ENVIRONMENTAL PRODUCT DECLARATION

WIND FARM WITH NORDEX DELTA4000 N149/5.X WIND TURBINES

NACELLE ASSEMBLY
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Germany

In compliance with ISO 14025 and ISO 14040/14044

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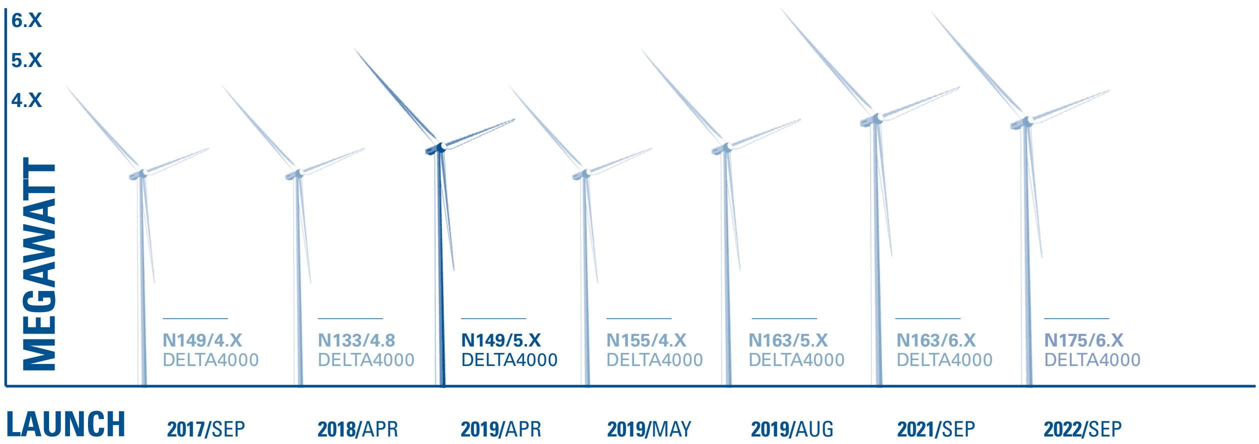
Contents

THE DELTA4000 PRODUCT PORTFOLIO



Based on more than 35 years of experience, the Nordex Group is an expert in connecting proven technology with innovative engineering. For the Delta4000 product series, we took over the Delta Generation's fundamental design and transferred it into the 4, 5 and 6 MW+ class. Depending on investment criteria in the customer's business case the wind park can be optimized with regards to AEP, rating, life time and sound requirements. In addition, this flexibility offers opportunities to optimize the revenues in line with PPA structures and merchant price profiles.

General Information

OWNER OF THE EPD
Nordex SE
Langenhorner Chaussee 600
22419 Hamburg, Germany

MANUFACTURING SITES

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Erich-Schlesinger-Str. 50
18059 Rostock
Germany

SCOPE OF THE EPD
According to EPDItaly's program regulations, this is a cradle-to-grave product EPD study on a 'Delta4000 N149/5.X wind farm' commissioned by the Nordex Group.

PROGRAM OPERATOR
EPDItaly
Via Gaetano De Castillia 10
20124 Milan
Italy

INDEPENDENT AND EXTERNAL VERIFICATION
This Environmental Product Declaration has been developed following the instructions of the EPDItaly program; further information and the document itself can be found at: www.epditaly.it.

The LCA study has been conducted according to the requirements of ISO 14040/44:2006.

Independent and external verification of the declaration and data was carried out according to ISO 14025:2010 by ICMQ, Via Gaetano De Castillia 10, 20124 Milan, Italy.
Accredited by Accredia.

CPC OF REFERENCE
171 "Electrical energy"

COMPANY CONTACT
Sustainability Department
Sustainability@nordex-online.com

COMPARABILITY
EPDs related to the same category of products but belonging to different programs may not be comparable.

RESPONSIBILITY
The Nordex Group relieves EPDItaly from any non-compliance of the environmental legislation self-declared by the manufacturer itself. The holder of the declaration will be responsible for the information and the supporting evidence; EPDItaly declines any responsibility with regard to manufacturer information, data and life cycle assessment results.

REFERENCE DOCUMENTS
This statement has been developed following the regulations of the EPDItaly Program, available at www.epditaly.it.

EPDItaly regulation (rev. 6.0)
PCR for wind turbines: EPDItaly 013 – rel. 1

Further explanatory material about the Delta4000 can be found here:

NORDEX GROUP WEBSITE
https://www.nordex-online.com/en/sustainability

TECHNOLOGY POWERED BY NATURE

THE NORDEX GROUP

As one of the world’s largest wind turbine manufacturers, the Nordex Group offers high-yield, cost-efficient wind turbines that enable long-term and economical power generation from wind energy in all geographical and climatic conditions.

The head office of the company, with the Executive Board and central corporate functions, is located in Hamburg, Germany.

Company

The development, manufacture, project management and servicing of wind turbines in the onshore segment has been the core competence and passion of the Nordex Group for almost 40 years. As one of the world's largest wind turbine manufacturers, the Nordex Group offers high-yield, cost-efficient wind turbines that enable long-term and economical power generation from wind energy in all geographical and climatic conditions.

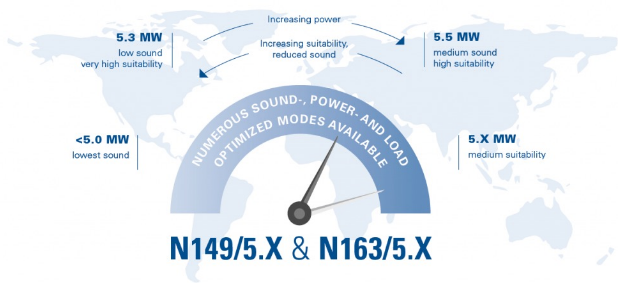
The wind turbine to be analyzed in this study is the N149/5.X, part of the Delta4000 series. With the Delta4000 platform, the Nordex Group relies on tried-and-tested series-production technology. The several wind turbine types in the Delta4000 series provide variable solutions for all wind conditions and cover wind power output requirements from 4.0 MW into the 6 MW+ class.

We focus on the development, production, and installation of complete wind turbine systems, including control software and key components. In particular, we assemble turbine nacelles and hubs at our own facilities. We develop the rotor blades in-house, and a significant number of the required blades are manufactured at our own production plants. The remainder are manufactured by contractors according to Nordex specifications. We procure components such as gearboxes, generators, and inverters from external suppliers, the majority of which are long-term partners.

We serve our customers in all focus markets through our own Sales organization. The Nordex Group offers installation of the supplied wind turbines and subsequent servicing over the turbines' whole operating life. Our close customer support is provided as part of usually long-term, comprehensive maintenance contracts. Services such as the supply of spare parts and customer training are also offered separately.
Apart from producing technologically leading products, the Nordex Group is also concerned with minimising its impact on the environment and is seeking to better understand the sustainability performance of its products through a life cycle perspective.

Therefore, the Nordex Group has implemented an integrated quality, occupational safety, health protection, and environmental management system, and had it certified to the ISO 14001 standard. Furthermore, our German production sites and office buildings have been ISO 50001-certified since 2014. Finally, the Nordex Group also holds certifications of the ISO 9001 and the ISO 45001 standards.

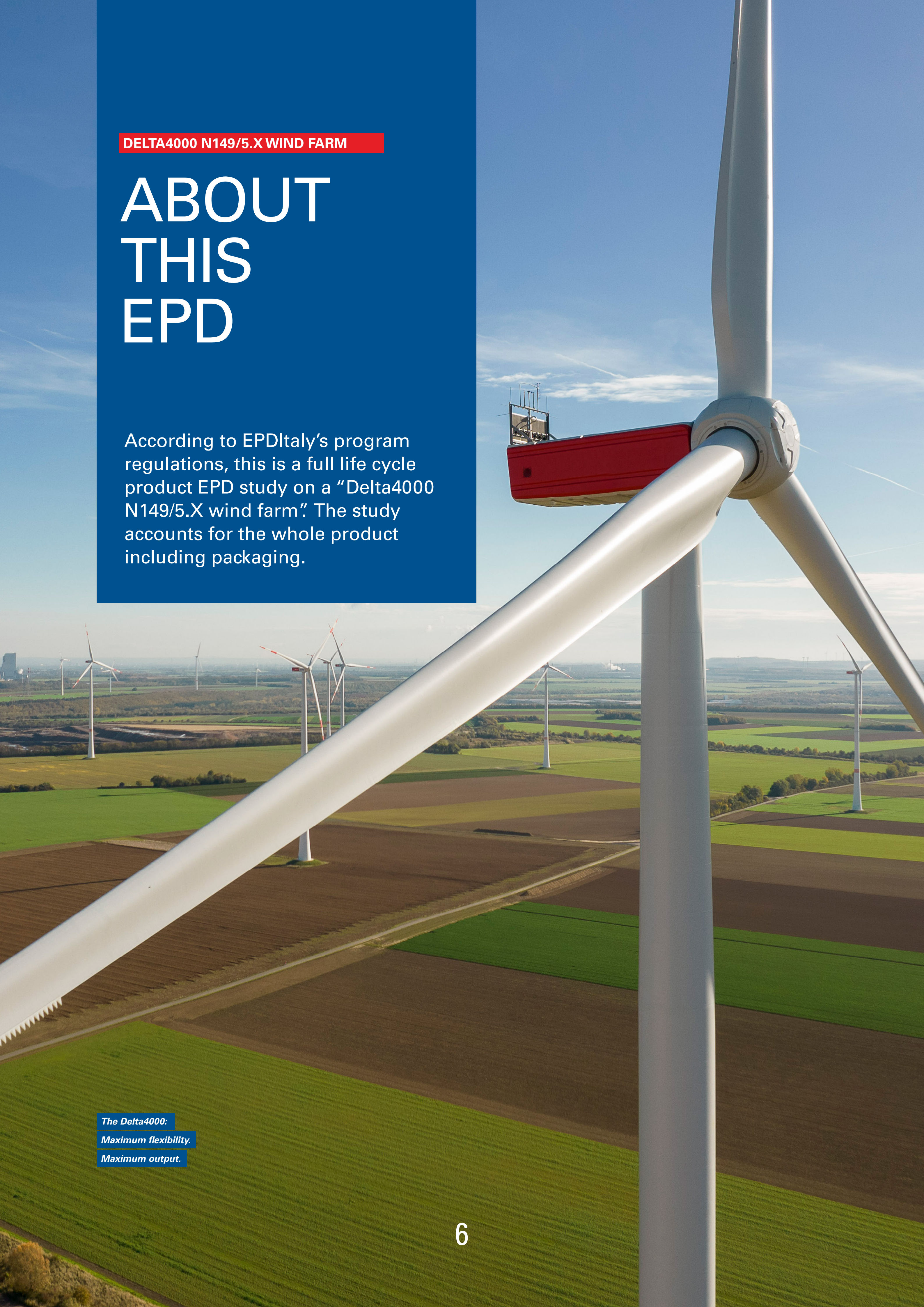
The product system to be assessed in this study is the N149/5.X, one turbine type of the successful Delta4000 series, which is the culmination of over 35 years of experience in the sector.



DELTA4000 N149/5.X WIND FARM

ABOUT THIS EPD

According to EPDItaly's program regulations, this is a full life cycle product EPD study on a "Delta4000 N149/5.X wind farm". The study accounts for the whole product including packaging.



The Delta4000:
Maximum flexibility.
Maximum output.

Scope and Type of EPD

The full life cycle of the turbine has been considered, from cradle-to-grave, i.e., from the point at which raw materials are extracted from the environment through to manufacturing, installation, operation and end-of-life. According to EPDItaly's program regulations, this is a cradle-to-grave product EPD on a "Delta4000 N149/5.X wind farm".

The study accounts for the whole product, including packaging. This includes the extraction and production of raw materials, the manufacturing of these materials into the finished product with packaging, the transportation and distribution of the product for use and end-of-life stages, the use stage and the end-of-life stage including recycling and final disposal.

The local system boundary for the wind farm ends with the connection to the electricity grid. The turbines in the wind farm are connected via medium voltage (MV) cables to the substation. The substation transforms the electricity to 110kV (high voltage, HV). The HV cable connects the wind farm to the grid.

Transport is included for inbound raw materials to the manufacturing sites and then distribution of the product system from the manufacturing site to the location of the wind farm. Transport was also included from the wind farm to end-of-life processing.

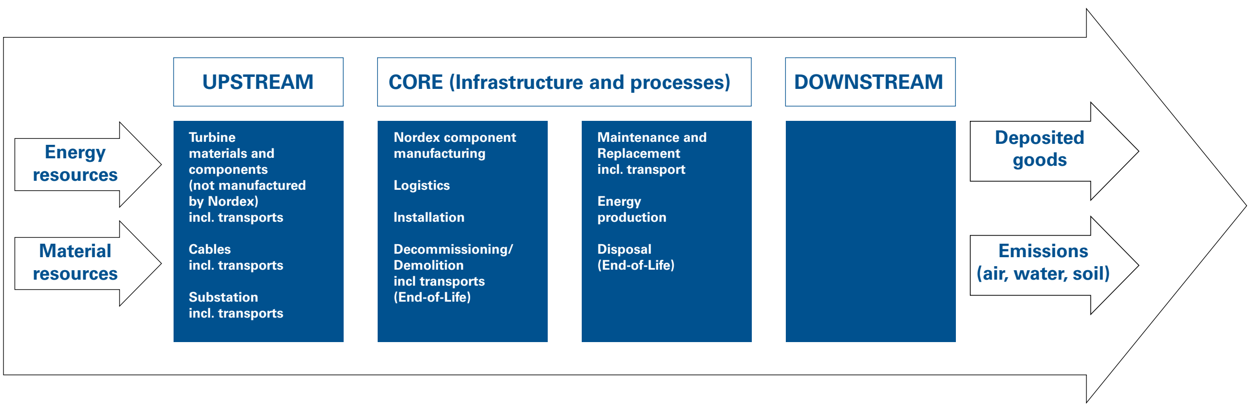
As required by the EPDItaly PCR for wind turbines, the life cycle was split into the upstream, the core (infrastructure and processes) stage and the downstream stage. The different stages are detailed as the following:

Upstream: The upstream module includes all relevant processes of the supply chain including the extraction of raw materials including waste recycling and the production of semi-finished products and auxiliary items, as well as the packaging of products and semi-finishing products and also the transport of raw materials to the manufacturing company (the wind turbine parts manufacturing sites and final manufacturing/ assembly site).

Core: There are two components of the core module; core infrastructure and core processes. Core infrastructure represents the construction of the turbine parts and wind farm carried out by the Nordex Group including all auxiliary materials required to construct the wind farm, structural elements, electricity control and conversion infrastructure. This stage also includes the disassembling of the wind farm, the transportation to disposal and the final disposal of the wind turbines. Core processes include activities associated with the operation and maintenance of the wind farm. The assessed system ends at the connection point with the national electricity grid. The infrastructure and the electrical losses due to the transmission via HV (high voltage) cable between the wind farm and the connection point are considered in the core stage.

Downstream: The downstream module includes all the relevant processes that take place outside of the control of the Nordex Group. This includes environmental impacts associated with activities after the connection point with the national electricity grid (associated processes and infrastructure); however, this was not included in the system boundary of this study.

FIGURE 1: OVERVIEW OF SYSTEM BOUNDARIES



The system boundaries have been summarised in Table 1, detailing stages both included and excluded.

TABLE 1: SYSTEM BOUNDARIES

Included		Excluded	
✓	Raw material production	X	Employee commuting
✓	Fabrication of raw materials into parts and components		
✓	Manufacturing		
✓	Installation		
✓	Associated infrastructure such as roads		
✓	Operation		
✓	End-of-life		

The boundary for the study is at the connection point to the grid. As such, electrical losses due to the voltage elevation in the substation as well as due to the distribution with the MV and HV cables inside and outside the wind farm have been included in the study. The boundary is taken to be the point at which the wind farm produces an equivalent of 1 kWh to be transmitted into the grid.

Impacts associated with employee commuting have been excluded as these are expected to be negligible for a manufactured product. However, all transports associated with the maintenance done by service teams and the replacement of parts during the service life of the turbines have been included.

SOFTWARE AND DATABASE

The LCA model was created using the LCA FE 10 Software system for life cycle engineering (software version 10.7.1.28), developed by Sphera Solutions Inc. The Managed LCA Content (MLC) 2023 LCI database is the basis for most of the life cycle inventory data for modelling the background system. Datasets from the database version 2023.2 are applied.

DECLARED UNIT

In LCA studies, the declared unit quantifies and describes the performance of a product system and is used as the basis for reporting results.

The function of a wind farm is to generate electricity by harnessing wind energy. As such, as defined by the PCR, the declared unit for this study is:

The generation of 1 kWh of electrical energy (net) considering the full lifetime of the wind farm (**Delta4000 N149/5.X** turbines), located in a Polish scenario and operating under special wind conditions (IEC wind class S), and thereafter distributed to a 110kV electrical grid. The assessed wind farm design is a special wind site (IEC wind class S (Special)) with the wind conditions at the site being appropriate for a class I-A. The average wind speed at hub height is 7.3 m/s. Site-specific parameters for losses and uncertainties are considered using a net annual energy production (AEP) calculation.

Product Description

Major components of a Delta4000 wind turbine are the tower and the foundation as well as the nacelle, main gear and blades.

Overall, the material mix for the Delta4000 N149/5.X turbine excluding the mass-dominant foundation is:

- 83.8% Steel (carbon steel, stainless steel, cast steel)
- 6.7% Glass fibre/Carbon fibre reinforced plastics
- 6.4% Polymers
- <0.1% Operating fluids
- <0.1% Electrics / Electronics
- 1.1% Aluminium
- 0.5% Copper
- 1.3% Others

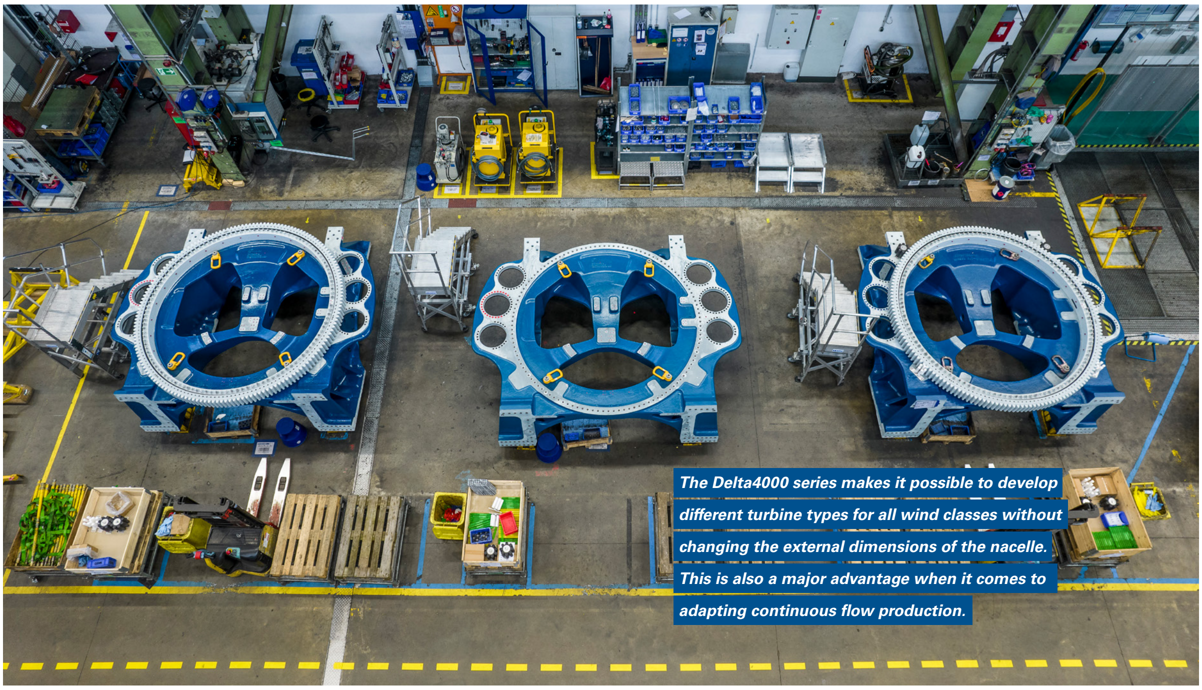
PRODUCTION PROCESS

The production process of this Delta4000 turbine can generally be divided into three parts:

- The rotor blades are designed by the Nordex Group and are manufactured according to Nordex specifications. For the specific wind farm assessed for this EPD, the blades supplied by a third-party manufacturer. The process can be divided into several stages: Initially, components such as root joints and shear webs are prefabricated. Subsequently, these are integrated into the manufacturing process of green bodies and the following completion process of the rotor blade: This includes i.a. the fabrication of the main shell, the shell bonding, trimming and laminating. Finally, the finishing processes such as painting and labelling are carried out before preparing the blades for transportation.

- The nacelle for this specific wind farm is assembled at a Nordex nacelle facility in Germany, in the form of line production with sequential line assemblies of machine houses and hubs. The nacelle assembly itself is generally divided into three production lines, one for each individual module – machine house, drive train and hub. For machine houses, there are six assembly stations and a preparation station which is subdivided into several components (such as generator, main frame or main cable). For the hub, there are three assembly stations as well as a pre-assembly station.

- The steel tower is supplied by a third-party manufacturer.



The Delta4000 series makes it possible to develop different turbine types for all wind classes without changing the external dimensions of the nacelle. This is also a major advantage when it comes to adapting continuous flow production.

LCA Results

The following tables detail the life cycle impact potential, resource consumption parameters and waste production parameters for the specified declared unit of the Delta4000 N149/5.X wind farm. The environmental impact indicators were determined using modelling as specified in EN15804:2012+A2:2019. The global warming potential was determined in accordance with EN15804:2012+A2:2019 as: fossil, biogenic and land use/land use change, according to the Baseline model of 100 years of the IPCC (2019).

TABLE 2: THE ENVIRONMENTAL IMPACT INDICATORS

Impact category	Unit	TOTAL	Upstream	Core	Downstream
GWP	kg CO_2 equivalent	9.97E-03	8.57E-03	1.40E-03	0.00E+00
GWP fossil	kg CO_2 equivalent	9.88E-03	8.56E-03	1.33E-03	0.00E+00
GWP biogenic	kg CO_2 equivalent	7.27E-05	6.76E-06	6.59E-05	0.00E+00
GWP LULUC	kg CO_2 equivalent	1.06E-05	2.33E-06	8.30E-06	0.00E+00
ODP	kg CFC 11 equivalent	3.87E-14	3.73E-14	1.42E-15	0.00E+00
EP-freshwater	kg P equivalent	1.95E-08	1.56E-08	3.90E-09	0.00E+00
AP	kg H+ equivalent	3.30E-05	2.72E-05	5.74E-06	0.00E+00
POCP	kg C2H4 equivalent	2.61E-05	1.88E-05	7.31E-06	0.00E+00
ADPE	kg Sb equivalent	1.38E-07	1.38E-07	3.36E-10	0.00E+00
ADPF	MJ, net calorific value	1.23E-01	1.09E-01	1.45E-02	0.00E+00
WDP	m^3 equivalent	1.01E-03	8.37E-04	1.69E-04	0.00E+00

GWP = Global warming potential; ODP = Ozone depletion potential; AP = Acidification potential; EP = Eutrophication potential; POCP = Photochemical ozone creation potential; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources, WDP = Water deprivation potential

Impact category	Unit	TOTAL	Upstream	Core	Downstream
PENRE	MJ, net calorific value	1.23E-01	1.09E-01	1.45E-02	0.00E+00
PERE	MJ, net calorific value	9.21E+00	1.81E-02	9.20E+00	0.00E+00
PENRM	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERM	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	MJ, net calorific value	1.23E-01	1.09E-01	1.45E-02	0.00E+00
PERT	MJ, net calorific value	9.21E+00	1.81E-02	9.20E+00	0.00E+00
FW	kg	1.14E-04	1.09E-04	4.32E-06	0.00E+00
SM	kg	4.65E-06	4.65E-06	0.00E+00	0.00E+00
RSF	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0.00E+00

PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water

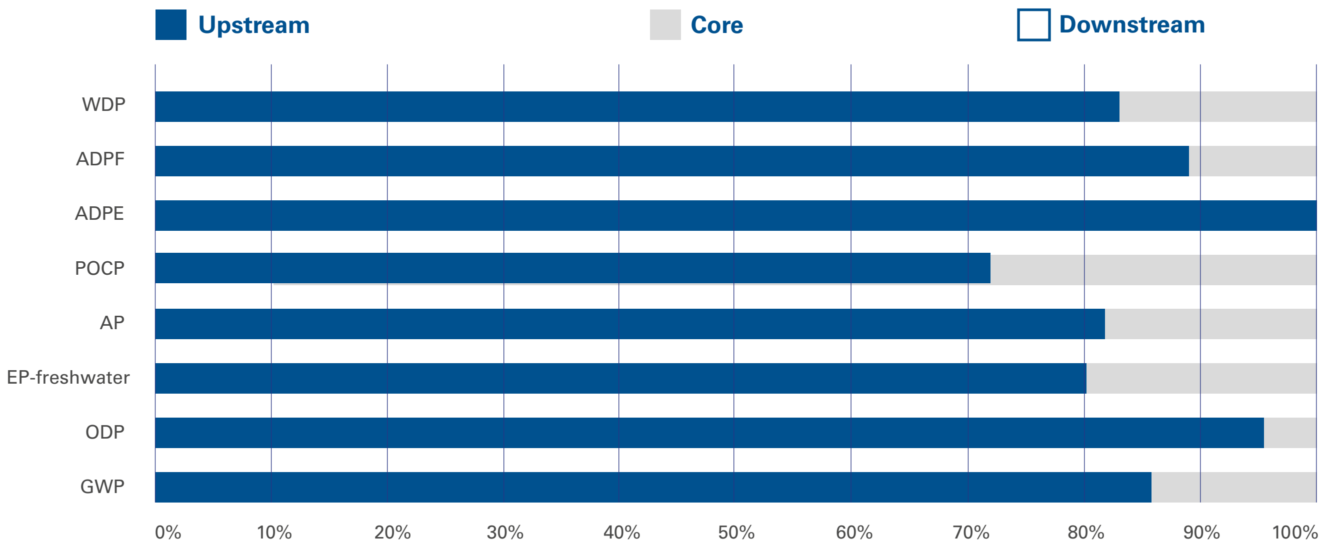
Impact category	Unit	TOTAL	Upstream	Core	Downstream
HWD	kg	1.68E-08	1.61E-08	7.28E-10	0.00E+00
NHWD	kg	1.67E-03	5.30E-04	1.14E-03	0.00E+00
RWD	kg	2.18E-06	2.11E-06	7.43E-08	0.00E+00
MFR	kg	8.06E-03	0.00E+00	8.06E-03	0.00E+00
MER	kg	7.34E-05	0.00E+00	7.34E-05	0.00E+00
CRU	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EET	MJ	8.50E-04	0.00E+00	8.50E-04	0.00E+00
EEE	MJ	4.45E-04	0.00E+00	4.45E-04	0.00E+00

HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EEE = Exported electrical energy; EET = Exported thermal energy


Innovative logistics methods ensure smooth transportation.

Result Interpretation

FIGURE 2: REPRESENTATION OF RELATIVE CONTRIBUTION



It can be seen from the results, presented per declared unit, that across the majority of impact categories, the upstream module (raw material and manufacturing stages not carried out by the Nordex Group) of the turbine is, by far, the most dominant contributor across the whole life cycle of the windfarm. This is due to the raw material procurement and upstream manufacturing associated with the wind turbine.

The foundation of the turbine by mass is 75.8% of the turbine however, as it is composed of approximately 94% concrete, the impact potential across all impact categories is significantly lower than that of the components that are composed of metals and other higher impact materials. The foundation contributes to approximately 13.9% of the total GWP over the full life cycle.

The tower accounts for 16.2% of the mass of the turbine however, due to the large amount of steel that contributes to the infrastructure, the GWP is approximately 34.6% of the full life cycle, showing it to be much more significant than the foundation by mass. Similarly, despite the blades only contributing 1.0% of the mass of the turbine, they are significant contributors in several impact categories and represent 15.1% of the total GWP. Freshwater eutrophication potential is the highest for the blades, this is largely due to the polymer parts, resin glass fibres and electricity required to manufacture the blades.

The E-module is the most significant contributor to resource use, metals and minerals which is due to the electronics present in the top-box and pitch-box (dataset proxy for electronics contains gold).

LAND USE AND LAND USE CHANGE (GWP LULUC)

The analysed Nordex wind farm comprises 11 wind turbines of the specification Delta4000 N149/5.X. The underlying data for GWP LULUC effects refers to the wind farm of "Wysoka". The affected area is mainly vegetated with patchy forests. Other land uses include sporadic clearings, pastures or crops, peat bogs and water bodies.

The resulting affected area per turbine is 1.42 ha. The calculation of the GWP LULUC effects are done based on (IPCC, 2019). The main assumptions for the calculations are:

- Land use shares were not taken from the download source which provides the generic land use shares for the region the wind park is located in
  - The satellite image of the study site in combination with the land use layer from the download source has to be taken as primary information and is treated with priority to the generic land use shares for the region
  - Based on the image it is assumed that no forest is present at the study site

- Removed above-ground biomass and dead organic matter is considered, changes in soil organic carbon (SOC) stocks is not considered
- Classification for the vegetation area: Temperate, Continental, Europe, secondary (relevant for above-ground biomass as well as dead wood and carbon litter stocks, compare tables 2.2 and 4.12 from the 2019 + 2006 IPCC Guidelines)
- Ratio of additionally cleared vegetation for construction of artificial surfaces: 10% for all of the artificial surface items
- Carbon content of biomass (dry matter): 50%

The resulting GWP LULUC effect is 0 t CO_2 per ha which also means 0 t CO2 per turbine.

Calculation Rules

ASSUMPTIONS

The assessed wind farm design is a special wind site (IEC wind class S (Special)) with the wind conditions at the site being appropriate for a class I-A. The average wind speed at hub height is 7.3 m/s. Site-specific parameters for losses and uncertainties are considered using a net annual energy production (AEP) calculation.
The certified standard lifetime of Delta4000 turbines is 20 years. In principle, the lifetime of those turbines can be extended by 10 or even 15 years to a total lifetime of 30 or even up to 35 years, according to the method of lifetime extensions and the related advisory opinions by UL (UL, 2022). The applied lifetime of turbines in a wind farm follows site-specific conditions. The analysed wind farm in Poland was designed for a lifetime of 20 years.

However, as specified by the PCR, the baseline assumption for the wind farm lifetime is 20 years. In LCAs on onshore wind turbines, the lifetime is often defined with 20 years as base case. To check the sensitivity on the results, a scenario with 25 years, but also with 30 years and 35 years lifetime is calculated.

CUT-OFF RULES

No cut-off criteria have been defined for this study. The system boundary was defined based on relevance to the goal of the study. For the processes within the system boundary, as much available energy and material flow data have been included in the model as possible. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

DATA QUALITY

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from Sphera Managed LCA Content (MLC) 2023 database were used. The LCI datasets from Sphera Managed LCA Content (MLC) 2023 database are widely distributed and used with the LCA FE 10 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies.

In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

PRECISION AND COMPLETENESS

- **Precision:** As the majority of the relevant foreground data are measured data or calculated based on primary information sources provided by the Nordex Group, precision is considered to be high. Seasonal variations/variations across different manufacturers were balanced out by using yearly averages. Most background data are sourced from Sphera Managed LCA Content (MLC) databases with the documented precision.
- **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. Some data points were omitted as documented earlier in this report. Nevertheless, completeness of foreground unit process data is considered to be high. Most background data are sourced from Sphera Managed LCA Content (MLC)databases with the documented completeness.

CONSISTENCY AND REPRODUCIBILITY

- **Consistency:** To ensure data consistency, all primary data were collected with the same level of detail, while most background data were sourced from the Sphera Managed LCA Content (MLC) databases.
- **Reproducibility:** Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modelling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modelling approaches.

REPRESENTATIVENESS

- **Temporal:** All primary data were collected for the year 2023. Most secondary data come from the Sphera Managed LCA Content (MLC)2023 databases and are representative of the years 2019-2022 (although two datasets have a reference year of 2005). As the study intended to compare the product systems for the reference year 2023, temporal representativeness is considered to be moderate/high.
- **Geographical:** All primary and secondary data were collected specific to the countries under study. Where country-specific data were unavailable, proxy data were used. Geographical representativeness is considered to be moderate.
- **Technological:** All primary and secondary data were modelled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Technological representativeness is considered to be high.

ALLOCATION

End-of-life allocation
(cut-off approach/baseline scenario)
The cut-off approach was utilised in this study as required by the PCR and Regulations of EPDItaly. The following details a short description of the cut-off approach that has been modelled for this study:

Material recycling (cut-off approach)

Any open scrap inputs into manufacturing remain unconnected. The system boundary at end-of-life is drawn after scrap collection to account for the collection rate, which generates an open scrap output for the product system. The processing and recycling of the scrap is associated with the subsequent product system and is not considered in this study.

Energy recovery & landfilling (cut-off approach)

Any open scrap inputs into manufacturing remain unconnected. The system boundary includes the waste incineration and landfilling processes following the polluter-pays-principle. In cases where materials are sent to waste incineration, they are linked to an inventory that accounts for waste composition and heating value as well as for regional efficiencies and heat-to-power output ratios. In cases where materials are sent to landfills, they are linked to an inventory that accounts for waste composition, regional leakage rates, landfill gas capture as well as utilisation rates (flaring vs. power production). No credits for power or heat production are assigned.

End-of-life allocation (substitution approach)

The cut-off approach from the base case of the LCA and EPD is replaced by the substitution approach which is typically applied for products including recyclable metals. A short description of the substitution approach (net-scrap calculation) follows:

Material recycling (substitution approach):

Open scrap inputs from the production stage are subtracted from scrap to be recycled at end-of-life to result in the net scrap output from the product life cycle. This remaining net scrap is sent to material recycling. The original burden of the primary material input is allocated between the current and subsequent life cycle using the mass of recovered secondary material to scale the substituted primary material, i.e., applying a credit for the substitution of primary material so as to distribute burdens appropriately among the different product life cycles. These subsequent process steps are modelled using industry average inventories.

Energy recovery (substitution approach):

In cases where materials are sent to waste incineration, they are linked to an incineration inventory dataset that accounts for waste composition and heating value as well as for regional efficiencies and heat-to-power output ratios. Credits are assigned for power and heat outputs using the regional grid mix and thermal energy from natural gas. The latter represents the cleanest fossil fuel and therefore results in a conservative estimate of the avoided burden.

Landfilling (substitution approach):

In cases where materials are sent to landfills, they are linked to an inventory that accounts for waste composition, regional leakage rates, landfill gas capture as well as utilisation rates (flaring vs. power production). A credit is assigned for power output using the regional grid mix.

DELTA4000 N149/5.X WIND FARM

MORE FACTS

The N149/5.X blade is a single piece blade based on the proven GFRP/CFRP differential construction concept Nordex is using in serial production since 2012.

The N149/5.X uses the N149/4.0-4.5 rotor blade, which further increases the modularity of the Delta4000 product series.

Additional Environmental Information

RESULTS FOR SUBSTITUTION APPROACH

These results reflect the life cycle impact of the wind farm with the implementation of the substitution approach with material credits for the net amounts of recyclable material instead of the cut-off approach. The results are the following:

The results are the following:

- GWP total – upstream, core, downstream: 5.69g CO_2eq / kWh
- GWP fossil – upstream, core, downstream: 5.35g CO_2eq / kWh

For those two key result indicators, it is demonstrated that the high amount of potentially recyclable materials has a significant influence on the overall results. Especially, the high amount of recycled steel makes a relatively big contribution on EoL material credits.

The cut-off and substitution approaches are detailed in the allocation section of this EPD.

RESULTS FOR LIFE TIME EXTENSION OF 25, 30 AND 35 YEARS

According to the technical design of the Delta4000 N149/5.X the life time is defined as 25 years. For the sake of comparability and to follow the requirements of the PCR, the base case in this LCA takes 20 years life time as a basis. This sensitivity analysis checks the influence of the extended life time on two result parameters. 25% longer life time results in 25% more energy produced. The result parameters related to AEP, namely the GWP, are reduced accordingly.

For 25 years life time:

- GWP total – upstream, core, downstream: 8.02g CO_2eq / kWh
- GWP fossil – upstream, core, downstream: 7.95g CO_2eq / kWh

For 30 years life time:

- GWP total – upstream, core, downstream: 6.68g CO_2eq / kWh
- GWP fossil – upstream, core, downstream: 6.62g CO_2eq / kWh

For 35 years life time:

- GWP total – upstream, core, downstream: 5.74g CO_2eq / kWh
- GWP fossil – upstream, core, downstream: 5.69g CO_2eq / kWh

LAND USE

The analysed Nordex wind farm comprises 11 wind turbines of the specification Delta4000 N149/5.X. The affected area is dominated by agriculture. The following table illustrates land use before and after the installation of the wind farm in more detail:

TABLE 3: LAND USE BEFORE AND AFTER INSTALLATION

CORINE LAND COVER CLASSES	Before (m²)	After (m²)
1 Artificial surfaces		
1.2 Industrial, commercial and transport units		
1.2.1 Industrial, commercial and public units	9991.82	104423
1.2.2 Road and rail networks and associated land	2498	37507
2 Agricultural areas		
2.1 Arable land		
2.1.1 Non-irrigated arable land	127864.13	12773.64
2.1.2 Permanently irrigated land	7103.56	709.65
2.4 Heterogeneous agricultural areas		
2.4.3 Land principally occupied by agriculture,	7103.56	709.65
with significant areas of natural vegetation		
5 Water Bodies		
5.1 Inland Waters		
5.1.2 Water Bodies	1561.22	0
TOTAL	156122.26	156122.26

A total of 15.61 ha have been affected and modified by the installation and operation of the wind farm. The occupied areas are mainly used for:

- Foundations
- Streets/Tracks
- Crane pads
- Cable trenches
- Substation/Control building

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Acronyms and Abbreviations

AEP
Annual Energy Production

ADP
Abiotic depletion potential

AP
Acidification Potential

CML
Centre of Environmental Science at Leiden

EF
Environmental Footprint

EoL
End-of-Life

EP
Eutrophication Potential

EPD
Environmental product declaration

GaBi
Ganzheitliche Bilanzierung (German for holistic balancing)

GHG
Greenhouse Gas

GWP
Global Warming Potential

HV
High voltage

IEC
International Electrotechnical Commission

ILCD
International Cycle Data System

ISO
International Organization for Standardization

LCA
Life Cycle Assessment

LCA FE
LCA For Experts modeling software (formerly known as GaBi)

LCI
Life Cycle Inventory

LCIA
Life Cycle Impact Assessment

MV
Medium voltage

NMVOC
Non-Methane Volatile Organic Compound

ODP
Ozone depletion potential

PCR
Product catergory rules

POCP
Photochemical ozone formation, human health

RSL
Reference service life

RoE
Return on Energy

VOC
Volatile Organic Compound

WDP
Water depletion potential

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