D1.1 OPEN ACCESS TECHNICAL DATABASE TO ADVANCE IMPACT ASSESSMENT AND ENERGY MODELLING FOR WIND ENERGY

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Description	This deliverable presents a database to advance impact assessment and energy modelling for wind energy. The database contains climatic and environmental data on world's wind farms (up to October 2021). For each European wind farm, it also includes estimations on expected material demands, land use and life cycle impacts. Additionally, the database includes life-cycle inventory examples for onshore and offshore turbines of various technical characteristics. To populate this database we developed WindTrace, an open-source parametrized life-cycle inventory model for onshore and offshore turbines. The contents of the database and the methods to develop WindTrace are presented, as well as mini-reviews on power curves and CT-curves.

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EXECUTIVE SUMMARY

This deliverable presents a database to advance impact assessment and energy modelling for wind energy. One of the most used approaches for impact assessment of wind energy is life-cycle assessment (LCA), a standardized methodology that evaluates the environmental impacts of a product, process, or service across its entire life cycle. It does so by accounting for all material, energy and waste flows associated with each life-cycle stage. Widely used LCA databases such as Ecoinvent include life-cycle inventories for wind turbines. However, they are based on primary data collected as far back as 1998, making them unable to reflect recent advancements in wind energy. For instance, they do not capture technological improvements or current growing trends in Europe, where the average onshore turbine size scaled from 2.7 MW in 2017 to 4.5 MW in 2023. In this context, this database aims to address two key gaps: first, to provide updated wind turbine data for more accurate impact assessment, and second, to do an assessment of the current European wind fleet. Addressing these gaps enables more refined performance analyses and scenario-based assessments.

As technical data is highly protected, we developed WindTrace, an open-source, parametric life-cycle inventory model built using the LCA Python framework Brightway2. WindTrace generates detailed and customizable inventories based on 22 turbine-specific technical parameters. It is more advanced than similar efforts in the field, as it feeds from more up-to-date data with a wider power range and number of datasets. Additionally, it offers a more comprehensive representation of life-cycle stages beyond material extractions and supports advanced LCA functionalities, such as background modifications to adapt steel manufacturing processes. This feature is particularly relevant given the anticipated transformations in steel production outlined in European decarbonization plans.

To achieve the first goal, the database provides life-cycle inventory samples for both onshore and offshore wind turbines, modelled using WindTrace. These samples represent currently installed and near-future wind turbines under various operating conditions. They incorporate variations in power output, hub height, lifetime, capacity factor, and steel production processes, ensuring flexibility for diverse modelling applications. Power curves define the relationship between wind speed and turbine output, making them essential for accurately predicting wind energy generation and assessing wind energy's role in decarbonization scenarios. For this reason, we conducted a mini-review on the availability of data for power curves and CT-curves, which is detailed in this report.

To achieve the second goal, we applied WindTrace to model the current onshore European wind fleet and conduct an environmental analysis. To this end, we updated the widely used Wind Power database, which contains data on world's wind farms and their geolocation (up to October 2021). An enhancement was the incorporation of climatic data from The Copernicus Climate Data (ERA5) into all entries, which is an essential factor for evaluating wind turbine performance, structural integrity, and energy yield. For the European fleet, we estimated key parameters such as hub height, rotor diameter, and the closest estimable geolocation, where data gaps existed. Moreover, we included results from WindTrace on material demands, land use, and life-cycle impacts, as well as climatic data. The database is fully interoperable with the Wind Power database through a unique ID, ensuring seamless integration for further analyses.

This database allows researchers, practitioners, and policymakers to analyse existing European developments, assess current trends, and derive insights for optimising future wind energy projects. Additionally, the incorporation of climatic data enhances scenario-based modelling, supporting strategic planning for wind energy deployment in line with decarbonisation goals.

1 INTRODUCTION

Wind energy plays a crucial role in Europe's decarbonization efforts. As of 2025, wind power accounts for 17% of the EU's electricity generation, with ambitious targets set under the European Green Deal and the European Wind Power Action Plan to expand wind power capacity from the current 278 GW (WindEurope, 2024) to 425 GW by 2030 and achieve net-zero emissions by 2050 (European Commission, 2019, 2023). However, achieving a just and effective implementation of wind capacity requires overcoming key challenges and taking complex decisions.

The sharing of technical data on wind turbines faces significant barriers rooted in proprietary interests (Kusiak, 2016). This lack of transparency slows the energy transition, as accurate impact assessments and energy modelling are essential for guiding its direction. Consequently, compiling a database with up-to-date technical data remains a major challenge, limiting informed decision-making. As part of JUSTWIND4ALL, the database presented in this work contributes to bridging this gap by providing more accessible and reliable data for wind energy analysis.

In the following subsections, we describe the process we followed to define the structure and contents of the database, and the modelling approach taken to populate the database.

1.1 DEFINITION OF THE DATABASE CONTENTS

The structure and contents of the database were defined using part of the conclusions of a workshop entitled "workshop on identification of barriers and information needs for ENBIOS modelling in the Catalan case study", held at the Institute for Environmental Science and Technology, in Barcelona in March 2023 and organized by Universitat Autònoma de Barcelona (UAB) and Renewables Grid Initiative (RGI). The workshop aimed to *identify the parameters that must be included for robust assessments of wind energy*. The 13 attendees of the workshop were policymakers, industry representatives, NGOs, and civil society operating in Catalunya, a case study of the project that served as a pilot.

The workshop activities departed from a previous identification of the general barriers to the implementation of wind energy (STEP 1). This was followed by the identification of barriers to both onshore and offshore wind energy that are specific in Catalunya (STEP 2) with an open discussion organized in a World Cafe. Barriers were then prioritized following the Eisenhower matrix (Bratterund et al., 2020) of relevance and urgency (STEP3). Finally, the main drivers of the barriers and potential ENBIOS contributions to overcome them were discussed using a two-round process coproduction based on an adaptation of group-level assessment for the five barriers that were classified as priorities (STEP 4).

The workshop concluded that impacts related to the life cycle of the turbines as well as impacts over biodiversity were to be prioritized. However, the lack of available data on material requirement came up as an obstacle to analysing future wind energy implementation scenarios. Delay in implementation due to the length of analysis needed for design was another main conclusion. Because of the impossibility to provide actual protected data, we created WindTrace, an open-source parametric life-cycle inventory model for wind turbines built from scratch within the project. More information about WindTrace is given in the next section.

To answer modellers needs, the open-source database presented in this deliverable has two parts. First, a repository of life-cycle inventory samples for both onshore and offshore wind

turbines modelled using WindTrace. These samples represent currently installed and near-future wind turbines under various operating conditions. They incorporate variations in power output, hub height, lifetime, capacity factor, and steel production processes, ensuring flexibility for diverse modelling applications. The data in this part can be promptly used for impact assessments and is structured as follows:

- Life-cycle inventory samples of current and near-future **onshore** turbines operating in different conditions and modelled using WindTrace. The inventories are given in a format ready to import in Brightway2.
- Life-cycle inventory samples of current and near-future **offshore** turbines operating in different conditions and modelled using WindTrace. The inventories are given in a format ready to import in Brightway2.

Second, it provides an update on the widely used Wind Power database (Pierrot, 2021), which contains data on world's wind farms and their geolocation (up to October 2021). The database is fully interoperable with the Wind Power database through a unique ID, ensuring seamless integration for further analyses. The data is structured as follows:

- For world's installed wind projects:
  - Climatic data (wind density, temperature and wind speed).
- For the European wind fleet:
  - Climatic data (wind density, temperature and wind speed).
  - An estimation on key parameters such as hub height, rotor diameter, and the closest estimable geolocation (where data gaps existed).
  - Mass of materials (WindTrace estimation).
  - Land use and land occupation (WindTrace estimation).
  - Life-Cycle Impact Assessment (calculated applying ReCiPe 2016 impact methods to WindTrace outputs).

1.2 MODELLING TECHNICAL DATA

As we introduced in the previous section, most of the data presented in this database has been produced using WindTrace. WindTrace is built on the principles of life-cycle assessment (LCA), which accounts for all energy and material inputs across the entire supply chain to evaluate the environmental impacts of a product or service. In conventional LCA, life-cycle inventories (LCI), such as those stored in widely used life cycle databases like Ecoinvent (Wernet et al., 2016) and GaBi (Kupfer et al., 2020), are static in nature. This means they represent a specific instance of a product or service within a particular context. For instance, in the case of wind turbines, Ecoinvent includes a 4.5 MW turbine modelled after the Enercon E-112, featuring a reinforced concrete tower. However, this type of tower is not representative of most wind turbines currently in use or being installed, limiting the general applicability of such data.

Parametric LCI models such as WindTrace offer a powerful alternative to traditional static LCI data, maintaining the detailed product-specific nature of conventional LCIs while facilitating their application to broader contexts. These models draw on data from literature and databases to generate tailored LCIs based on key technical parameters, effectively balancing the granularity of static inventories with the flexibility to generalize across diverse scenarios (Hellweg & Milà Canals, 2014). By leveraging parametric variables, such models provide a more precise and adaptable representation of product inventories, addressing data scarcity (Mueller et al., 2004).

The deliverable is structured as follows. In section 2, we describe the technologies included in the database. In section 3, we present WindTrace and its modelling approach. Finally, in section 4 we describe the database, the datasets included and the methods to populate it. Although it is not included in the database, this section also includes a mini-review on open-source datasets for wind turbine power curves and CT-curves.

2 TECHNOLOGIES INCLUDED

2.1 ONSHORE TURBINES

Horizontal axis wind turbines collect the kinetic energy of wind and transform it into electricity. One of the main components of a wind turbine are the blades, which capture the wind's kinetic energy and convert it into rotational motion. The hub connects the blades to the main shaft and enables their rotation. The nacelle houses critical components such as the gearbox, which increases the rotational speed from the blades to match the generator's operating speed (unless it is a direct-drive turbine), and the generator, which converts it into electrical energy. The tower supports the nacelle and blades, while the yaw system rotates the nacelle to align the blades with the wind direction, and the pitch system adjusts the blade angles to optimize efficiency and prevent damage from high winds. The foundation provides structural stability, anchoring the turbine to the ground. Additionally, power electronics and transformers regulate and convert electricity to match grid requirements. Despite differences in design, the main components and materials used remain. The latter include mainly: steel and iron materials, aluminium and alloys, copper, zinc, fiberglass (or carbon fibre), polymer materials, concrete, electric and electronic components, and rare earth (depending on the drivetrain) (Vestas, 2018b).

2.2 OFFSHORE TURBINES

Offshore wind turbines share most structural components with their onshore counterparts, including blades, hub, nacelle, generator, and tower. However, due to their offshore nature, their foundation system differs significantly. The choice of foundation type depends primarily on water depth and seabed conditions. Fixed-bottom foundations, which are suitable for shallow waters (typically up to 60-70 meters deep), include gravity-based structures, monopiles, tripods, and jacket foundations (Figure 1a). Among these, monopiles have been the most widely used, particularly in the North Sea, due to their cost-effectiveness, simplicity, and suitability for relatively shallow depths. However, as wind farms move further offshore into deeper waters, fixed-bottom solutions become less viable.

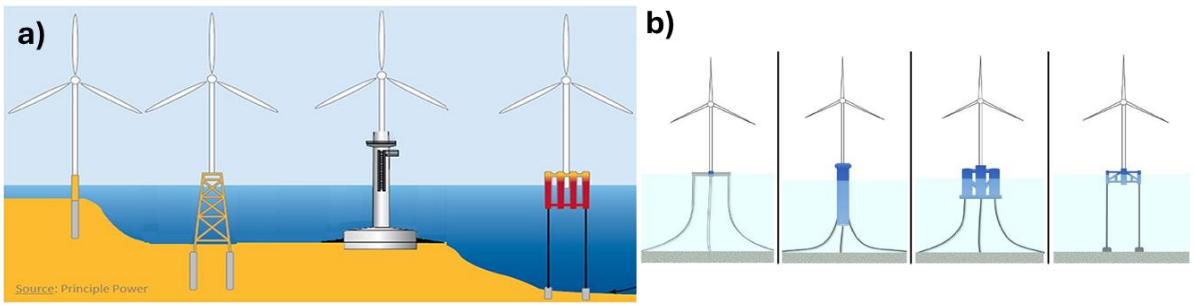

Figure 1. a) Offshore foundation types. From left to right monopile, jacket, gravity-based, and floating. b) Established floating structure designs. From left to right barge, spar-buoy, semi-submersible platform and tension-leg platform.

For deeper waters, floating foundations have emerged as a promising solution, enabling the deployment of wind turbines in locations with stronger and more consistent wind resources. The most established floating foundation concepts include semi-submersible platforms, spar buoys, tension-leg platforms (TLPs), and barges (Figure 1b). While many floating wind turbines remain in the test phase, several commercial projects have already been deployed:

- Hywind Scotland (30 MW, spar buoy). The world's first commercial floating wind farm, located off the coast of Scotland.
- Hywind Tampen (88 MW, spar buoy). A floating wind farm in Norway designed to power offshore oil and gas platforms.
- Kincardine (50 MW, semi-submersible). One of the largest floating wind projects, situated off the coast of Scotland.

Despite the success of these projects, the future of floating offshore wind remains dynamic and uncertain, with new concepts constantly emerging. A key example is Mingyang's OceanX model, a novel double-rotor 16.6 MW turbine, which has already been installed at China's Qingzhou IV Offshore Wind Farm. Even though the path floating platforms will take in the coming years is uncertain, WindTrace focuses on established foundation concepts, including floating platforms described in Figure 1b, as will be discussed in section 3.2.

3 WINDTRACE MODELLING

3.1 CONTEXT: PARAMETRIC LIFE-CYCLE INVENTORIES FOR WIND ENERGY

Several life-cycle parametric models have been previously described in the literature for wind turbines and farms. These include an offshore park model proposed by Blanc et al., (2012), a tool to model specifically Enercon turbines (Zimmermann, 2013), and a simplified model for greenhouse gas emissions per kWh produced by an onshore turbine. More recent attempts were more robust and included advanced LCA capabilities such as background adaptations using prospective databases for offshore turbine modelling (C. Li et al., 2022), or geographic and time-explicit background markets adaptations for the Danish context (Sacchi et al., 2019).

However, the models previously proposed in the literature face several limitations. These include a restricted range of turbine samples from which data is derived, outdated or insufficiently updated datasets, or a lack of open-source accessibility. Additionally, many models provide limited detail on life-cycle stages beyond material production, constraining their applicability for comprehensive environmental assessments.

In order to overcome these limitations, we developed WindTrace, a parametric life-cycle inventory model that allows to build tailor-made inventories for onshore and offshore wind turbines and parks in Europe. The model is implemented in a python package, making use of the capabilities of the framework for life-cycle assessment Brightway 2.5 (Mutel, 2017). It is available in GitHub (https://github.com/LIVENlab/WindTrace_public), where examples of use are provided. The main contribution of WindTrace is related to the completeness and up-to-date datasets used to model material data inputs of the turbine. They are derived from 25 datasets, four dating back to 2007 and the rest spanning the 2014-2023 period, covering a power range from 150 kW to 6.2 MW. This provides a broader and up-to-date power range compared to previous attempts, enhancing the tool's robustness for modelling current and near-future turbines. Moreover, WindTrace also offers a deep level of detail in life-cycle stages other than materials.

3.2 WINDTRACE OVERVIEW

The main objective of WindTrace is to model the material, energy and other needs to build, maintain and decommission a wind park and the individual turbines that constitute it. Figure 2 presents a schematic overview of WindTrace's workflow for onshore turbines, highlighting its key components and processes. The model requires 19 input parameters from the user. Of these, 11 parameters must be specified to meet user-defined requirements, while 7 parameters are optional, with predefined default values available for cases where specific input data is unavailable. The user-provided inputs are integrated with up-to-date technical data sourced from literature and industry reports to generate comprehensive Life Cycle Inventory (LCI) data.

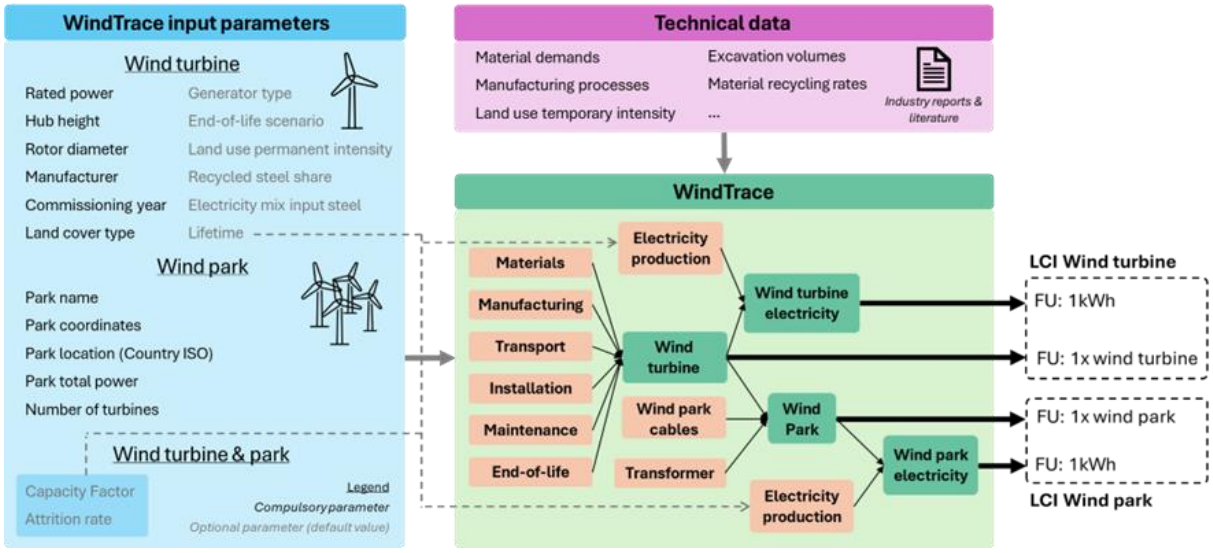

Figure 2. Scheme of the WindTrace workflow. Grey arrows correspond to input data and black arrows are outputs. The blue boxes define the parameters that must be included in the model to generate the LCIs for each turbine or wind park. The purple box lists the data that was used for building the WindTrace model. FU = Functional Unit.

In the case of offshore turbines, WindTrace has a different module, where the workflow is slightly modified to accommodate three new parameters: distance to shore, foundation type and seabed depth. The offshore module allows to model the turbine (only tower, nacelle, rotor and blades) and the foundations separately, as shown in Figure 3. Thus, the user can choose among gravity-based, monopile, tripod, or six types of floating foundations which include barge, spar buoy (concrete), spar-buoy (iron), spar-buoy (steel), semi-submersible platform or tension-leg platform.

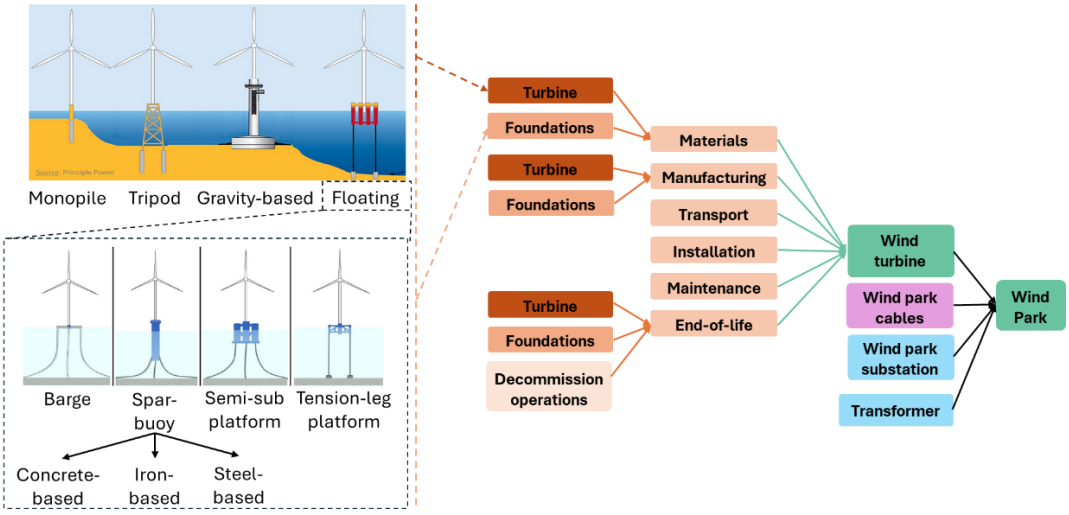

Figure 3. Scheme of the WindTrace offshore module inventory structure.

The outputs of WindTrace include LCIs for:

1) The entire wind park, encompassing the wind turbines, intra-array cables, and transformer
2) A single wind turbine, covering all life-cycle stages such as material requirements, manufacturing, transportation, installation, maintenance, and end-of-life management.

These outputs can be expressed both per unit of infrastructure (e.g., a single wind turbine or a complete wind park) and per kilowatt-hour (kWh) of electricity generated, offering flexibility and precision in environmental assessments.

Apart from the onshore and offshore modules, WindTrace has a third module that enables to deal with different end-of-life strategies for a wind turbine or park. This includes repowering, lifetime extension through substitution of damaged turbine pieces, or substitution of the turbine for one of the same characteristics, maintaining certain elements of the common wind park infrastructure such as cabling, transformer or foundations.

3.3 WINDTRACE DESCRIPTION

3.3.1 MODELING OF LIFE-CYCLE STAGES FOR ONSHORE TURBINES

In this section, the system boundaries, data sources, and assumptions to build the life-cycle inventory foreground of the wind turbines and park will be briefly described, both for the cases of onshore and offshore. For background data, we employed the database Ecoinvent v3.9.1 (Wernet et al., 2016) using the cut-off system model. Further details on the general modelling approach and each of the life-cycle stages will be available in (Sierra-Montoya et al., 2025).

3.3.1.1 Material demands

A set of discrete turbines from the industry was used as a basis to generalize turbine inventories. Materials from the turbine and the foundations were modelled according to data from 21 Vestas turbine types in the range from 2 MW to 6.2 MW. The data was collected from Vestas LCA reports from the period 2011-2023, including the following:

- 2 MW: V90-2.0 (Vestas, 2011), V100-2.0 (Vestas, 2015a), V110-2.0 (Vestas, 2015b), V116-2.0 (Vestas, 2018b), V120-2.0 (Vestas, 2018c).

- 2.6 MW: V100-2.6 (Vestas, 2013).
- 3.0 MW: V90-3.0 (Vestas, 2012).
- 3.3 MW: V105-3.3 (Vestas, 2014a), V112-3.3 (Vestas, 2018a), V117-3.3 (Vestas, 2014b), V126-3.3 (Vestas, 2014c).
- 3.45 MW: V105-3.45 (Vestas, 2017a), V112-3.45 (Vestas, 2017b), V117-3.45 (Vestas, 2017c), V126-3.45 (Vestas, 2017d), V136-3.45 (Vestas, 2017e).
- 4.2 MW: V117-4.2 (Vestas, 2019), V136-4.2 (Vestas, 2022a), V150-4.2 (Vestas, 2022b).
- >6.0 MW: V150-6.0 (Vestas, 2023a), V162-6.2 (Vestas, 2023b).

Materials from four turbines in the range 0.15 MW to 2 MW were also included, with data coming from (Burger & Bauer, 2007). To model wind turbine input needs, the mass of each material is fitted as a function of the wind power capacity, except for steel that is modelled as a function of the hub height instead. Figure 4 shows the fitting curves for each material in the turbine and the foundations (showing only onshore turbine foundations). Despite the use of rare earth elements was not contemplated in the reference data, meeting its wind industry demands in the coming years poses a major challenge (Alves Dias et al., 2020; J. Li et al., 2020). Therefore, WindTrace includes material intensities for praseodymium, neodymium, dysprosium, terbium, and boron (Carrara et al., 2020).

Steel is the main material of the tower, which makes it the highest in mass in the turbine (between 54% and 71% according to Vestas' reports), excluding the foundations. Because steel production is a carbon intensive process (Holappa, 2020), the adaptation of its background to the case of wind industry could have a huge influence on the climate change impact results. Europe has a strong steel industry, with 126 million metric tonnes produced in 2023, and it only became a net importer of this material by 2016 (Eurofer, 2024). Thus, WindTrace adapts the steel background activity assuming that its production is made in Europe solely. The shares of primary and secondary steel inputs are considered with geographical and temporal resolution (2012 – 2021), using data from the European Steel in Figures Reports, which report share values for primary steel between 56.4% and 59.5% during this period.

3.3.1.2 Manufacture and transportation

The manufacturing stage includes the industrial transformation processes to shape materials of wind turbines. For each material in the turbine and foundations an Ecoinvent manufacturing process was assigned, as summarized in Table S4. This stage also includes the electricity used in the assembly of the nacelle. To make the process geographically specific, the location of wind turbine manufacturing sites in Europe from Vestas, Siemens Gamesa, Nordex, Enercon and LM Wind was collected from their official websites. The location of the closest manufacturer's factory was used to calculate the transportation distance to the wind farm location and to choose the national electricity mix employed during the manufacturing process. A single manufacturing site and road transportation in a straight line were assumed for simplification purposes.

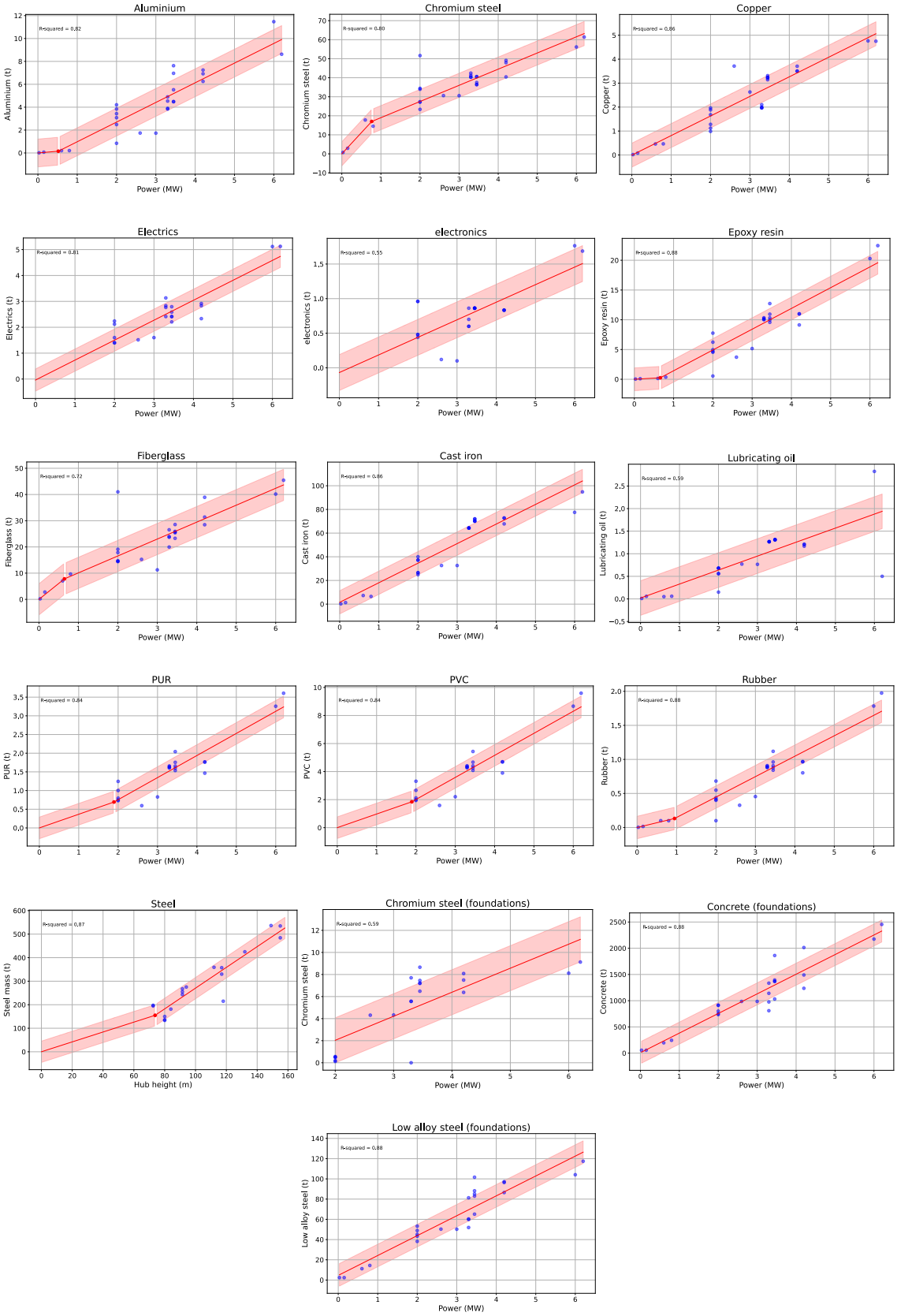

Figure 4. Materials in the turbine and foundations.

3.3.1.3 Installation

The installation stage includes the temporary and permanent land transformation due to the deployment of the access roads, the substation, the transformer, and the turbines, according to land use shares provided by Denholm et al., 2009 and Siemens Gamesa, 2022. It also includes the excavation activities to set the turbine foundations and the construction of the access roads.

3.3.1.4 Maintenance

The maintenance stage includes inspection trips every six months (Elsam Engineering, 2004) and lubricating oil changes every two years (Abeliotis & Pactiti, 2014). The replacement of turbine sub-components during its operational lifetime is excluded from the system boundaries due to its highly case-specific nature, being too unpredictable to be generalised.

3.3.1.5 End-of-life

Since in WindTrace we followed a cut-off system model approach, the end-of-life stage considered no environmental burdens related to recycling processes, as these are allocated to the user of the recycled material (Sonderegger & Stoikou, 2022). Four end-of-life scenarios can be selected in WindTrace.

3.3.1.6 Wind turbine electricity production

WindTrace estimates the electricity produced by a turbine and creates a life cycle inventory per kWh accordingly. The annual electricity production of a wind turbine depends on the annual capacity factor, which measures the actual electricity output of a turbine relative to its maximum electricity output at full capacity over a year. However, as the turbine gets older, the efficiency of the turbine is reduced due to physical attrition of turbine components, affecting its capacity factor (Germer & Kleidon, 2019; Olauson et al., 2017; Staffell & Green, 2014). Thus, to estimate the electricity production of a wind turbine in WindTrace, a decreasing capacity factor formula is used as defined in (Equation 1, where *CF* is the annual capacity factor, CF_i is the capacity factor of the first year, *k* is the attrition rate, and *age* is the operation year. Considering this, the electricity production of a turbine ($E_{turbine}$) is defined as the sum of the annual electricity production of a turbine of a certain power ($P_{turbine}$) throughout its operation lifetime (*LT*) as expressed in (Equation 2.

$$\textit{(Equation 1)}\ CF = CF_i \times (1-k)^{age}$$

$$\textit{(Equation 2)}\ E_{turbine} = P_{turbine} \times 365 \times 24 \times CF_i \sum_0^{LT-1} (1-k)^{age}$$

3.3.1.7 Wind park modelling

The wind park inventory contains the wind turbines, the intra-array cables, and the transformer. The system boundaries of the park are set at the transformer, leaving the electricity grid out of the scope. The cables are modelled considering the materials, manufacturing process and excavation activities. The transformer is modelled scaling an ABB transformer of 500 MVA, including the required materials, electricity and heat to build it (ABB, 2003). The wind park power (P_{park}) serves to calculate the electricity production of a wind park (E_{park}, Equation 3), which is used by WindTrace to create a life cycle inventory of the wind park per kWh.

$$\textit{(Equation 3)}\ E_{park} = P_{park} \times 365 \times 24 \times CF_i \sum_0^{LT-1} (1-k)^{age}$$

3.3.2 OFFSHORE TURBINES AND PARKS

3.3.2.1 Material demands

Material demands for offshore turbines are modelled the same as onshore turbines. However, the foundations are modelled independently, with the following options: gravity-based, monopile, tripod, or six types of floating foundations which include barge, spar buoy (concrete), spar-buoy (iron), spar-buoy (steel), semi-submersible platform or tension-leg platform.

Gravity-based foundation is an approach that relies on the weight of the foundations to make the whole infrastructure stable on the seabed. Therefore, there is no seabed penetration. It is an option in shallow waters, usually less than 15 meters deep (Bilgili & Alphan, 2022; Jiang, 2021; Wu et al., 2019). We used data from (Tsai et al., 2016), where they describe gravity-based foundations for a 3 MW turbine, consisting of a transition piece (steel), the cement base that gives stability to the structure, and the scour protection based on gravel. In WindTrace, these foundations are scaled as assuming a linear relation between the power and foundations mass. Moreover, we assume that an increase in sea depth is always modelled as an enlargement of the transition element, but not the general structure. This poses a limitation to the modelling, as this might not be the case in real structures.

Monopiles are the most common type of foundations in shallow waters, usually below 35 meters depth (Bilgili & Alphan, 2022; Jiang, 2021; Wu et al., 2019). For example, they are almost exclusively used in all projects in the North Sea. In WindTrace, the monopile includes a steel transition piece, a cement grout and a scour protection consisting of gravel. The length of the monopile is calculated as a function of the penetration depth and the sea depth. The larger the power of the turbine, the more penetration is required to stabilize the infrastructure, while the deeper the sea depth, the longer the tower. The diameter of the tower is also variable, and it is modelled as a function of the turbine power. The approach is adapted from Sacchi et al., (2019).

Tripod structures are used in depths between 35-60 meters (Bilgili & Alphan, 2022; Jiang, 2021; Wu et al., 2019). We took data from Tsai et al., (2016) to model these foundations for a 3 MW turbine. In WindTrace, we use the same approach as for the gravity-based foundations described above.

Finally, six types of floating platforms can be chosen. The primary data for this modelling is summarized in Table 1. Essentially, we carried out a literature review and grouped all platforms with the same floating concepts. Then, we calculated a mass intensity for each material, in kg per MW. These material intensities are later used in WindTrace.

3.3.2.2 Manufacturing and transport

Tha manufacturing phase is modelled in the same way than onshore turbines.

Dragging the turbines from port to location was modelled assuming the use of vessels. We rescaled Garcia-Teruel et al., 2022 data. Specifically, we calculated the tonnes per kilometer (tkm) required for the dragging as a function of the mass and the distance to shore.

3.3.2.3 Installation

The installation phase in the LCI encompasses vessel operating time, scaled from Garcia-Teruel et al., (2022), as well as transformation and occupation flows of the seabed, calculated from Tsai et al., (2016).

Table 1. Summary of data on floating platforms collected from the literature, and calculated material intensities (in kg/MW) for each floating platform.

Floating concept	Semi-sub platform	Spar-buoy concrete	Spar-buoy iron	Spar-buoy steel	Tension-leg	Barge
References	Brussa et al., 2023; Garcia-Teruel et al., 2022; Raadal et al., 2014; Yuan et al., 2023	Bang et al., 2019; Pulselli et al., 2022	Garcia-Teruel et al., 2022	Chipindula et al., 2018; Pulselli et al., 2022; Raadal et al., 2014	Raadal et al., 2014	Yildiz et al., 2021
Mass intensity (kg/MW)	5,3E+05	9,9E+05	1,4E+06	2,6E+05	1,9E+05	2,7E+06
steel (%)	90,9	16,0	41,3	97,5	95,8	16,7
concrete (%)	1,4	84,0	0,0	2,5	0,0	79,5
iron (%)	7,7	0,0	58,7	0,0	0,0	1,1
hdpe (%)	-	-	-	-	7,3	0,0
steel (kg/MW)	4,8E+05	1,6E+05	5,9E+05	2,6E+05	1,8E+05	4,6E+05
concrete (kg/MW)	7,6E+03	8,4E+05	0,0E+00	6,5E+03	0,0E+00	2,2E+06
iron (kg/MW)	4,0E+04	0,0E+00	8,3E+05	0,0E+00	0,0E+00	3,0E+04
hdpe (kg/MW)	-	-	-	-	1,4E+04	0,0E+00

3.3.2.4 Maintenance

Although current maintenance approaches of floating turbines are based on tow-to-port, the trend of the field is to do on-site maintenance (Centeno-Telleria et al., 2025; Hu et al., 2024) to minimize costs. Actually, the first major offshore corrective mainenance without dragging to port for floating turbines was successfully carried out in September 2024 in the Kincardine Offshore Windfarm, in Scotland (Hashemi, 2024) For this reason, we assume that for all types of foundations, the maintenance will be carried out on-site using heavy lift vessels. The included maintenance considers planned maintenance, broken pieces repairment, including 18 lubricating oil replacements and 17 changes of power electronic components throughout the lifetime of the turbine. All replacements are assumed to be repaired and not replaced, reducing the need for extra materials.

3.3.2.5 End-of-life

It includes the use of vessels for the decommissioning operations based on Garcia-Teruel et al., (2022), as well as the the end-of-life treatment of all materials and components in the wind farm. For the latest, the same approach as for the onshore turbine is followed, with the inclusion of the substation, cabling and offshore foundations.

3.3.2.6 Wind park modelling

The wind park inventory contains the wind turbines, the intra-array cables, the transformer, substation platform and cables to shore. The cables modelling approach which differs from onshore turbines. We modelled them as reported by Brussa et al., (2023), where the intra-array cables are 35% MVAC 66kW (120 mm^2 section) and 65% MVAC 60kW (500 mm^2 section), while the cables to shore (export cables) are HVDC 500kW. No onshore cables to reach the

onshore substation are considered. We assume a constant turbine spacing of 7.7 times the rotor diameter, as this was the mean spacing for offshore parks in the UK in 2019 (Bosch et al., 2019). However, this can be a limitation, as the yearly mean spacing has been progressively increasing up to 8.4 times the rotor diametes, probably to diminish wake effect issues (Bosch et al., 2019). In WindTrace, we assume the transformer is mounted on a substation platform, that was modelled following (Brussa et al., 2023).

4 DATABASE

4.1 DESCRIPTION

The full database emerging from this work is available at the institutional repository of UAB (DDD) and in the Zenodo Community for JUSTWIND4ALL in Excel format. It includes two parts separated in two Excel files.

The first part (D1_1_turbine_samples.xlsx) consists of a repository of life-cycle inventory samples for both onshore and offshore wind turbines modelled using WindTrace. These samples represent currently installed and near-future wind turbines under various operating conditions. They incorporate variations in power output, hub height, lifetime, capacity factor, and steel production processes, ensuring flexibility for diverse modelling applications. The data in the Excel file contains the following spreadsheets:

a) Summary: a short database content description and licensing information.
b) Turbine_samples_metadata: includes a brief description of WindTrace, the technical characteristics of the turbine samples included in the database, and how to read the inventory_samples spreadsheets both for onshore and offshore turbines.
c) Onshore_inventory_samples: it contains samples of Life-cycle inventories of onshore turbines with different technical characteristics. Format of the file structured to be compatible with the open-source LCA software Brightway2 (Mutel, 2017). Explanation on how to read the samples in the sheet 'Turbine_samples_metadata'.
d) Offshore_inventory_samples: it contains samples of Life-cycle inventories of offshore turbines with different technical characteristics. Format of the file structured to be compatible with the open-source LCA software Brightway2 (Mutel, 2017). Explanation on how to read the samples in the sheet 'Turbine_samples_metadata'.

The second part (D1_1_European_fleet.xlsx) consists of an update on the widely used Wind Power database (Pierrot, 2021), which contains data for world's wind farms and their geolocation (up to October 2021). The database is fully interoperable with the Wind Power database through a unique ID, ensuring seamless integration for further analyses. It contains the following spreadsheets:

a) Summary: including a short database content description and licensing information.
b) Database_metadata: describes the content and the fields included in each spreadsheet, as well as their data sources.
c) Technical_data_World: it is the first spreadsheet of the database after the metadata sheets. It contains data from world's installed wind projects including climatic data. Data extension of the Wind Power database (Pierrot, 2021) with connection through an ID.
d) Technical_data_Europe: it contains data from European wind projects, an extension of the Wind Power database with connection through an ID. It includes improved geographical scope, and an estimation of the hub height and the rotor diameter for

those wind projects with data gaps. It also provides connection between the Wind Power database and the Wind Power Manufacturers and Turbines database (Pierrot, 2023) via ID_technical.

e) LCI_Materials: it contains the mass of materials for European wind projects modelled using WindTrace. Data extension of the Wind Power database with connection through an ID.
f) LCI_Land: it contains the land use and land occupation of European wind projects modelled using WindTrace. Data extension of the Wind Power database with connection through an ID.
g) LCIA_Impacts: it contains the Life-Cycle Impact Assessment of European wind projects using inventories modelled using WindTrace and ReCiPe 2016 impact methods. The functional unit is one park (not kWh). Data extension of the Wind Power database with connection through an ID.

4.2 DATASETS

In this section, the methods used to populate the database are presented.

4.2.1 WIND TURBINE MODELLING SAMPLES (ONSHORE AND OFFSHORE)

As we mentioned above, the database (D1_1_turbine_samples.xlsx) includes data on a set of turbines with varying characteristics to improve energy modelling and impact assessments. This includes life-cycle inventories for onshore and offshore turbines in brightway2 Excel format. This section presents the methods to create these inventories as well as a mini-review on available data for power curves and CT-curves.

Table 2. Characteristics of the onshore turbine models included in the database.

Modified parameters	Turbine 2.0MW (based on Vestas V90-2.0)	Turbine 4.5MW (based on Vestas V150-4.5)	Turbine 6.0MW	Turbine 8.0MW
Power (MW)	2	4,5	6	8
Hub height (m)	97 (constant)	90, 110	125, 155	155 (constant)
Capacity factor	0.15, 0.2, 0.25	0.25, 0.35	0.3, 0.35	0.4, 0.45
Lifetime (years)	20 (constant)	20 (constant)	20 (constant)	25, 30
Electricity mix in steel production	Current European (constant)	Current European (constant)	Current European, current Norway	Current Norway (constant)

4.2.1.1 Onshore turbines

The spreadsheet *onshore_inventory_samples* in the database provides inventories (modelled using WindTrace) with different technical characteristics, namely nominal power, hub height, capacity factor, lifetime and electricity mix for steel production. The structure of the database is ready to be imported in the life-cycle assessment open-source tool Brightway2. Table 2 shows the characteristics of the turbine variations included in the database. More information on how to read the inventory names in the database metadata.

4.2.1.2 Offshore turbines

The spreadsheet *offshore_inventory_samples* in this database provides inventories (modelled using WindTrace) similarly to *onshore_inventory_samples*. The offshore database includes four types of turbines with different technical characteristics. Three of them are based on real turbine models already in operation, and the last one has only been announced by the manufacturer. The database includes an example of each turbine according to the real technical specifications of the wind farm where it is operating. Because all the examples correspond to monopile turbines, we also modelled each of the turbines maintaining the technical characteristics of the site but changing the foundation types and sea depths. Table 3 synthesises it. More information on how to read the inventory names in the database metadata.

Table 3. Characteristics of the offshore turbine samples included in the database.

Model	Siemens Gamesa SWT-6.0-154	Vestas V164-8.0 MW	Vestas V164-10.0	Vesats V236-15.0
Manufacturer	Siemens Gamesa	Vestas	Vestas	Vestas
Power (MW)	6	8	10	15
Rotor diameter (m)	154	164	164	236
Hub height (m)	120	105	122	143
Wind park example	Rampion Offshore Wind Farm (UK)	Burbo Bank Offshore (extension)	Seagreen Offshore (Scotland)	-
Foundations type	Monopile	Monopile	Monopile	Monopile
Sea depth (m)	20-50	3.5-17	42-58	-
Distance to shore (km)	13-20	8	27	-
CF (%)	39	35	40,58	-
Location	(50.750, -0.300)	(53.500, -3.200)	(56.633, -2.217)	-
Commissioning year	2018	2017	2023	-

4.2.1.3 Power curves

Power curves are essential in energy modelling as they define the relationship between wind speed and turbine power output, enabling accurate predictions of wind energy generation. They are crucial for optimizing wind farm layouts, forecasting grid balancing needs, and evaluating the role of wind energy in decarbonization scenarios, among others. In this section, we do a mini-review of data availability on power curves for different wind turbine models.

The webpage https://en.wind-turbine-models.com/powercurves (accessed 31-Jan-2025) provides data on 374 power curves from various wind turbine models and manufacturers. The smallest turbine listed is the *superwind SW 350-II* (0.35 kW), while the biggest turbine is the *W2E Wind to Energy W2E-215/9.0* (9.0 MW). The site features an interactive visualization tool that allows users to filter turbines by rotor diameter and rated power, as well as compare power curves of different models.

A repository with available power curves is hosted in GitHub (https://github.com/NREL/turbine-models) and provided by the National Renewable Energy Laboratory (NREL). The repository includes data in csv format on distributed wind energy turbines (i.e., small turbines for on-site consumption), and reference onshore and offshore turbines:

- 25 distributed wind energy turbines in the range of 1 kW (*SWIFT_1kW_2.1*) to 225 kW (*VestasV29_225kW_29*).
- 14 offshore reference turbines from NREL, the International Energy Agency (IEA), the Denmark Technical University (DTU) and the LEANWIND project (Desmond et al., 2016), in the range of 5 MW to 18 MW.
- 21 onshore reference turbines from NREL, IEA, Vestas, and General Electrics, in the range of 660kW to 7MW.

Another repository (https://github.com/YvesMSaintDrenan/WT_PowerCurveModel) provides a parametric model for wind turbine power curves incorporating environmental. It accounts for technical features of the turbine (power density, cut-in and cut-out speeds, limits on rotational speed and aerodynamic efficiency), and environmental factors (turbulence intensity, air density, wind shear and wind veer). More details on the model can be consulted in the corresponding research paper (Saint-Drenan et al., 2020).

4.2.1.4 CT-curves

The Thrust Coefficient (CT) Curve in wind energy represents the relationship between the thrust coefficient and the wind speed for a given wind turbine. The thrust coefficient is a dimensionless number that describes the fraction of the wind's dynamic pressure that is converted into axial force (thrust) on the turbine rotor. CT-curves are useful in wind energy because they help characterize the aerodynamic behaviour of a wind turbine by describing how the thrust force exerted on the rotor changes with wind speed, which is crucial for optimizing turbine performance, assessing wake effects in wind farms, designing load-bearing structures, and improving control strategies to minimize mechanical stress and maximize energy output. In this section we do a mini-review of open-source data availability on CT-curves for different wind turbine models.

Unfortunately, data on CT-curves on commercial or reference turbines is very scarce. One example is the Denmark Technical University (DTU) PyWake tool (https://gitlab.windenergy.dtu.dk/TOPFARM/PyWake). This tool has three built-in turbines, which are the commercial Vestas V80 from the offshore park Hornsrev1, and the reference IEA 3.4 MW turbine, and DTU 10MW reference turbine. These turbines can be loaded and their CT-curves can be accesses using the function powerCtFunction(wind_speeds) for a range of wind speeds.

4.2.2 WORLD AND EUROPEAN WIND FLEET

Departing from data from The Wind Power Database on World wind farms updated to October 2021, we add layers of information to this data and allow the connection with the original dataset via an ID code. For World wind farms, we provide additional climatic data. For European wind farms, we provide data gaps filling on the original data (i.e., estimated location, hub height and rotor diameter), data on materials, land use and occupation, and life cycle impacts calculated using WindTrace for each wind farm.

4.2.2.1 Climatic data

Climatic and environmental data is critical for energy modeling as it directly influences wind turbine performance, structural integrity, and energy yield assessments. Thus it is very relevant for wind energy modelling. For each World's wind farm location in The Wind Power database, we added data on wind density, temperature and wind speed. For all these variables, the mean, maximum and minimum values were added. Data was taken from ERA5 (Hersbach et al., 2020). Original entries without a specified location were excluded from the database. Wind density values could not be retrieved from ERA5 for 7,362 entries and therefore are given as NaN values.

4.2.2.2 Data filling methods on the European wind fleet

The Wind Power database provides data on the wind farm coordinates, the wind turbine manufacturer and model, and the hub height, among others. With the turbine model, specific data on its technical characteristics can be gathered through the Wind Power Manufacturers and Turbines database (e.g., rotor diameter, generator type, …). However, data is not complete for all wind farms. This can pose a limitation for data analysis of the dataset or to use the dataset for modelling. In our case, we want to use the dataset to run WindTrace and being able to provide estimations on material requirements and environmental impacts of each wind farm in Europe.

As shown in Figure 2, WindTrace requires inputs that define some of the technical characteristics of the wind farm and the wind turbines that conform it. The original dataset of The Wind Power database has 23090 wind farm entries in Europe. Excluding offshore turbines, which were not analysed in this study, the number of entries is reduced to 22703 (1.7% of farms excluded). However, there are necessary parameters for WindTrace which have a low level of completeness, such as hub height (63%) or generator type (72%) (see Table 4). Therefore, using the original dataset we would be excluding as many as 37% of the wind farms for the analysis. For this reason, we used a data filling method to estimate data on: (1) coordinates, (2) hub height, (3) rotor diameter (when no turbine model data is available), (4) turbine power (when no turbine model data is available) and (4) generator type. Filling these data gaps would increase the number of turbines ready to be modelled using WindTrace.

Table 4. Required parameters to run WindTrace, with their equivalent in The Wind Power and Manufacturers and turbines databases, and their degree of completeness in the original datasets.

WindTrace parameter	Reference database	Variable name in the database	Completeness (%)
Wind park power	The Wind Power	Total power	95
Park location	The Wind Power	ISO code	100
Commissioning date	The Wind Power	Commissioning date	92
Coordinates (latitude, longitude)	The Wind Power	Latitude, Longitude	95
Number of turbines	The Wind Power	Number of turbines	97
Manufacturer	The Wind Power	Manufacturer	86
Turbine model	The Wind Power	Turbine	78
Hub height	The Wind Power	Hub height	63
Generator (for generator type)	Manufacturers and Turbines	Generators	72

Figure 5 summarizes the decision tree implemented to fill the data gaps. In Figure 5, we compiled a dummy example with fake data from the Wind Power database and Manufacturers and Turbines database, that we will use to help following the decision tree.

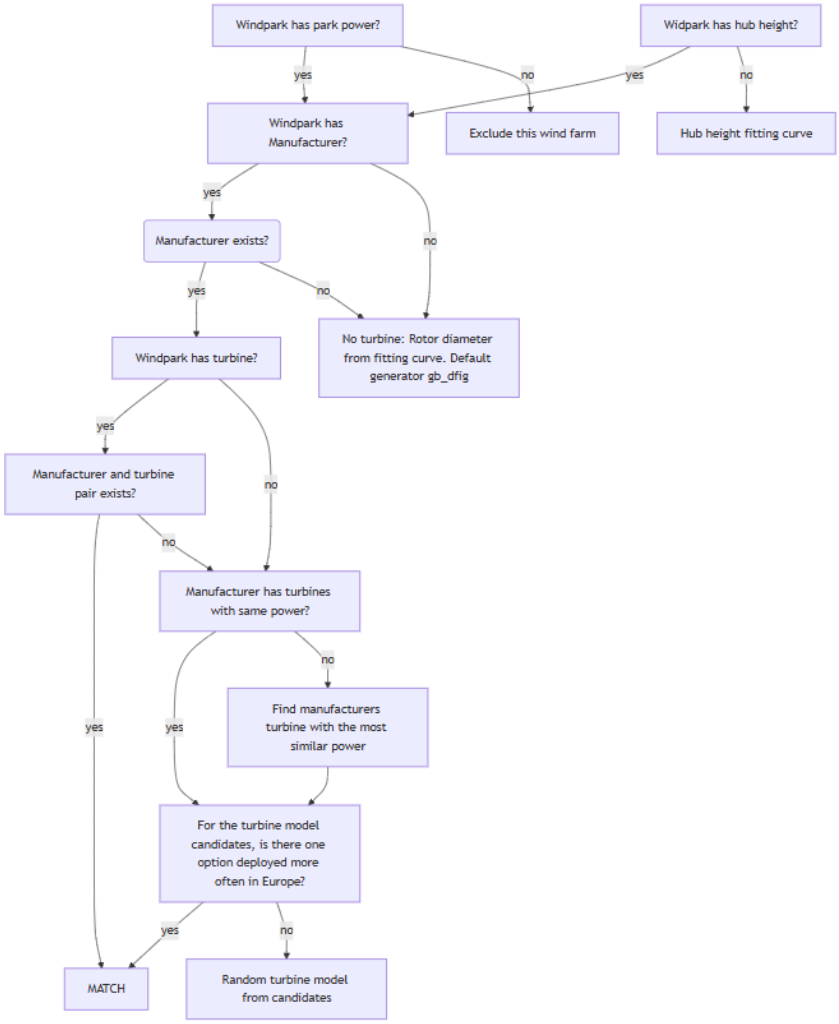

Figure 5. Decision tree implemented to fill data gaps in The Wind Power Database.

The first step is to exclude those entries for which there is no data on the wind park power (5.16% of farms excluded). This would be the case of ID 1 in Figure 6a. For the 22541 remaining entries, the next step is to determine if they have a hub height. If they don't, as for example in Figure 6a ID 2, then the hub height is interpolated from the rated power by using a fitting curve created with all European turbines in The Wind Power database (see an example in Figure 7).

The next step is to match each wind farm in the Wind Power database with the corresponding turbine technical data in the Manufacturers and Turbines database, in order to have data on the rated power, the rotor diameter, and the generator type. This step is divided into three sub-steps. First, we check if the manufacturer in the Wind Power database exists in the Manufacturers and Turbines database. If we consider Figure 6a ID 3, the manufacturer 'Manufacturer_1' is not listed in the Manufacturers and Turbines database. When this is the case, it is not possible to do any matching. Thus, the rated power, the rotor diameter and the generator type must be estimated. The rated power is estimated by dividing the total power of the park by the number of turbines, assuming all the turbines

have the same power. The rotor diameter is interpolated from the power using a fitting curve, similar to the approach shown in Figure 7. Finally, we consider that the default generator type is gear-boxed double fed induction generator (gb_dfig). Second, in case the manufacturer does exist, we check if the wind park has a value for the turbine model. If there is no value, then we search in the Manufacturers and Turbines database for a turbine from the same manufacturer with the same power or a power close to it. This would be the case of Figure 6a ID 4. Finally, if the wind farm has both a manufacturer and a turbine model, then we check whether this combo exists in the Manufacturer and Turbine database. In Figure 6a ID 5 that is not the case, as the combo Nordex N50/800 is not listed in the Manufacturers and Turbines database. Then we would follow the previous approach and search for a Nordex turbine of similar power.

Finally, there is the possibility that the combo manufacturer-turbine exists in the Manufacturers and Turbines database. This is case of Figure 6a ID 6, where GE Energy 1.5sl is in both databases. This is the ideal and most likely case, when we would immediately obtain the rated power, rotor diameter and gearbox type.

(a) The Wind Power database

ID	Continent	ISO code	Manufacturer	Turbine	Hub height	Number of turbines	Total power	Strategy
1	Europe	FR	Nordex	N80/2400	60	5	nan	Exclude
2	Europe	IT	Vestas	V90/2	nan	5	10000	Fitting curve
3	Europe	FR	Manufacturer_1	N80/2500	60	2	5000	Fitting curve
4	Europe	FR	Gamesa	nan	44	12	10200	Find similar turbine from the same manufacturer
5	Europe	FR	Nordex	N50/800	50	10	8000	Find similar turbine from the same manufacturer
6	Europe	FR	GE Energy	1.5sl	70	8	12000	Match all data from *Manufacturers and Turbines database*

(b) Manufacturers and Turbines database

ID	Name	Manufacturer	Rated power	Rotor diameter	Gear box	Generators
1	1.5sl	GE Energy	1500	77	Yes	DFIG
2	V90/2	Vestas	2000	77	Yes	DFIG
3	77	Vensys	1500	76,8	No	SYNC PM

Figure 6. Example data from the Wind Power Database and the Manufacturers and Turbines database. Each entry in the Wind Power database corresponds to a particular data gap case, where the strategy to follow is explained with it.

So far, we have described the workflow to match hub height, rated power, rotor diameter, and generator type. However, we are still missing a way to assign coordinates to those wind farms that do not have them. Because The Wind Power database provides the name of the city and/or the area where the farm is located, we assign the coordinates of the centroid of the specified city, or area in case the city is not given.

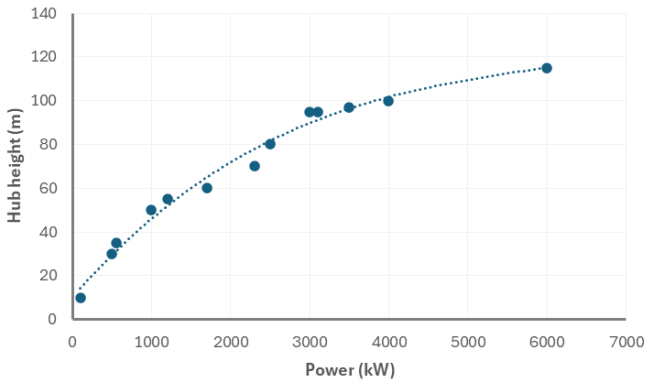

Figure 7. Example of fitting curve to interpolate hub height from power (non-real data).

We believe that the data estimations provided by the data filling method are not only useful for a later application to WindTrace, but they have independent value. Having these

estimations could be useful for data analysis or to do modelling exercises other than WindTrace. For this reason, we included the results of the data filling process in the spreadsheet *Technical_data_Europe* in the database. *Resolved location* is the name of the estimated location, *Resolved location type* is to what kind of administrative boundaries the estimated location refers to (e.g., country, city, county, …), and *Estimated hub height* and *Estimated rotor diameter* refer to the calculated hub height and rotor diameter respectively. These columns only include information on those wind farms for which an estimation was needed. Note that empty cells in these columns means that the original Wind Power database already has data for that wind farm.

Table 5. Parameters employed in WindTrace with their description and source for their implementation in the analysis of the European wind fleet.

Parameter	Description	Source
Park name	Name of the wind park	The Wind Power (updated)
Park power	Total power of the wind park [MW]	The Wind Power (updated)
Number of turbines	Number of turbines in the wind park	The Wind Power (updated)
Park location	ISO 3166-1 alpha-2 country code	The Wind Power (updated)
Park coordinates	WGS84 coordinates of the wind park (latitude, longitude)	The Wind Power (updated)
Manufacturer	Name of the turbine manufacturer	The Wind Power (updated. Default LM Wind)
Rotor diameter	Diameter of the rotor [m]	The Wind Power (updated)
Turbine rated power	Nominal power of the individual turbines [MW]	The Wind Power (updated)
Hub height	Height of the turbine [m]	The Wind Power (updated)
Commissioning year	Year when the turbine started operation	The Wind Power (updated)
Recycled steel share	Recycled content share of steel	Share corresponding to the previous year to commissioning according to data from Eurofer
Electricity mix steel	Country of the electricity mix for steel production	Current European mix according to producing countries (Eurofer)
Land use permanent intensity	Permanent direct land transformation per MW	3000 m^2/MW
Generator type	Gearbox and type of generator	The Wind Power (updated. Default doubly fed induction generator)
Land cover type	Land cover type prior to turbine installation	Default *row crops*
End-of-life scenario	Scenario based on material recycling rates (1: baseline, 2: optimistic, 3: pessimistic)	Baseline
Lifetime	Expected lifetime of the turbine (years)	• Operating turbines: *20 years*. • Decommissioned turbines: commissioning year – decommissioning year
Capacity factor	Ratio of average delivered electricity to maximum theoretical production	Not used. We calculate inventories and impacts per unit of park, not per kWh.
Attrition rate	Annual efficiency reduction due to wear	Not used. We calculate inventories and impacts per unit of park, not per kWh.

4.2.2.3 WindTrace applied to the European wind fleet

Once all the data is ready without data gaps, WindTrace can be used to estimate the following for each European wind farm:

- Material demands (mass per each material), including steel, chromium steel, cast iron, aluminium, copper, epoxy resin, rubber, polyurethane, polyvinylchloride, polyethylene, fiberglass, electronics, electrics, lubricating oil, and rare earth metals.
- Land transformation (i.e., direct squared meters of land changing from its previous cover type to accommodate the wind turbine infrastructure), and land occupation (i.e., occupied land area adjusted by the occupation time. This is important to consider temporary land transformation that may occur specially at the moment setting up the wind park)
- Life cycle impact assessment of European wind projects using inventories modelled using WindTrace and ReCiPe 2016 (Huijbregts et al., 2017), cumulative exergy demand and cumulative energy demand impact methods. The functional unit is one park (not kWh).

Table 5 explains the parameters used in WindTrace and what was the source of the data for its implementation in the analysis of the European fleet. Essentially, most of the parameters are given directly from the Wind Power database version with the data gaps filled. However, parameters *recycled steel share*, *electricity mix steel*, *land use permanent intensity*, *land cover type*, *end-of-life scenario*, and *lifetime* (only for those turbines still running) had default values.

WindTrace was ran for each wind farm in The Wind Power database in Europe, and its results are given in different spreadsheets in the database. *LCI_Materials* shows the estimated material masses, *LCI_Land* contains the estimated land transformation and occupation, while *LCIA_Impacts* provides results on life cycle impacts for ReCiPe2016, cumulative exergy demand and cumulative energy demand impact methods.

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6 APPENDIX 1: EC SUMMARY REQUIREMENTS

Changes with respect to the DoA	• Changing the lead beneficiary of Deliverable D1.1 - Open access technical database to advance impact assessment and energy modelling for wind energy from AU to UAB as a mitigation measure for Critical risk 4. • Changing the due date for Deliverable D1.1 from M24 (October 2024) to M28 (February 2025).
Dissemination and uptake	Public
Short summary of results (<250 words)	This deliverable presents a database to advance impact assessment and energy modelling for wind energy. To populate this database we developed WindTrace, an open-source parametrized life-cycle inventory model for onshore and offshore turbines. The database contains data on world's wind farms (up to October 2021), with estimations on expected material demands, land use and life cycle impacts for each wind farm in Europe. Additionally, the database includes life-cycle inventory examples for turbines of various technical characteristics. The contents of the database and the methods to develop WindTrace are presented, as well as mini-reviews on power curves and CT-curves.
Evidence of accomplishment	This deliverable, the associated database and the code of the GitHub project https://github.com/LIVENlab/JW4A_D1_1 used to populate the databse are avilable in Zenodo Community for JUSTWIND4ALL.