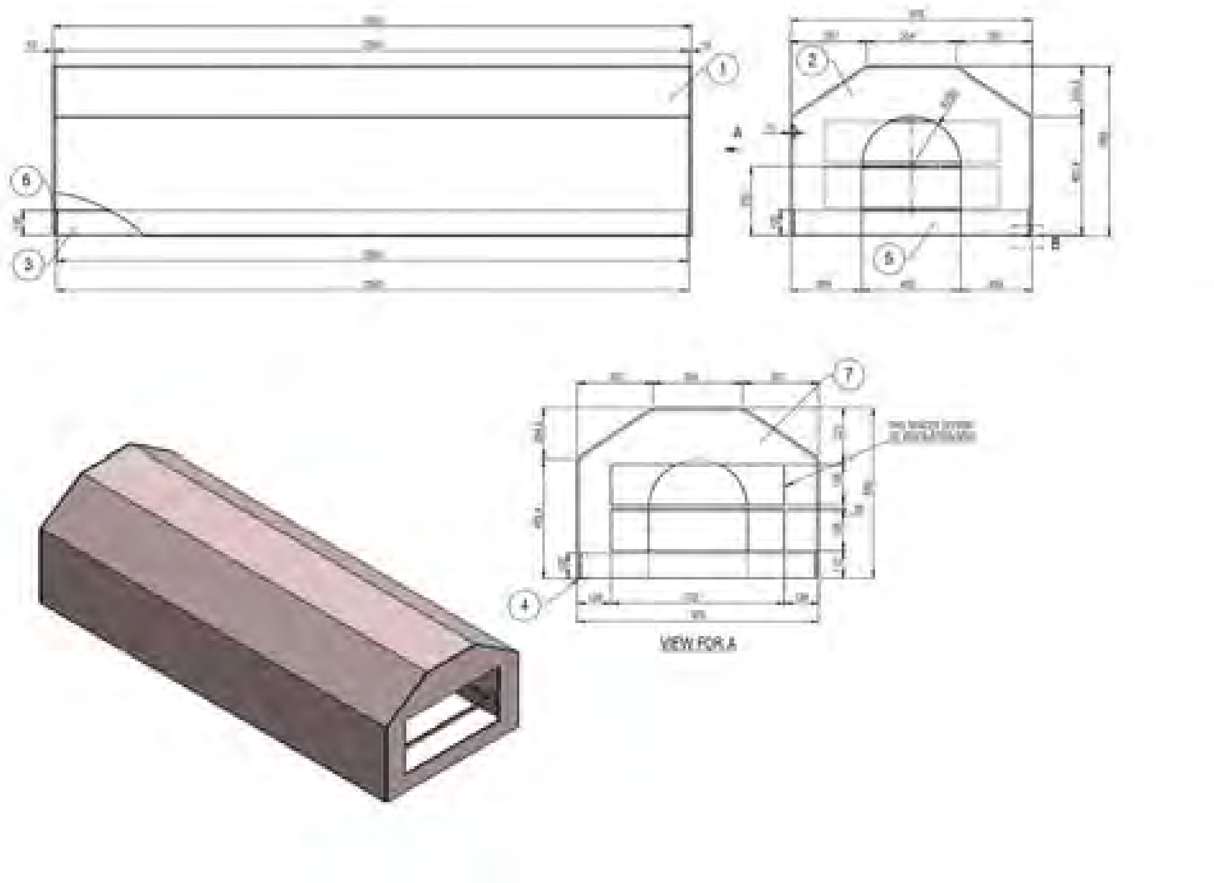


Figure 38. Nacelle cover of the H20 WT

Material: GRP
Theoretical weight: ~169 kg

- SCADA

At the Kokoszki pilot, the objective of the SCADA system is not only to monitor the turbines but also to reduce their maintenance costs. If a proper preventive maintenance is performed, those costs can be lowered. Thus, the SCADA system monitors the SWT power performance in order to detect any deviations from the standard behaviour. Whenever a persistent power deviation is detected, the SCADA system will send an e-mail to the SWT owner informing about the issue. Therefore, any events which lead to losses in power generation will be detected almost immediately which will result in improved preventive maintenance regime.

To calculate the SWTs power performance, both meteorological data and power output must be measured. The SCADA system thus needs to acquire data from the both the meteorological mast and from the SWT installations converter. The converter has its own sensors to measure different parameters and to obtain a feedback regarding its performance. Thus, the SCADA system can capture these measurements (communicating with the converter via Modbus) and read the various measured parameters as required. Additionally, a self-made data-logger acquires all meteorological data and sends them to the SCADA using also Modbus. These data allow calculating the SWT power performance and checking for any deviations.

The SCADA system not only calculates the SWT power performance, but also records several signals from the SWTs power system electronics and the meteorological mast. To enable it to monitor each parameter and to study its behaviour, the SCADA system feature has an "alarm daemon" which produces a warning when certain performance parameters reach values above given thresholds. These thresholds are defined based on analysis of the historical behaviour of the performance.

The matrix below lists the performance parameters different SCADA systems can monitor.

Table 14. List of signals

Signal	Definition	H20
Vs_R	Converter Output Voltage Phase R	✓
Vs_S	Converter Output Voltage Phase S	✓
Vs_T	Converter Output Voltage Phase T	✓
Is_R	Converter Output Current Phase R	✓
Is_S	Converter Output Current Phase S	✓
Is_T	Converter Output Current Phase T	✓
Idc	DC Bus Current	✓
Vdc	DC Bus Voltage	✓
Ich	Converter Chopper Current	✓
Vsg_R	Generator Output Voltage Phase R	✓
Vsg_S	Generator Output Voltage Phase S	✓
Vsg_T	Generator Output Voltage Phase T	✓
Isg_R	Generator Output Current Phase R	✓
Isg_S	Generator Output Current Phase S	✓
Isg_T	Generator Output Current Phase T	✓
P	Active Power	✓
Q	Reactive Power	✓
S	Apparent Power	✓
E	Energy	✓
F	Frequency	✓
Ech	Chopper Energy	✓
PF	Power Factor	✓
THD	Total Harmonic Distortion	✓
W1	Rotation Frequency of Turbine	✓
W2	Rotation Frequency Multiplier	✓
Vx	Vibration in the x-axis	✓
Vy	Vibrations in the y-axis	✓
Vz	Vibrations in the z-axis	✓
Tg	Generator Temperature	✓
Tc	Converter Temperature	✓
Ws	Nacelle Wind Speed	✓
Pc	Active Power Consign	✓
Qc	Reactive Power Consign	✓
Ds	Slow Disconnection Signal	✓
De	Emergency Disconnection Signal	✓
Ready	The wind turbine is ready	×
Working	The wind turbine is working	×

In the H20 demo, the SCADA implement the Modbus protocol using a wireless system. The SCADA system has three different electronic devices. All of them are plug-and-play, ensuring a highly versatile and usable operation.

The SCADA human interface is web-based, so operation from a distance using mobile devices e.g. smartphones, tablets, laptops and desktop computers is possible. Online charts showing current and historical outputs along with other settings can be managed and viewed online using the interface. Security is maintained by restricting access with login screens, username and password systems so registered persons can have access to data.

Figure 39. SCADA core

- Converter

The 20 kW converter for Kokoszki has been developed using two inverters in back to back topology, being installed inside a protective cabinet with dimensions 800x1200x400 mm (WxHxL). The cabinet has a 3P+N+G 32 A male connector for coupling to the grid, and direct coupling to cabinet terminals inside the cabinet for the generator, and comprises power supplies, safety measures, signal acquisition and control boards to manage the power stage of the converter, including connection and disconnection to the grid.

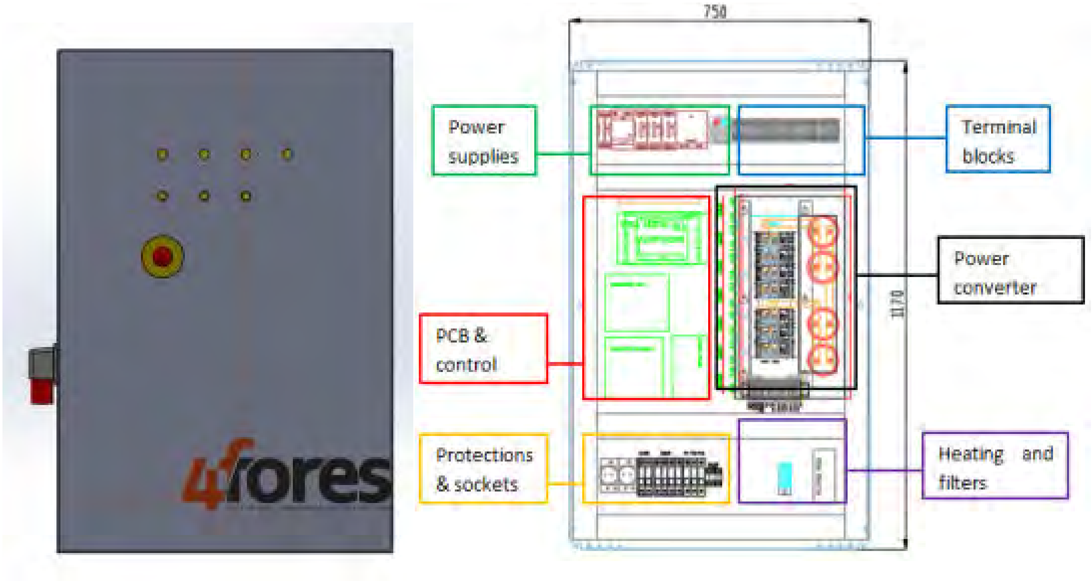


Figure 40. 20 kW converter.

During operation, the converter monitors grid voltage and frequency levels to make sure grid conditions are within tolerable ranges according to "Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators". In case either the grid levels are outside tolerable ranges or no grid is detected, the power flow into the grid is be stopped and disabled, and the converter is be electrically isolated from the grid by actuation of a contactor installed between grid and power converter. Power flow between grid and converter is enabled again after it is made sure the grid voltage and/or frequency are within the adequate levels, being the converter reconnected to the active grid to deliver power only when wind is available.

The cabinet is locked with a key lock, and is operated through three pushbuttons in the front panel; the current status of the converter and SWT is shown by 4 light pilots in the front panel of the converter. In case of emergency, an emergency stop can be manually triggered operating the emergency pushbutton in the front of the cabinet.

The cabinet must remain at all times tight to a firm solid body, either ground or tower (preferred), by means of adequate supporting/anchorage equipment.

- Pitch system

The pitch is an autonomous system that takes advantage of high speed winds to rotate each blade by its longitudinal axis and change the profile that faces the wind to reduce its rotation speed. This will allow to maintain control on the rotation and also to reach maximum production for low speed wind.

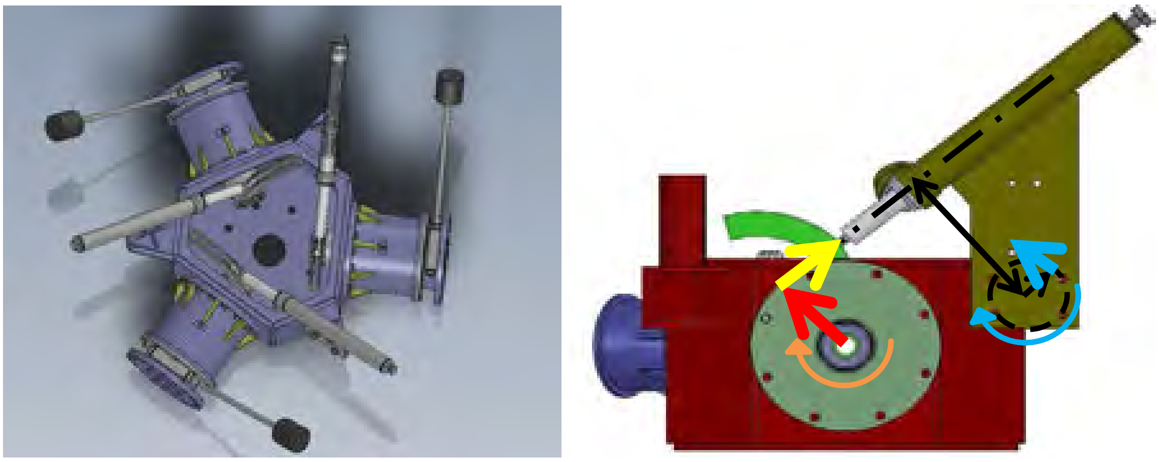


Figure 41. 20 kW pitch system

4.2 Schedule for the installation

4.2.1 Pre-Construction

4.2.1.1 Building permit

In comparison to the first pilot, also in Poland the installation on wind energy devices on ground such as K20 at Kokoszki does requires a building permit. The procedure to apply for a building permit is as follows:

1. Submit four copies of all construction documents for the project, including the certificates, calculations, agreements, permits and any other documents required by specific provision as well as the credentials of the designer;
2. Evidence of title holders permission to install on the property.
3. Documentation showing conformity with the Conditions for Construction and Land Development, the regulations on spatial planning and development under Kokoszki local spatial development plan (if required). The Authority then has 65 days to issue a building permit.

4.2.1.2 Notification to the power distributor

As at Choczewo a permission to connect distributed energy generators of less than RES ≤ 40 kW to the grid such as at Kokoszki is notified in advance to the DSO. The notification comprises information on the end user, receiving structure, installation technical details, compliance declarations (for technical compatibility) and schematics of the proposed connection to the host installation. The energy company must be notified at least 30 days before the anticipated start of operation of the micro-installation.

A grid connection agreement (with the DSO) is to be created and the required safety and measuring systems will be installed by the utility company clearing the way for grid connection and energy export. A sales agreement must also be created.

Give the size (i.e. RES ≤ 40 kW), a license in order to generate electricity is not required at Kokoszki either.

4.2.1.3 Land for use

As BAPE, the pilot coordinator for the SWIP project is not the owner of the land where installation is to occur, the legal permission to use the land (lease) land will be signed by both parties (BAPE/ SWIP and the owner.

4.2.2 Transport

As at other pilots, attempts are being made to transport and install the SWT components in as economic way as possible. This is being pursued through competitive quotes from local sub-contractors. At Kokoszki this exercise comprises the following procurement:

- The blades will be manufactured by PPL and will be shipped to Poland
- Platform (Generator, shafts, gearbox, etc). All the items that are supported by the platform will be manufactured (or purchased) in Spain by FORES and shipped to Poland
- Tower (SOLUTE) will look for manufacturing companies in Spain and Poland. The final location will depend mainly on the price.
- Hub (SOLUTE) will look for manufacturing companies in Spain and Poland. The final location will depend mainly on the price.
- Pitch system (PPL) will look for manufacturing companies in Lithuania and Poland
- Yaw system; to be built in Zaragoza and shipped to Poland
- Cover of the nacelle (PPL) will manufacture ship it to Poland
- SCADA (CIRCE) manufactured and will be sent to its facilities in Spain or directly to Poland.
- Converter; to be built in Zaragoza by FORES.
- Basket (for maintenance purposes in the nacelle) will be manufactures in Poland

4.2.3 Co-ordination of assembling and supervision of the civil and installation works

BAPE as the demo pilot coordinator at Kokoszki is charged with supervising and coordinating all activities related to installation at the demo site. These comprise:

- Ensuring the proposals and designs conform to polish requirements.
- Ensuring the proper transportation of all elements (including those from other partners) to the demo-site.
- Planning the assembly of the WT
- Supervising the assembly of the WT by the installation company.
- Supervising and coordinating the civil works.
- Supervising the installation of the supporting structure, the wind turbine and the power connection (by the installation company).
- Commissioning of the WT.

4.2.4 Gantt Chart

See “Annex I.III Gantt Chart for Pilot 2 in Kokoszki”.

4.3 Stakeholders involved

4.3.1 Defined responsibilities

There are a range of stakeholders that have an interest in the Kokoszki pilot. The table below lists them under various groupings and sets out how liaison with them will be achieved, and by whom.

Table 15. Responsibilities of the project partners for the 20WT

	Responsibility	Partners and stakeholders
1	horizontal axis blades design	PPL
2	PM generator and converter design, and electrical installation, SWT control system, WT certification and safety system	FORES
3	Foundation, tower and anchorages, hub	
4	Selection of the site for the WT	BAPE
5	Re-design (adaptation of the construction design) to Polish regulations	BAPE
6	Power connection design based on Polish regulations	BAPE
7	Applying for the power connection	BAPE
8	Applying for the building permission	BAPE
9	Transport of the WT elements to the pilot site	PPL, FORES, SOLUTE, USFD
10	Construction of the WT foundation, assembling of the WT (tower, platform, generator, nacelle,)	BAPE, FORES
11	WT connection to the electrical installation	BAPE
12	Noise and vibration mitigation solutions	KTH
13	Wind resource software validation	METEODYN
14	Co-ordination and supervision	BAPE, FORES
15	IT installation	CIRCE
16	WT certification	FORES

Parties involved (SOLUTE, FORES, PPL) will prepare a document explaining how the different part of the wind turbine match each other. This document will be delivered to BAPE.

SOLUTE and FORES will assist during assembly process.

4.3.2 Project partners

Table 16. Project partners involved in the development of the 20WT

	Responsibility	Partners
1	SCADA	CIRCE
2	Construction of the PM prototype and testing, converter design, converter and PCB assembling and testing	FORES
3		METEODYN
4	Blades design and manufacturing	SOLUTE (design), PPL (manufactured)
5	Platform and anchorages design, hub	SOLUTE
6	Noise assessment	KTH
7	Tests of the scaled blades model	USFD
8	Yaw system	USDF

4.3.3 External stakeholders

Table 17. External stakeholders in Kokoszki

	Responsibility	Stakeholders
1	Building documentation, electrical schemes	Administrative staff: Department of investments and energy
2	Notification on WT installation	Head of Wejherowo County
3	Electrical connection permission	DSO energy company

4.3.4 Facilitating stakeholders

The specific stakeholder facilitation task to be undertaken at Kokoszki are set out in this table; .

Table 18. Facilitating stakeholders in Kokoszki

	Responsibility	Stakeholders
1	Calculations, design and drawings of the foundation and the WT Assembly drawing, drawings of elements with details of connections and requirements for manufacturing of elements Calculation of weight and costs Supervision of civil works: - Construction of the foundation - Assembly of the tower and platform - Installation of WT	Civil engineers
2	Inventory of electrical supply and distribution in Kokoszki Scheme of connection Connection point to the distribution grid Design of connection Supervision of electrical works: - Modification of electrical circuits - Connection of WT to power supply box	Power engineer
3	Construction of the foundation Manufacturing of the tower, Assembling of the tower and platform, Installation of the WT	Construction companies

4	Electrical connection	Electrical engineer
5	Data collection and processing issues	IT specialist

4.3.5 Local citizens

Local residents at Kokoszki will be liaised with as follows;

Table 19. Local citizens in Kokoszki

	Responsibility	Stakeholders
1	Participation in meetings	Local community
2	Participation in meetings	Local press

4.3.6 Stakeholders of the Kokoszki industrial park

Closer to the specific location of the pilot, the stakeholder consultation will take the form of the following;

Table 20. Stakeholders of the Kokoszki industrial park

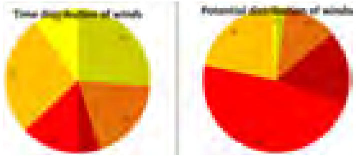
	Responsibility	Stakeholders
1	Site planning, agreement on the WT construction	Kokoszki Building comp
2	Participation in meetings	Kokoszki Building comp.
3	Existing electrical installation scheme	Kokoszki Building comp.
	Agreement on the power connection	Kokoszki Building comp.

4.4 Demo Site Context

4.4.1 Climate conditions

The climate in the city of Gdańsk is heavily influenced by its proximity to the sea and the presence of nearby hills. Gdańsk is characterized by significant precipitation levels. The average annual temperature is 6.7°C.

The predominant wind in Kokoszki is westerly. The next table classifies the wind conditions among three regimes: small winds, medium winds, and high winds. The wind characteristics of the last two regimes are detailed. 65% of the potential energy comes from the high winds regimes.



	Medium winds	High winds
Speed limit	3m/s to 6m/s	Above 6m/s
% of time	47%	18%
% of potential	33%	65%
Mainly during…	day	day
Direction	E-N-E and W	W
Turbulence	21%	21%
Mean Shear α	0.3	0.3
Up-flow angle		
Twist		
Turbulent Length scale	110m/120m	110m/120m
Inst. Shear amp.	0.3σ	0.3σ
Inst. Shear freq.	0.3 Hz	0.3Hz

Figure 42. Kokoszki - wind resources assessment

4.4.2 Orography

Kokoszki District in Gdansk is a local industrial area.

To the south-west of the planned WT there are warehouses, production, office and administrative buildings. The area around the buildings is paved rather than permeable or natural. There are no residential buildings in the area. To the north and east, the area is undeveloped with an open (to the wind) aspect. Storage areas and low-rise buildings are located to the west (the direction of the dominant wind). The ground where the WT is going to be installed is currently paved with concrete slabs.

Figure 43. Kokoszki view (W – left photo, E – right photo)

Figure 44. Kokoszki view (N – left photo, S – right photo)

Figure 45. Orography of the pilot location in Kokoszki

4.4.3 Type of WT to be installed

In Gdansk, the number of renewable energy sources installed is relatively low. The main renewable electricity sources are photovoltaic installations. In the Kokoszki area there is one pilot installation of a 40 kW wind turbine. It was constructed at the end of 2015 and is in the start-up phase. The Low-carbon Economy Plan adopted for Gdansk in 2015 calls for wider use of distributed/dispersed renewable energy.

Under the SWIP project a 20 kWh horizontal axis wind turbine will be installed in the Kokoszki district. It is specifically designed to improve acceptance in such an area. The installation cannot exceed altitude of 155.0 m above sea level due to proximity of the radar systems of the nearby airport. This limit implies that the total height of the WT (foundation, mast, blades) cannot exceed 20 m.

The WT is designed with three blades (2.65 m each) and a 15 m tower.

The technical parameters of the WT at Kokoszki are:

- installed power – 20 kW
- WT height (including blades) – 17.65 m
- max. rotation speed – 120 rpm
- cut off wind speed – 20 m/s

4.5 Risk and mitigation plans

For Kokoszki the following risks to successful installation and operation have been identified hereunder. Their corresponding mitigation measures are also set out below.

Table 21. Risks contingency plans (Kokoszki)

Risk	Risk description	Mitigation approach / Contingency plan
1	Objections of the energy company regarding the project (e.g. inverter, safety, power quality)	Project/design amendments
2	Objections of the energy company at the stage of installation acceptance	Exchange of inverter and/or metering equipment
3	Not enough (at least 3) offers for the supporting structure of the WT – lack of professionals engaged in small WT installations	Another inquiry - in order to collect 3 offers
4	Bad weather conditions preventing tower installation (wind, rain))	Rescheduling works
5	Bad weather conditions on the day of turbine installation (with crane)	Rescheduling works
6	Non-compliance of the platform parameters with the tower top	Fitting/matching both elements (drilling new holes, replacing screws, removing construction from the platform for improvement
7	Objection to the notification for the power connection by the energy company	Adjust the documentation
8	Delay in issuing building permit the Architecture Department of the Gdansk City	Delivery of additional information and documentation
9	Delay in agreement between Kokoszki construction company (ground owner) and Energy company	Negotiations with DSO to speed – up the process
10	Delay of tower/turbine installation in case ground owner does not prepare the place appropriately opóźnienie montażu wież/turbiny z uwagi na zajętość placu przez właściciela gruntu	Rescheduling works
11	WT/generator failure during operation phase	Each partner is responsible for the part developed by him. BAPE identifies the problem, communicates to the specific partner who has to develop the damaged part and that partner should fix the problem
12	Local grid connection requirements are not	An isolate configuration has to be managed for testing the WT

	meet	performance under real conditions.
13	WT components damaged during the transportation to the demo site and or during the assembling process	The delivered time is set taking as reference the Milestones schedule established by the SWIP project and the time costs to manufacture and deliver a replacement for the damaged or inadequate component
14	Local authority refused issuing the building permit	New location is agreed for the WT installation

5 Monitoring and evaluation programme to assess wind turbines and components performance

5.1 Introduction

According to the project development, at this moment three pilot facilities are being built, each of them presenting different features:

Table 22. Pilot facilities

Pilot	Location	Wind turbine		SCADA
		Rated power	Axis	
V1	Choczewo (Poland)	1 kW	Vertical	No
H4	Zaragoza (Spain)	4 kW	Horizontal	Yes
H20	Kokoszki (Poland)	20 kW	Horizontal	Yes

All prescriptions presented in this document are expected to be followed by each of the partners involved in these three pilot facilities, so measurements may be considered as consistent and reproducible. Despite all these prescriptions, any additional measure to achieve a higher level of accuracy or reliability of the results can be applied but it should be cleared stated and technically justified.

Nevertheless some difficulties and inconveniences regarding the operation of the small wind turbines in urban or peri-urban areas, such as nearby obstacles or high values of turbulence, will be present at any pilot facility, so uncertainties related to results might be greater than those that would appeared if wind turbines may be operated at an open and flat terrain faced to free stream.

5.2 Measurement procedure

5.2.1 Basic variables to be measured

To evaluate the wind turbine performance at least the following magnitudes should be measured and averaged every 1 minute, along a minimum period of 6 months:

- Net active power (P)
- Wind turbine status (S)
- Wind speed (V)
- Wind direction (D)
- Air temperature (T)
- Relative humidity (H)
- Barometric pressure (B)

For those pilot wind turbines supplied with SCADA, the following variables (signals or set-points) will be used to obtain the magnitudes mentioned above:

Table 23. SCADA variables to be used

Signal	Definition	Unit
P	Active Power	kW
Pc	Active Power Consign	kW
Qc	Reactive Power Consign	kVAr
Ds	Slow Disconnection Signal	-
De	Emergency Disconnection Signal	-

Net active power (P) will be the 1-min averaged Active Power signal (P) and Wind turbine status (S) will be considered "OK" when the following conditions are fulfilled:

- Active Power Consign (Pc) is equal to 120 % of rated value and Reactive Power Consign (Qc) is equal to 0 kVAr (normal operation)
- Slow Disconnection Signal (Ds) and Emergency Disconnection Signal (De) are set to zero over the whole 1-min period

For the pilot wind turbine not supplied with SCADA, a power measurement equipment will be installed at the generator or converter output, so Net active power (P) can be calculated as the 1-min average of the instantaneous value of delivered active power (obtained as the combination of measured voltage and current). In this case, the following (or similar) devices will be installed:

Table 24. Power measurement equipment to be installed

Measurement device	Accuracy
Voltage probe	0.5 %
Current meter	0.5 %
Power transducer	0.5 %
Data-logger	0.1 %

In this case, Wind turbine status (S) will be considered "OK" if Net active power (P) is positive (i.e. the wind turbine is generating energy, thus not consuming from the network or batteries).

The rest of mentioned magnitudes (V, D, T, H and B) will be obtained as the 1-min average of the corresponding values provided by the measurement system installed at each meteorological mast. For those pilot wind turbines supplied with SCADA, these data can be obtained from the SCADA system and for the wind turbine without SCADA, these data will be registered in the data-logger. Nevertheless, some considerations will be taken into account to obtain them properly:

- Wind speed (V) will be obtained from the anemometer (cup or sonic) placed at the higher measurement level of the meteorological mast, unless there is another one available at a height closer to the wind turbine hub height[1]. If using a sonic anemometer, the wind

[1] For a horizontal axis wind turbine, hub height is the height of the center of the swept area (area projected by the rotor movement upon a plane normal to the rotation axis) of the wind turbine rotor above the ground. For a vertical axis wind turbine, hub height is the height of the equator plane.

speed measurement will only correspond to the horizontal component of the 3-D wind speed vector (W). Wind speed will be measured or converted to meters per second [m/s].

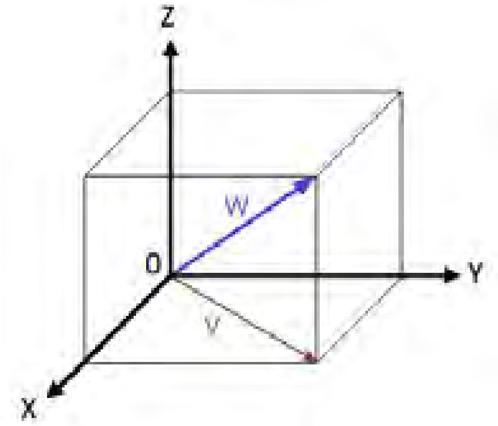


Figure 46. Projection of wind speed vector on the horizontal plane XY

- Wind direction (D) will be obtained either from a wind vane or a sonic anemometer. It will be selected that one located as close as possible to the hub height of the wind turbine. If using a sonic anemometer, the wind direction measurement will only correspond to the horizontal projection of the 3-D wind speed vector. Wind direction will be measured or converted to degrees [º]. According to the commonly accepted convention, wind direction is reported by the direction the wind is blowing from, measured clockwise from North (0º).

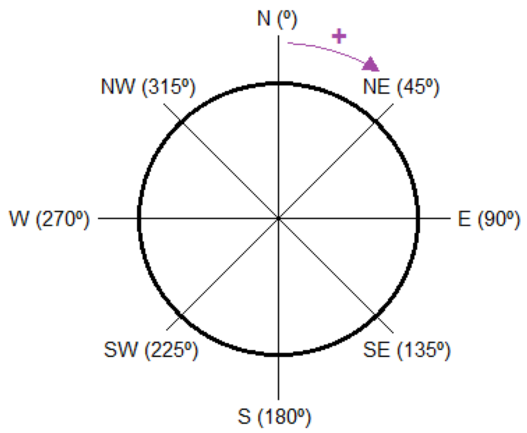


Figure 47. Wind direction measurement convention

- Air temperature (T) will be obtained from the thermometer or temperature probe installed at the meteorological mast and will be measured or converted to kelvins [K]:

$$T[K] = T[^{o}C] + 273.15$$

- Relative humidity (H) will be obtained from the hygrometer or thermo-hygrometer installed at the meteorological mast and will be measured or converted to the ratio of the partial pressure of water vapour in the mixture to the equilibrium vapour pressure of water.

- Barometric pressure (B) will be obtained from the barometer (pressure sensor) installed at the meteorological mast and will be measured or converted to pascals [Pa]:

$$B[Pa] = B[mbar] \cdot 100$$

- If the barometer is placed at a measurement height different from the wind turbine hub height, then Barometric pressure (B) values will be corrected according to the following equation[2]:

$$B_{corrected} = B_{measured} \cdot \exp\left[\frac{-g_n}{R \cdot T} \cdot \left(H_{hub} - H_{measure}\right)\right]$$

where R = 287.05 J / kg K, g_n = 9.806 m/s^2, H_{hub} is the hub height and $H_{measure}$ is the measurement height.

According to 1-min averages of previous magnitudes, 1-min Air density (ρ) will be obtained using the following formula:

$$\rho = \frac{1}{T} \cdot \left[\frac{B}{R} - H \cdot B_w \cdot \left(\frac{1}{R} - \frac{1}{R_w}\right)\right]$$

$$B_w = 0{,}0000205 \cdot e^{0{,}0631846 \cdot T}$$

where Rw = 461.5 J / kg K. Air density (ρ) will be expressed in kilograms per cubic meter [kg/m3].

5.2.2 Other interesting variables

It might result interesting, especially for those wind turbine supplied with SCADA, to monitor the following variables as well:

Table 25. Other interesting SCADA variables

Signal	Definition	Unit
Q	Reactive Power	kVAr
PF	Power Factor	-
F	Frequency	Hz
THD	Total Harmonic Distortion	%
W1	Rotation Frequency of Turbine	rpm
W2	Rotation Frequency of Multiplier	rpm
Tg	Generator Temperature	ºC
Vx	Vibration in the x-axis	mm/s
Vy	Vibrations in the y-axis	mm/s
Vz	Vibrations in the z-axis	mm/s

For evaluating the wind turbines components performance, all the above magnitudes can be measured and averaged every 1 minute, along a minimum period of 6 months.

It is also possible that, according to the necessary measurement equipment described in Table 3 for wind turbines not supplied with SCADA, some of them can be easily added to the basic

[2] For a correct application of this equation, both heights should be measured or referred to the same ground reference level.

variables presented in clause 2.1, if extra channels are available in the selected data-logger. For example, Reactive Power (Q) or Power Factor (PF) are likely to be provided by the power transducer. Generator Temperature (Tg) or Vibration in one axis (Vx, Vy or Vz) might be monitored by means of sensors or transducers whose output signal is a voltage (or current) proportional to that variable.

Other variables, whose behaviour is supposed to vary in a slower way, such as Frequency (F), Total Harmonic Distortion (THD) or Rotation Frequency of Turbine[3] / Multiplier[4] (W1 / W2) might be measured in situ just for a short period of time[5] (for example, 10 measurements of 1-min duration every week). For that purpose, a portable measurement device can be used: for instance, a power analyser for F and THD (see Figure 3) and a tachometer for W1 and W2 (see Figure 4). Special care should be taken in order to measure those variables at different wind conditions, i.e. covering several Wind speed (V) intervals[6] and if possible different Wind direction (D) sectors. It would be desirable that at least 10 measurements per month at any defined wind condition were available.

Figure 48. Measurement of power quality using a portable analyser (www.fluke.com)

[3] Rotation Frequency of Turbine must be understood as the rotational speed of the wind turbine rotor, expressed in revolutions per minute [r.p.m.].

[4] Rotation Frequency of Multiplier must be understood as the rotational speed of the generator (i.e. the rotor speed multiplied by the wind turbine gearbox, if it exists), expressed in revolutions per minute [r.p.m.].

[5] In such a case it will result essential to complete a schedule indicating date and time of the manual measurements performed during the measurement period.

[6] For instance, selected Wind speed (V) intervals to be covered may be these: V < 4 m/s, 4 m/s ≤ V ≤ 7 m/s, 7 m/s < V ≤ 11 m/s and V > 11 m/s. Alternatively, wind speed intervals might be substituted by active power intervals.

Figure 49. Measurement of rotational speed using a tachometer (www.fluke.com)

Although it is not implemented as an available magnitude in the SCADA, for pitch control wind turbines, it may be highly recommended to measure the evolution of pitch angle[7]. To this end, the installation of a rotary encoder, placed in the joint of one of the blades and the wind turbine hub, might be necessary (see Figure 5). It is feasible then that the rotary transducer output (a group of digital signals or a RS-232 connection) may be easily input for its recording in the data-logger.

Figure 50. Installation of a rotary encoder in one blade (www.baumer.com)

5.2.3 Noise

In Choczewo, the values of permitted sound levels in the environment (equivalent, denoted as LAeq, T), for both day and night, are defined in the table - *Annex To The Regulation Of The Minister Of Environment On Permissible Noise Levels In The Environment*. These levels relate to

[7] Pitch angle is the angle between the chord at a given blade radial point (usually at 100 % of blade radius) and the rotation plane of rotor.

the areas requiring protection against noise. Averaging time (determination or the measurement of sound level) was adopted in the regulation as 16 hours during daytime and 8 hours at night for road traffic noise sources and for other sources as 8 hours during the day and 1 hour at night.

Table 26. Permitted noise levels in the environment

No.	Land appropriation	Permitted noise level in dB	
		Other facilities and activity being the source of noise	
		LAeq D day T=8h	LAeq N night T=1h
1.	a. A-protective zone of health resort b. Area of hospitals outside the city	45	40
2.	a. Single-family residential areas b. Building area associated with a permanent or temporary stay of children and youth c. Area of nursing homes d. Area of hospitals in towns	50	40
3.	a. Areas of residential buildings and collective residence b. Areas of farmsteads c. Recreational and resting areas d. Residential and service areas	55	45
4.	Downtown areas of cities with over 100 thousand residents	55	45

Once operational, the noise emission for all three wind turbines will be assessed according to the procedure and conditions described in IEC 61400-11 "Wind turbine generator systems- Part 11 Acoustic noise measurement techniques" and reported as the recommendations of the BWEA 2008 "Small Wind Performance and Safety standard" stipulate. The objective of these standards is to measure the total generated sound power of the turbine and to establish suitable distances to nearby imission points of interest. In the case of urban sites possible deviations of the procedure estimating the sound power could occur and if so will be reported. Noise classifications according to the BWEA 2008 standard will be reported and compared to the sound power estimations form SWIP Task 7.2. The acoustic measurement equipment will be a sound level meter class 1 as specified in the IEC standard.

5.3 Wind turbine performance evaluation

5.3.1 Affected wind directions

5.3.1.1 Obstacles

During the measurement period, special care shall be taken in order to mark wind speeds coming from directions affected by significant obstacles8, seen both from the meteorological mast and the wind turbine. For that purpose, 12 sectors will be defined, each one having 30° (see Table 5). Further analyses will be performed taking into account that division, thus data from one sector only can be compared with data from that sector. Additionally, it will be reported every sector having wind directions directly in the wake of surrounding obstacles.

Table 27. Wind direction sectors

#	Direction	Range
1	N	(345º, 15º]
2	NNE	(15º, 45º]
3	ENE	(45º, 75º]
4	E	(75º, 105º]
5	ESE	(105º, 135º]
6	SSE	(135º, 165º]
7	S	(165º, 195º]
8	SSW	(195º, 225º]
9	WSW	(225º, 255º]
10	W	(255º, 285º]
11	WNW	(285º, 315º]
12	NNW	(315º, 345º]

Example

In the following figure, two obstacles are present in the surrounding area of the wind turbine and the meteorological mast. For that reason, wind directions directly affected by both obstacles are geometrically calculated from the point of view of the wind turbine (blue lines) and the meteorological mast (red lines) as well.

[8] For the application of the procedure described in this document, an obstacle shall be considered as significant if its height is equal or greater than 1/6 of the wind turbine hub height.

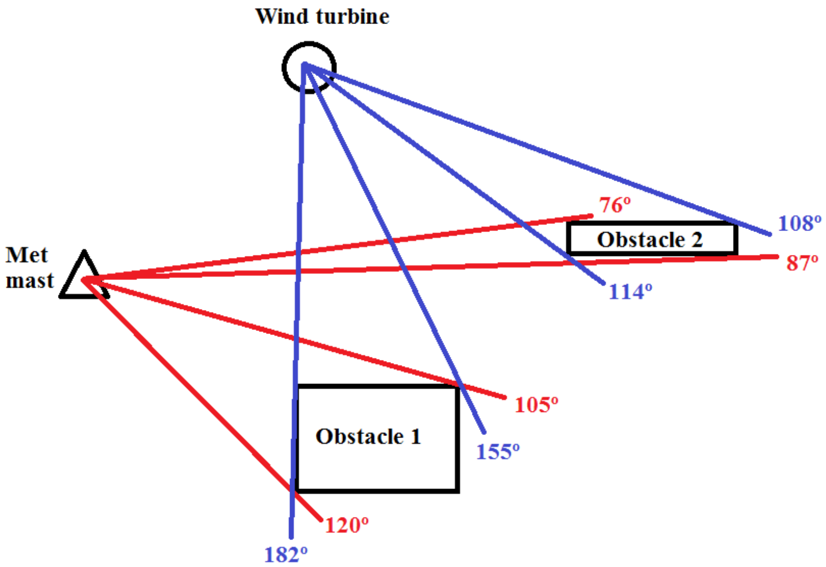


Figure 51. Example of wind directions directly affected by obstacles

According to Figure 6, the following sectors will have marked wind data:

- Wind direction coming from 108º to 114º: affected sector # 5
- Wind direction coming from 155º to 182º: affected sectors # 6 and 7
- Wind direction coming from 76º to 87º: affected sector # 4
- Wind direction coming from 105º to 120º: affected sectors # 4 and 5

5.3.1.2 Tested wind turbine

In addition to the exclusion described in the previous clause, wind speeds coming to the meteorological mast from directions affected by the wind turbine will be marked as well. In a similar way that shown above, sectors where wind directions directly in the wake of the wind turbine will be reported in order to take into account this disturbance in a further analysis.

Example

When rotating, the tips of the wind turbine blades describe a circle whose borders can be considered as the limits of an obstacle from the point of view of the meteorological mast. So, wind speeds coming from the extents of the swept area9 of the wind turbine (green lines in the following figure) may be affected.

[9] For a horizontal axis wind turbine, swept area is the area projected by the rotor movement upon a plane normal to the rotation axis. For a vertical axis wind turbine, swept area is the area projected by the rotor movement upon a vertical plane.

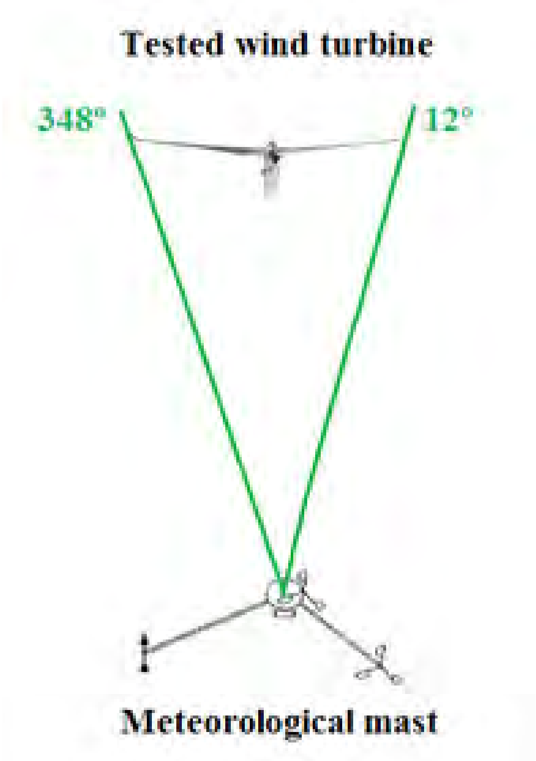


Figure 52. Example of wind directions directly affected by the tested wind turbine

According to Figure 7, the following sectors will also have marked wind data:

- Wind direction coming from 348º to 12º: affected sector # 1

Obviously, the angles of the green lines comprising the limits of wind directions directly in the wake of the wind turbine will be a function of the corresponding swept area (i.e. rotor diameter) and the actual distance of the tested wind turbine to the meteorological mast, which will be different from a pilot facility to another.

5.3.2 Data selection

In order to ensure that only data acquired during normal operation of the tested wind turbine are used, data acquired under the following circumstances shall be removed:

- 1-min average data comprising less than 54 seconds of measured variables.
- Wind turbine status is not "OK", according to 2.1.
- Air temperature lower than 2 ºC and at a relative humidity greater than 80 %.
- Manual disconnection of the wind turbine.
- Wind turbine, SCADA or measurement equipment failure.
- Meteorological magnitudes out of its physical range (see Table 6).

Table 28. Physical ranges for each meteorological magnitude10

Magnitude	Units	Range
Wind speed	m/s	0 – 75
Wind direction	º	0 – 360
Air temperature	ºC	-35 – 55
Relative humidity	%	0 – 100
Barometric pressure	hPa	700 – 1080

5.3.3 Data normalization

All acquired data shall be normalized to a representative air density (ρo) at each pilot facility. If a typical air density is unknown, then a reference air density (e.g. 1.225 kg/m3) will be used for evaluating the performance of the wind turbines along the measurement period.

According to the power regulation type of the tested wind turbine, normalization will be applied to different 1-min average data:

- For stall control wind turbines, whose pitch angle and rotational speed are constant, normalization shall be applied to measured active power data, according to equation:

$$P_{normalized} = P_{measured} \cdot \left(\frac{\rho_o}{\rho} \right)$$

- For pitch control wind turbines, normalization shall be applied to measured wind speed data:

$$V_{normalized} = V_{measured} \cdot \left(\frac{\rho}{\rho_o} \right)^{1/3}$$

5.3.4 Power performance analysis

Once all correction and normalization tasks are performed according to clauses 3.2-3.3, the resulting 1-min data will be sorted into wind speed intervals of 1 m/s and mean values of power will be obtained:

$$P_i = \frac{1}{N_i} \sum_{j=1}^{N_i} P_{n,j,i}$$

where Ni is the number of 1-min data in each wind speed interval i.

Wind speed intervals will be defined as follows:

for each 1-min wind speed data V_k, then (i – 0,5 m/s) ≤ V_k < (i + 0,5 m/s)
where i is an index ranging from 1 m/s to the maximum measured wind speed.

This classification and consequent average of active power in each wind speed interval will be obtained monthly along a minimum period of 6 months. These calculations have to be done and presented separately for every wind direction sector.

[10] The ranges shown in Table 5 are applicable physical limits for each meteorological magnitude, but may be reduced if related sensors ranges are more restrictive according to their constructive conditions or the specifications from manufacturers.

As a summary of this evaluation, a table and a graph, similar to the examples shown below, will be reported at each pilot facility. If any of the mean values of active power at every wind speed interval is out of a confidence interval of the corresponding average plus or minus its standard deviation, then it will be marked in red.

Table 29. Example of tabular presentation of power performance evaluation

Month	Mean value of active power [W] in each wind speed interval													
	1 m/s	2 m/s	3 m/s	4 m/s	5 m/s	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 m/s	12 m/s	13 m/s	14 m/s
#1	0.0	0.2	2.3	10.2	20.6	35.2	56.2	75.5	100.9	-	-	-	-	-
#2	0.0	0.0	2.9	10.1	20.4	35.0	42.2	-	-	-	-	-	-	-
#3	0.0	0.0	2.9	10.0	19.5	34.9	49.4	-	-	-	-	-	-	-
#4	0.0	0.0	3.3	10.4	21.1	34.9	51.2	72.4	95.0	123.8	162.9	189.8	229.6	298.1
#5	0.0	0.0	3.3	9.7	19.9	35.1	46.2	-	-	-	-	-	-	-
#6	0.0	0.0	2.4	9.6	21.3	40.0	51.5	71.8	96.5	124.0	154.1	184.9	212.5	305.6
Average	0.0	0.0	2.8	10.0	20.7	35.8	49.4	71.0	95.2	123.9	156.3	187.3	225.7	303.1
Std. dev.	0.0	0.2	2.0	3.0	4.5	3.9	6.9	9.9	11.5	13.5	14.6	14.2	16.6	20.2

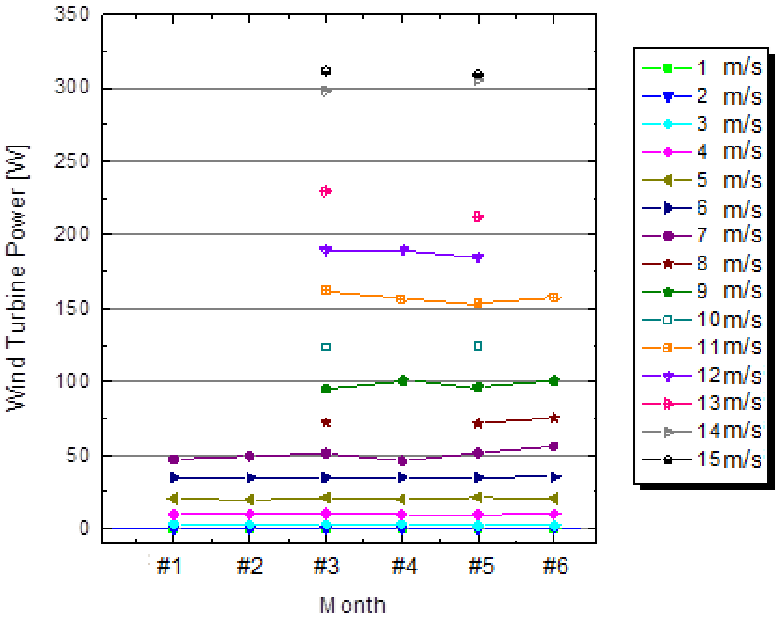


Figure 53. Example of graphical presentation of power performance

To ensure there is an enough representativeness of data during the measurement performance, the number of valid 1-min data used for power performance evaluation will be also documented in a table like the one shown below. If there is a wind speed interval in which the number of valid 1-min data is lower than 10, then it will be marked in red.

Table 30. Example of tabular presentation of number of valid 1-min data per wind speed interval

Month	Number of valid 1-min data used for power performance evaluation in each wind speed interval												
	1 m/s	2 m/s	3 m/s	4 m/s	5 m/s	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 m/s	12 m/s	13 m/s
#1	4450	34502	4502	7514	14424	427	521	27	32	27	5	0	0
#2	3558	34554	22554	7574	14754	759	88	15	8	22	0	0	0
#3	6541	41244	39512	41427	2574	2652	215	21	17	10	12	0	0
#4	11945	22145	20024	17542	8579	402	98	102	54	12	6	0	0

#5	1850	25850	2810	5542	2204	824	354	37	42	3	3	0	0
#6	22562	42106	22001	18454	3658	658	581	58	19	47	15	9	0

Additionally, in order to get a general view of the meteorological conditions and eventually detect a significant change of them during the measurement period, a table presenting all the information contained in the example shown below will be also reported.

Table 31. Example of tabular presentation of meteorological conditions during the measurement period

Month	Average Air density	Max and min Temperature	Average and maximum Turbulence intensity (TI) 1 m/s – 3 m/s	4 m/s – 7 m/s	8 m/s – 10 m/s	11 m/s – 14 m/s
#1	1.154 kg/m^3	22.1 ºC / 4.5 ºC	0.05 / 0.12	0.04 / 0.12	0.05 / 0.12	0.04 / 0.11
#2	1.027 kg/m^3	18.1 ºC / 2.4 ºC	0.06 / 0.21	0.06 / 0.15	0.03 / 0.15	0.03 / 0.12
#3	1.044 kg/m^3	20.2 ºC / 6.5 ºC	0.08 / 0.17	0.07 / 0.12	0.04 / 0.12	0.07 / 0.12
#4	1.141 kg/m^3	26.6 ºC / 8.9 ºC	0.05 / 0.11	0.05 / 0.14	0.05 / 0.14	0.04 / 0.13
#5	1.135 kg/m^3	30.5 ºC / 9.9 ºC	0.02 / 0.13	0.02 / 0.13	0.08 / 0.13	0.06 / 0.13
#6	1.147 kg/m^3	36.1 ºC / 12.5 ºC	0.07 / 0.11	0.06 / 0.16	0.07 / 0.10	0.05 / 0.11

Finally, some graphical presentation of selected 1-min data during the measurement period will be presented:

- Monthly scatter plot of Active Power (P) as a function of Wind speed (V)
- Monthly scatter plot of Wind speed (V) as a function of Wind direction (D)
- Time evolution of Active Power (P) during all the measurement period
- Time evolution of Wind turbine status (S) during all the measurement period
- Time evolution of Wind speed (V) during all the measurement period
- Time evolution of Wind direction (D) during all the measurement period
- Time evolution of Air temperature (T) during all the measurement period
- Time evolution of Relative humidity (H) during all the measurement period
- Time evolution of Barometric pressure (B) during all the measurement period

Some of the graphs listed above may be presented in a same picture if it is technically possible and enough clearness for their interpretation is kept.

Annex I contains examples of the all the above required graphical presentations.

In the wind turbines with SCADA system, a further analysis has to be done in order to find alarms related to any kind of deviation between the rated/average values and the measured parameters. The SCADA systems have a log-book where every alarm coming from the converter is stored. Additionally, several alarms regarding the meteorological measurements are logged. So it is possible to connect some deviations from the expected values with an incident in the wind turbine.

5.4 Components of the wind turbine evaluation

According to the variables, listed in clause 2.2, whose measurements might result interesting for wind turbine components performance evaluation, some graphs are listed below in order to be reported at each pilot facility if possible:

- Monthly scatter plot of Reactive Power (Q) as a function of Active Power (P) or Wind speed (V) -> converter
- Time evolution of Reactive Power (Q) during the measurement period -> converter
- Monthly scatter of Power Factor (PF) as a function of Active Power (P) or Wind speed (V) -> converter
- Time evolution of Power Factor (PF) during the measurement period -> converter
- Monthly scatter of Frequency (F) as a function of Active Power (P) or Wind speed (V) -> converter/generator
- Time evolution of Frequency (F) during the measurement period -> converter/generator
- Monthly scatter plot of Total Harmonic Distortion (THD) as a function of Active Power (P) or Wind speed (V) -> converter
- Time evolution of Total Harmonic Distortion (THD) during the measurement period -> converter
- Monthly scatter plot of Rotation Frequency of Turbine (W1) or Rotation Frequency of Multiplier (W2) as a function of of Active Power (P) or Wind speed (V) -> generator
- Monthly scatter plot of Generator Temperature (Tg) as a function of Active Power (P) or Wind speed (V) -> generator
- Time evolution of Generator Temperature (Tg) during the measurement period -> generator
- Monthly scatter plot of pitch angle as a function of Active Power (P) or Wind speed (V) -> control system + blades
- Time evolution of pitch angle during the measurement period -> control system + blades
- Monthly scatter plot of Vibration in x/y/z-axis (Vx / Vy / Vz) as a function of Active Power (P) or Wind speed (V) -> blades
- Monthly scatter plot of Vibration in x/y/z-axis (Vx / Vy / Vz) as a function of Wind direction (D), if relevant -> blades
- Any other plot or graph that may be considered as relevant for this analysis

Each proposed graph represents the behaviour of one or several components of the wind turbine, as it is shown above.

Some of the graphs listed above may be presented in a same picture if it is technically possible and enough clearness for their interpretation is kept. All these graphs may be presented in a similar way as those mentioned in clause 3 (see examples of them included in Annex I).

5.5 Reporting format

Once the measurement data is finished and recorded data are processed and analysed according to previous clauses, each demo coordinator will issue a report containing the following minimum information:

- Identification of the pilot facility
- Period of measurement
- Sketches, drawings or photographs of the pilot facilities, showing the position of the meteorological mast, the wind turbine and obstacles and main dimensions and distances

- Wind directions considered as affected and, therefore, sectors with marked data
- Identification of additional measurement equipment installed or used for carrying out the wind turbine and/or its components evaluation
- Sketches, drawings or photographs of the installation or utilization of additional measurement equipment
- Any special consideration regarding the measurement procedure not covered by this document
- Any special consideration regarding wind turbine and/or its components evaluation not covered by this document
- Numerical results and graphs required in clause 3
- Graphs required in clause 4, if available
- Any consideration or comment regarding results and graphs presented in the report
- Any inconvenience or technical difficulty found when applying this document that might cause not fulfilling its prescriptions
- Log-book, indicating main events happening during power performance test
- Detected correlations between deviations from the expected values and incidents in the wind turbine
- Photographs of any damaged component

5.6 Conclusions

The aim of all prescriptions presented in this document is to describe a methodology in order to provide enough level of accuracy and consistency of measurements and wind turbines and components performance evaluation, according to the objectives of Task 8.1 of this project.

Although all circumstances involving the three pilot facilities are tried to be covered in this document, it is possible that some might not be considered. In such a case, it will be responsibility of the partner to apply all technical measures and required solutions, according to its own judgement and the philosophy of this document.

In no case the results obtained applying this methodology should be considered as a precise performance of wind turbines and their components at the pilot facilities, due to all uncertainties involving the measurements. These results should not be considered as exact figures but an approach to the behaviour of the turbines and its evolution / degradation over time.

6 Conclusions

Within this document all technical aspects of the wind turbine prototypes have been discussed and key parameters and connection requirements for mechanical, electrical and IT elements and units have been addressed for each of the pilot sites, giving the big picture of the different technologies that are going to be installed in the different pilot sites.

Once all this aspects have been clarified, schedules of installation were developed and agreed for each site taking into account local requirements, planned availability of WT components and units and involvement of the project consortium. Also, external and facilitating stakeholders are identified and will be involved in the process of WTs installation and commissioning.

Within this deployment plan, all partners involved in the design, supply, installation and monitoring of the WTs performance have been involved and have confirmed their responsibility and participation during the deployment phase in order to ensure successful implementation of WTs at the pilot sites.

During the implementation phase a set of issues can appear, it is necessary that these problems could be solved in a quicker and efficient manner. In order to try to advance on the possible issues that may happen and to save time and money, all potential and hypothetical risks have been analysed for each pilot site and alternative solutions (mitigation plans) have been proposed.

The process of preparation of pilot projects developed by many partners in different regions and concerning various technologies showed that there are significant legal differences in partner countries in terms of designing, obtaining development consents, WTs connection as well as availability of materials on local markets, this reveals the complexity of the demonstration, which is not only a technical challenge but also implies normative and regulations which can condition the development of each demo site. Showing this, to treat each demo site as a stand-alone sub-project seems to be the best option.

Taking into consideration the abovementioned, successful implementation of the pilot projects requires common understanding and cooperation of all stakeholders.

The Deployment Plan contains a transparent timetable scheduling installation and commissioning of pilot WTs. The schedule is crucial to coordinate work. The implementation of the Deployment Plan shall guarantee planned installation, commissioning and later monitoring of WTs operation at each demo site.

ANNEX I. Gantt Charts for pilots

I.I. Gantt Chart for Pilot 1 in Choczewo

Pilot 1 - VT2 kW Choczewo		responsible Partner	Year 3						Year 4							
			B16		B17		B18		B19		B20		B21		B22	
			1.04.16	1.05.16	1.06.16	1.07.16	1.08.16	1.09.16	1.10.16	1.11.16	1.12.16	1.01.17	1.02.17	1.03.17	1.04.17	1.05.17
			31	32	33	34	35	36	37	38	39	40	41	42	43	44
	1. Design															
1.1	blades design	PPL														
1.2	supportive structure design	SOLUTE														
1.3	adaptation of the WT and electrical design	BAPE														
1.4	generator design	FORES														
1.5	IT installation	FORES														
1.6	converter design	FORES														
1.7	electrical installation design	FORES														
1.8	notification procedure	BAPE														
	2. Manufacture															
2.1	Vertical axis blades	PPL														
2.2	generator and the frame	FORES/SOLUTE														
2.3	auxiliary frame	SOLUTE														
2.4	IT installation	FORES														
2.5	converter	FORES														
2.6	SWTs certification	FORES														
	3. Transport															
3.1	generator + converter+high/low speed shafts	FORES/BAPE														
3.2	frame & WT	SOLUTE/BAPE														
3.3	anchorages (supportive structure)	SOLUTE/BAPE														
3.4	blades	PPL/BAPE														
	4. Civil works and Installation															
4.1	civil works on the building roof	BAPE														
4.2	assembling of the supportive structure	BAPE/SOLUTE														
4.3	converter and cabinet	FORES														
4.4	installation of the WT	BAPE and FORES														
4.5	IT installation	FORES														
4.6	electrical installation	BAPE														
	5. Start up															
5.1	WT operational	BAPE + FORES														
	5. Monitoring and evaluation															
6.1	WT productivity	CIRCE														
6.2	noise	CIRCE/KTH														
6.3	Comparative analysis of the results - Improvement of wind resource analysis methodology	FORES														
6.4	Final assessment and conclusions	CIRCE														

I.II. Gantt Chart for Pilot 2 in Zaragoza

	Pilot 2 - HT 4 kW Zaragoza	responsible Partner	Year 3						Year 4							
			B16		B17		B18		B19		B20		B21		B22	
			1.04.16	1.05.16	1.06.16	1.07.16	1.08.16	1.09.16	1.10.16	1.11.16	1.12.16	1.01.17	1.02.17	1.03.17	1.04.17	1.05.17
			31	32	33	34	35	36	37	38	39	40	41	42	43	44
	1. Design															
1.1	**Blades design**	PPL	■													
1.2	**Foundation design**	CIRCE	■													
1.3	**Mast design**	SOLUTE/CIRCE	■													
1.4	**Generator design**	CIRCE	■													
1,5	**SCADA design**	CIRCE	■													
1,6	**converter design**	CIRCE	■													
1,7	**Nacelle design**	CIRCE	■													
1,8	**Hub, Wind vane, Yaw design**	SOLUTE	■													
1,7	**Building permit procedure**	CIRCE	■													
	2. Manufacture															
2.1	**Horizontal axis blade**	PPL		■	■	■	■	■								
2.2	**Generator design/purchase**	CIRCE		■												
2,3	**Mast**	SOLUTE/CIRCE		■	■	■	■	■								
2,4	**SCADA**	CIRCE		■	■	■										
2,5	**Converter**	CIRCE		■	■	■										
2,6	**SWTs certification**	CIRCE			■	■	■	■	■	■	■	■	■	■	■	■
2,7	**Nacelle**	CIRCE		■	■											
2,7	**Hub, yaw, wind vane**	SOLUTE		■	■	■	■	■								
	3. Transport															
3,1	**Mast**	SOLUTE/CIRCE						■								
3,2	**blades**	PPL/BAPE							■							
3,3	**hub, yaw,wind vane**	SOLUTE						■								
	4. Civil works and Installation															
4.1	**civil works on the building**	CIRCE						■								
4.2	**assembling of the supportive structure**	CIRCE							■							
4.3	**converter installation**	CIRCE							■							
4.4	**installation of the WT**	CIRCE							■							
4.5	**SCADA installation**	CIRCE							■							
4.6	**electrical installation**	CIRCE							■							
4.7	**SWT assembly**	CIRCE							■							
	5. Start up															
5,1	**SWT safety test**	CIRCE				■			■							
5.1	**WT operational**	CIRCE							■							
	5. Monitoring and evaluation															
6.1	**WT productivity**	CIRCE							■	■	■	■	■	■	■	
6.2	**noise**	CIRCE/KTH							■	■	■	■	■	■	■	
6.3	**Comparative analysis of the results - Improvement of wind resource analysis methodology**	CIRCE							■	■	■	■	■	■	■	
6.4	**Final assessment and conclusions**	CIRCE									■	■	■	■	■	■

I.III. Gantt Chart for Pilot 2 in Kokoszki

Pilot 3 - HT20 kW Kokoszki		responsible Partner	Year 3						Year 4							
			B16		B17		B18		B19		B20		B21		B22	
			1.04.16	1.05.16	1.06.16	1.07.16	1.08.16	1.09.16	1.10.16	1.11.16	1.12.16	1.01.17	1.02.17	1.03.17	1.04.17	1.05.17
			31	32	33	34	35	36	37	38	39	40	41	42	43	44
	1. Design															
1.1	blades design	SOLUTE														
1.2	foundation design	SOLUTE														
1.3	mast design	SOLUTE														
1.4	adaptation of the design	BAPE														
1.5	generator design	FORES														
1.6	hub	SOLUTE														
1.7	pitch control system	SOLUTE														
1.8	SCADA design	CIRCE														
1.9	converter design	FORES														
1.10	building permit procedure	BAPE														
	2. Manufacture															
2.1	horizontal axis blades	PPL														
2.2	platform to support generator and generator design/purchase	FORES														
2.3	mast	SOLUTE/BAPE														
2.4	SCADA	CIRCE														
2.5	converter	FORES														
2.6	SWTs certification	FORES														
2.7	hub	SOLUTE														
2.8	pitch control	PPL														
2.9	yaw system	USDF														
2.10	nacelle	FORES														
2.11	nacelle cover	PPL														
2.12	nacelle basket	SOLUTE														
	3. Transport															
3.1	platform to support generator+generator + converter+high/low speed	FORES/BAPE														
3.2	mast & anchorages (supportive structure)	SOLUTE/BAPE														
3.3	blades	PPL/BAPE														
3.4	hub	SOLUTE														
3.5	pitch control	PPL														
3.6	yaw system	USDF														
3.7	nacelle	PPL														
	4. Civil works and Installation															
4.1	civil works: foundation	BAPE														
4.2	assembling of the tower and supportive structure	BAPE														
4.3	converter installation	FORES														
4.4	WT assembly	BAPE and FORES+SOLUTE														
4.5	installation of the WT	BAPE														
4.6	SCADA installation	CIRCE														
4.7	electrical installation	BAPE and FORES														
	5. Start up															
5.1	SWT safety tests	FORES														
5.2	WT operational	BAPE and FORES														
	5. Monitoring and evaluation															
6.1	WT productivity	CIRCE														
6.2	Noise	CIRCE/KTH														
6.3	Comparative analysis of the results - Improvement of wind resource analysis methodology	FORES														
6.4	Final assessment and conclusions	CIRCE														

ANNEX II. Reporting presentation examples

This annex contains some examples of the required graphical presentations to be included in the reports issued by each of the partners involved in the three pilot facilities.

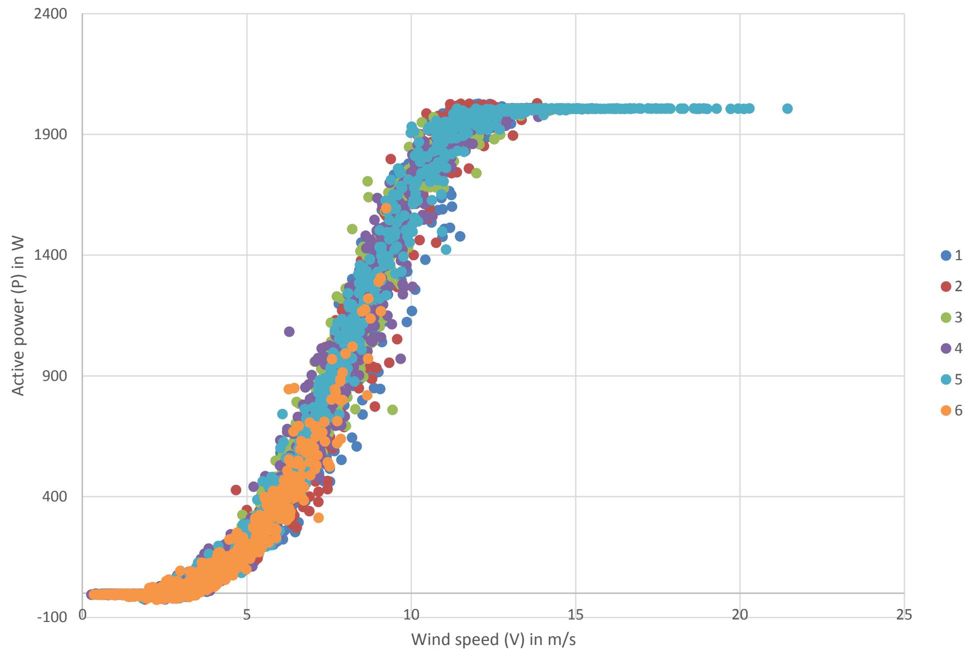


Figure 54. Example of graphical presentation of monthly scatter plot of P as a function of V

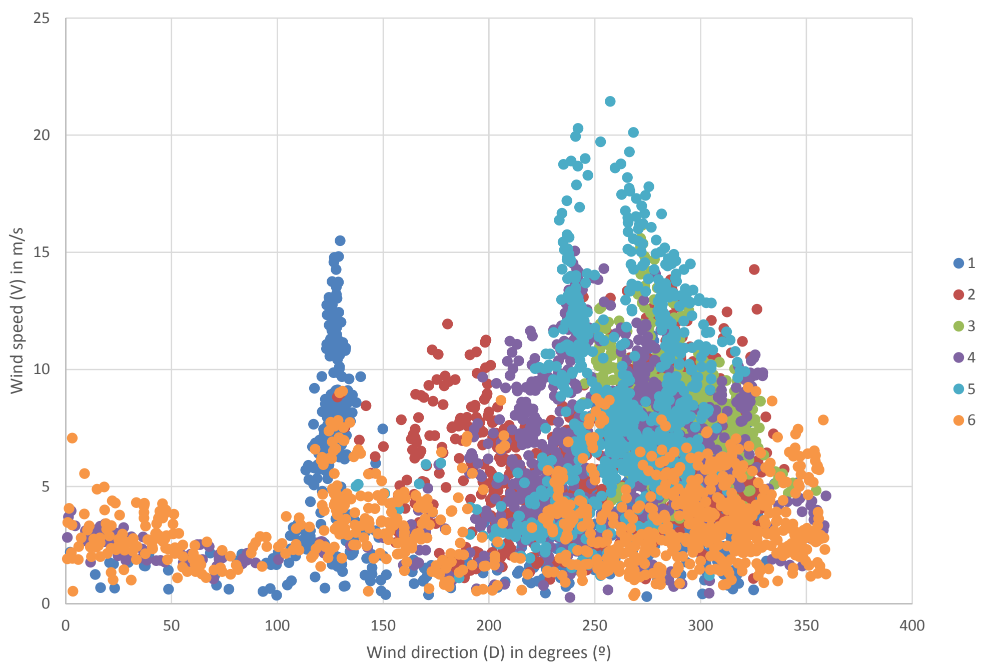


Figure 55 Example of graphical presentation of monthly scatter plot of V as a function of D

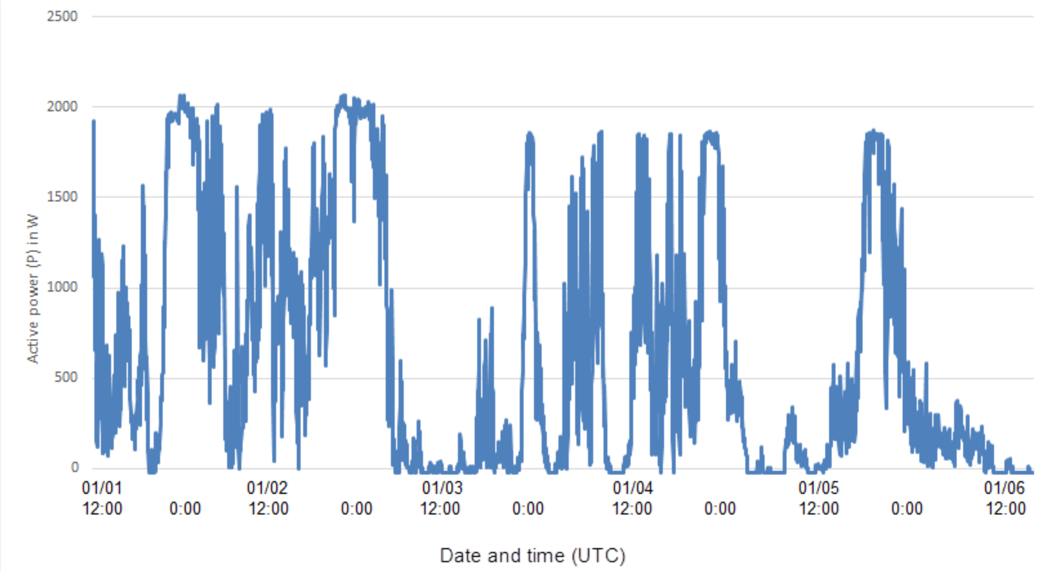


Figure 56. Example of graphical presentation of time evolution of P

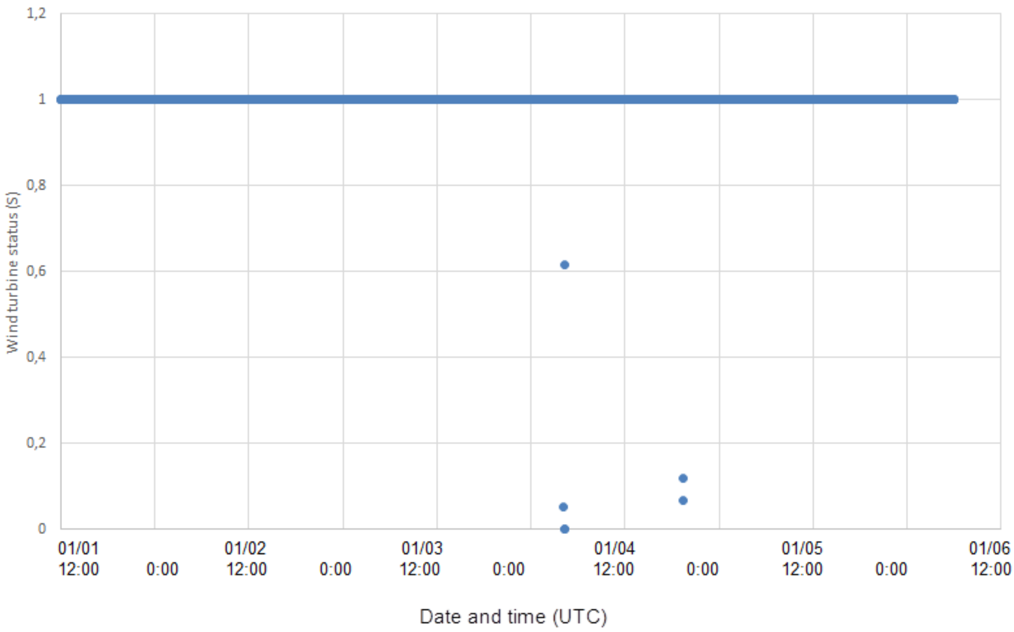


Figure 57. Example of graphical presentation of time evolution of S

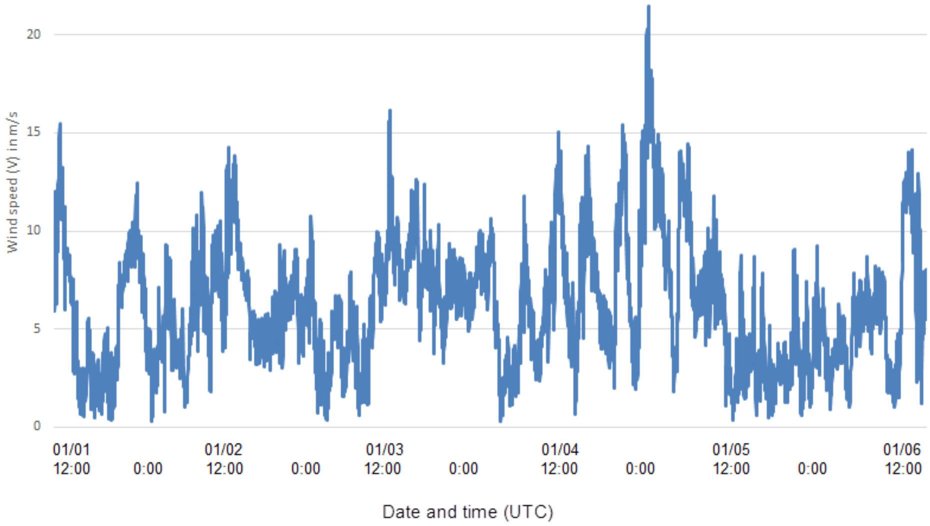


Figure 58. Example of graphical presentation of time evolution of V

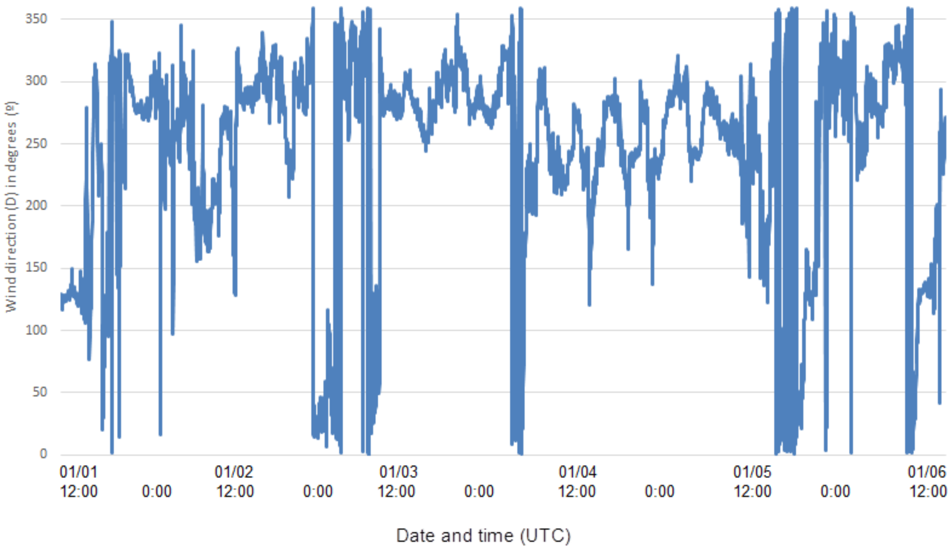


Figure 59. Example of graphical presentation of time evolution of D

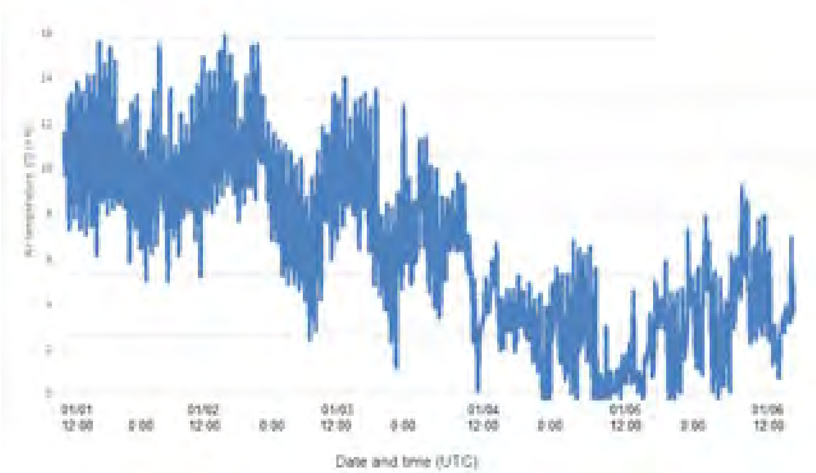


Figure 60. Example of graphical presentation of time evolution of T

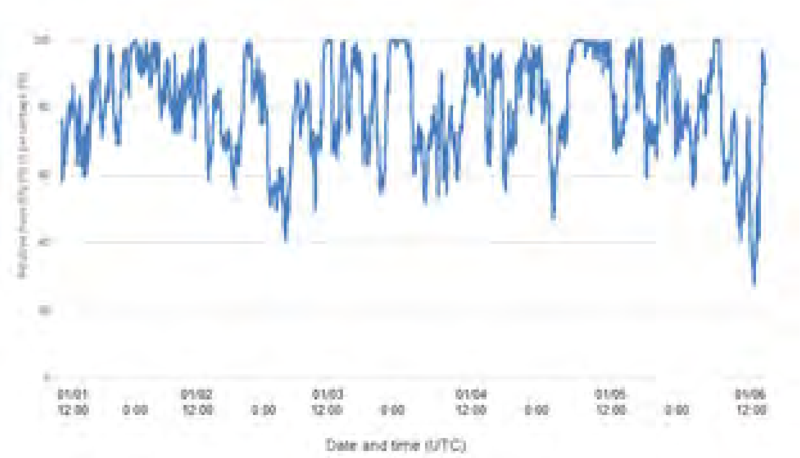


Figure 61. Example of graphical presentation of time evolution of H

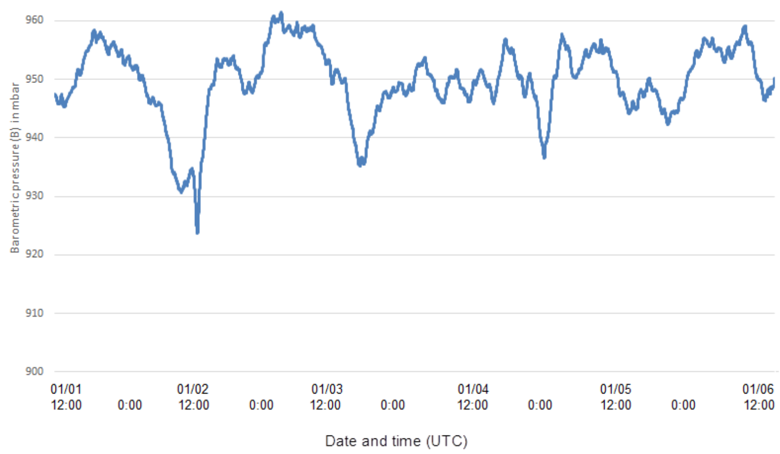


Figure 62. Example of graphical presentation of time evolution of B