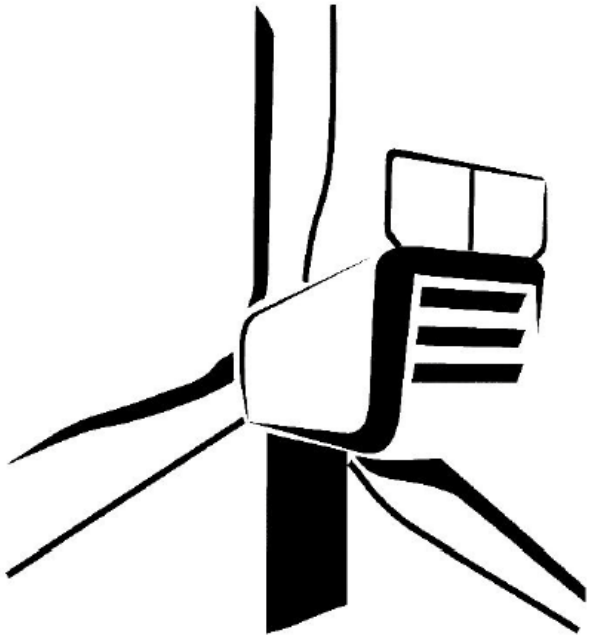
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1 General

1.1 Introduction

Due to the necessity for reducing the greenhouse gas CO_2, the number of wind turbines (WTs) has significantly increased during recent decades.

Every WT is designed for a limited service life. After this time has expired, the WT must be disassembled, disposed of and the site must be restored to its original condition – the condition prior to the erection of the WT. The operator of the WT must save up provisions for this purpose. Nordex provides disassembly instructions for the WT and this compilation of the dismantling effort. The costs estimated for the dismantling are already saved up and put aside for financial security while the WT is still operating.

However, it has become apparent that old WTs above a power capacity of approx. 150 kW are usually not scrapped but disassembled and exported abroad. When selling a WT, it is important to carefully plan, execute and document the following steps for dismantling: disconnection through the grid operator, disassembly of the WT (in reverse order of the erection), packing and transport. Selling the WT or components of the WT is always more favorable than scrapping.

Individual components, especially motors or transformers, can be overhauled and reused. They will then no longer be classified as electronic scrap and can continue yielding revenue. Partial or complete reuse, however, cannot be considered in this document, as the market for old WTs and spare parts always changes and any sales return is a matter of negotiation.

The dismantling is completed with the dismantling of the foundation, all ancillary buildings, the cabling to the supply grid, and the access roads.

1.2 Abbreviations

Abbreviation	Designation	Description
CRP	Carbon-fiber reinforced plastic	Additional materials in the rotor blade
GRP	Glass-fiber reinforced plastic	Materials in rotor blade and nacelle housing
MV	Medium voltage	–
TCS	Precast concrete hybrid tower	–
TS	Tubular steel tower	–
WT	Wind turbine	–

2 Factors affecting the costs of WT dismantling

2.1 Site-specific factors

The costs for the dismantling of WTs depend on the site-specific conditions, such as landscape, costs for access roads and crane costs. Therefore, the figures calculated here for access roads can only represent guide values for the actual costs in Germany. Another guide value is the originally incurred costs during the erection of the wind farm. These are often not known to Nordex.

In interconnected wind farms, there are additional costs, e.g., for a substation, separate met masts or buildings. On the other hand, fixed costs, such as planning and mobilization costs for the cranes, are allocated to the entire wind farm.

2.2 Regional factors

The disposal costs and sales returns depend on the individual disposal companies and the region. For a particular project, i.e., a specific location, the current regionally applicable costs and prices must in each case be obtained and applied afresh.

For the arising transport costs, max. 50 km have been applied.

2.3 Additional factors

The disposal costs and the sales returns for scrap metal and electronic scrap depend largely on the economy. In addition, changes in legal requirements can influence disposal and its costs.

The costs for planning, documenting and monitoring the dismantling can vary widely and cannot be considered here. Legal concerns, e.g., lease agreements, can also not be considered. The economies of scale in the dismantling of several WTs are also not considered.

3 WT N133 data

The following data refer to Nordex Delta4000 wind turbines with one of the indicated towers. They should be considered only an example as all foundations are designed for the specific project.

WT type	Unit	N133
Rotor blade		
• GRP and CRP	[t]	approx. 46
• Electrical components	[t]	approx. 0.2
Rotor hub		
• Steel	[t]	approx. 57
• Electrical components (switch cabinets)	[t]	approx. 1.5
• GRP (spinner)	[t]	approx. 0.5
Nacelle		
• GRP	[t]	approx. 3.5
• Steel	[t]	approx. 121
• Electrical components		
– Switch cabinets, converter	[t]	approx. 15
– Transformer	[t]	approx. 10
– Copper (from cables)	[t]	approx. 1.0

WT type	**Unit**	**N133**			
Designation		TS78-00	TS83	TS100-00	TS105-01
• Height of the rotor hub	[m]	78.0	82.5	102.0	104.7
Towers					
• Steel as per tower drawing	[t]	approx. 173	approx. 162	approx. 261	approx. 275
• Volume of concrete	[m^3]	–	–	–	–
• Mass of reinforcement	[t]	–	–	–	–
• Mass of tendons	[t]	–	–	–	–
Foundation					
• Volume of concrete	[m^3]	–	approx. 542 [1)]	–	approx. 743/631 [1)]
• Mass of reinforcement (incl. anchor cage)	[t]	–	approx. 60 [1)]	–	approx. 96 (approx. 112) / approx. 85 (approx. 101) [1)]
Cabling	[t]	approx. 0.8			
Electrical components					
• MV switchgear, switch cabinet in the tower base	[t]	approx. 3.5			
Hazardous waste					
• Oils, greases, transformer oil, coolant, etc.	[kg]	approx. 3040 (oils: 800; greases: 140; transformer oil: 1800; coolant: 300)			

WT type	**Unit**	**N133**			
Designation		TS110	TS118-00	TS125-02	TCS164
• Height of the rotor hub	[m]	110.0	118.0	125.4	164.0
Towers					
• Steel as per tower drawing	[t]	approx. 258	approx. 370	approx. 366	approx. 164
• Volume of concrete	[m^3]	–	–	–	approx. 473
• Mass of reinforcement	[t]	–	–	–	approx. 49
• Mass of tendons	[t]	–	–	–	approx. 42
Foundation					
• Volume of concrete	[m^3]	approx. 743 [1)]	751/687 [2)]	approx. 841 [1)]	approx. 697 [1)]
• Mass of reinforcement (incl. anchor cage)	[t]	approx. 91 [1)]	102/93 [2)] (122/113 [2)])	approx. 124 [1)]	approx. 91 [1)]
Cabling	[t]	approx. 0.8	approx. 1.1	approx. 1.0	approx. 0.9
Electrical components • MV switchgear, switch cabinet in the tower base	[t]	approx. 3.5			
Hazardous waste					
• Oils, greases, transformer oil, coolant, etc.	[kg]	approx. 3040 (oils: 800; greases: 140; transformer oil: 1800; coolant: 300)			

[1)] Variant with buoyancy.
[2)] Variant with/without buoyancy.

Further explanations on the table:

- The quantities of plastics other than GRP are negligible.
- Additional options are not taken into account.
- The hybrid tower consists of a concrete tower and a tubular steel tower. No anchor cage is required in the foundation for this tower.

4 WT N149 data

The following data refer to Nordex Delta4000 wind turbines with one of the indicated towers. They should be considered only an example as all foundations are designed for the specific project.

WT type	**Unit**	**N149**
Rotor blade		
• GRP and CRP	[t]	approx. 60
• Electrical components	[t]	approx. 0.2
• Copper [1)]	[t]	approx. 0.9
Rotor hub		
• Steel	[t]	approx. 55
• Electrical components (switch cabinets)	[t]	approx. 1.5
• GRP (spinner)	[t]	approx. 0.5
Nacelle		
• GRP	[t]	approx. 3.5
• Steel	[t]	approx. 121
• Electrical components		
– Switch cabinets, converter	[t]	approx. 15
– Transformer	[t]	approx. 10
– Copper (from cables)	[t]	approx. 1.0

WT type	**Unit**	**N149**			
Designation		TS105	TS108	TS100-00	TS125-01
• Height of the rotor hub	[m]	104.7	108.0	100.4	125.4
Towers					
• Steel (as per tower drawing)	[t]	approx. 275	approx. 295	approx. 261	approx. 366
• Volume of concrete	[m^3]	–	–	–	–
• Mass of reinforcement	[t]	–	–	–	–
• Mass of tendons	[t]	–	–	–	–
Foundation					
• Volume of concrete	[m^3]	approx. 743/631 [2)]	–	–	approx. 841/692 [2)]
• Mass of reinforcement (incl. anchor cage)	[t]	approx. 96 (approx. 112) / approx. 85 (approx. 101) [2)]	–	–	approx. 124 (approx. 144) / approx. 107 (approx. 127) [2)]
Cabling	[t]	approx. 0.8			approx. 1.0
Electrical components					
• MV switchgear, switch cabinetin the tower base	[t]	approx. 3.5			
Hazardous waste					
• Oils, greases, transformer oil, coolant, etc.	[kg]	approx. 3040 (oils: 800; greases: 140; transformer oil: 1800; coolant: 300)			

WT type	**Unit**		**N149**		
Designation		TS135	TS145-01	TS155	TCS164
• Height of the rotor hub	[m]	135.0	145.0	154.9	164.0
Towers					
• Steel (as per tower drawing)	[t]	approx. 365	approx. 407	approx. 484	approx. 164
• Volume of concrete	[m^3]	–	–	–	approx. 473
• Mass of reinforcement	[t]	–	–	–	approx. 49
• Mass of tendons	[t]	–	–	–	approx. 42
Foundation					
• Volume of concrete	[m^3]	–	–	–	approx. 697 [3)]
• Mass of reinforcement (incl. anchor cage)	[t]	–	–	–	approx. 91 [3)]
Cabling	[t]	approx. 1.0	approx. 1.1	approx. 1.2	approx. 0.9
Electrical components					
• MV switchgear, switch cabinetin the tower base	[t]	approx. 3.5			
Hazardous waste					
• Oils, greases, transformer oil, coolant, etc.	[kg]	approx. 3040 (oils: 800; greases: 140; transformer oil: 1800; coolant: 300)			

[1)] For anti-icing variant only.
[2)] Variant with/without buoyancy.
[3)] Including adapter.

Further explanations on the table:

- The quantities of plastics other than GRP are negligible.
- Additional options are not taken into account.
- The hybrid tower consists of a concrete tower and a tubular steel tower. No anchor cage is required in the foundation for this tower.

5 Applied costs and returns

The most important cost factors are the following:

- Rotor (with rotor hub)
- Nacelle
- Tower (incl. cabling)
- MV switchgear
- Foundation
- Transformer
- Crane hard standing areas
- Crane
- Transport costs
- Personnel costs

All disassembly costs are considered in chapter 5.9, page 15. The transport costs are considered in the respective prices/returns.

Only the materials steel, aluminum, copper and GRP are listed separately. The quantities of other materials are negligible. Electronic scrap and hazardous waste must be disposed of separately by law. Returns from cast iron are a little higher than those from steel. All prices stated in this document are net prices rounded to whole numbers. Since raw material costs may fluctuate greatly, the actual daily prices may differ significantly. Costs and return also depend on region and quantity.

- Sale of steel: approx. € 260.00 per t
- Sale of copper with insulation: approx. € 1,600.00 per t
- Sale of aluminum: approx. € 900.00 per t
- Sale of electronic scrap: approx. € 100.00 per t
- Costs for hazardous waste: approx. € 360.00 per t
- Costs for GRP material, crushing and disposal: approx. € 268.00 per t
- Costs for foundation breakup, transport, disposal and backfilling: from € 50 per m^3
- Costs for earth work, crane hard standing areas and access roads: from € 15 per m^2
- Crane costs: € 8,000.00 per day + one-time cost of € 25,000.00–80,000.00
- Personnel costs: € 4,000.00 per day

5.1 Rotor and rotor hub

The rotor must be disassembled using a crane. The rotor blades are crushed on site, transported away and passed to thermal or material recycling. Metal parts, such as lightning protection, are neglected here. The crushing process places high demands due to the size of the rotor blades and for reasons of dust protection and can account for approx. 30 % of the costs.

5.2 Nacelle

The nacelle must be disassembled using a crane. The nacelle can be disassembled into the following individual components: drive train (rotor shaft and gearbox), generator and the support frame construction. It can then be transported away for recycling.

5.3 Tower

The tubular steel tower of the WT must be disassembled using a crane. The aluminum installations and copper cables are removed. The tower is disassembled on site and transported away. A concrete tower is blown up. The concrete is broken up and the reinforcement is scrapped.

5.4 Electronic scrap

The electrical components in the WT and in the compact transformer substation must be disposed of separately as they are subject to the regulations on electronic waste. This applies to switch cabinets, transformers and MV switchgear. The electronic scrap is sorted and recycled by specialist companies. Depending on the degree of sorting, the recycling company and the raw material prices, the returns and costs for electronic scrap can vary widely.

5.5 Foundation

The foundation in accordance with DIBt (Deutsches Institut für Bautechnik [German Institute for Civil Engineering]) is a circular shallow foundation with steel reinforcement. The foundation must be broken up partially or completely in accordance with the specifications of the building permits or other regulations.

Blowing up the foundation might be the most effective method. The concrete must be disposed of and the reinforcement scrapped. Depending on the official requirements or the technology used, it may be cheaper to break up and dispose of the entire foundation; this case was applied here.

5.6 Transformer/substation

The substation (1 per wind farm) and the transformer (1 per WT) must be disassembled and transported away. This results in transport and disposal costs and sale returns. There is no foundation.

5.7 Cabling/underground cable

Copper and aluminum cables are recovered during WT disassembly. The cabling between the WTs within the wind farm is not considered here, because the number of WTs and distances differ between projects.

5.8 Crane hard standing areas and access roads

In accordance with the Nordex sales documentation, crane hard standing areas and access roads are necessary for the WT and exist since its erection. These areas must be deconstructed after completion of the dismantling work (excavation and backfill with soil). A minimized crane hard standing area is assumed.

The access roads between the WTs within the wind farm are not considered here, because the number of WTs and distances differ between projects.

5.9 Cranes and disassembly costs

An 800 t crane and a 120 t auxiliary crane are required for deconstruction work. One-time "mobilization costs" of € 25,000.00 to € 80,000.00 are incurred for crane deployment. The large margin is due to unpredictable local conditions. There are additional crane costs for each working day, and in wind farms, for the additional logistic requirements of the cranes.

For the dismantling of the WT and the transport of the WT components, 4 days are estimated.

The figures given here as an example assume a 100 m tower. The crane costs depend greatly on the tower height and the max. required hook load (degree of disassembly of the WT).

5.10 Hazardous waste

The hazardous waste materials arising from a WT must be collected separately and recycled or disposed of by special companies. They include batteries, coolants and lubricants. Nordex provides a list of the coolants and lubricants used, including quantities.

Batteries are in the rotor hub, in the switch cabinet in the tower base and – where applicable – in switch cabinets for obstacle lights and in any other installed options.