Decommissioning of Onshore Wind Turbines

Industry Guidance Document

WindEurope

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The contents of these guidelines were submitted to the International Electrotechnical Commission TC88 for Wind Turbines, to create an amendment to 61400-28 CD Technical Specification Wind energy generation systems – Through life management and life extension of wind power assets.

These guidelines do not constitute advice, are not exhaustive and do not indicate specific course of action. Detailed professional advice should be obtained before taking or refraining from action in relation to any of the contents of this guide, or the relevance or applicability of the information herein.

Health & Safety considerations still need to be identified and verified.

Wind EUROPE

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EXECUTIVE SUMMARY

Today 34,000 turbines are 15 years or older, representing 36 GW of onshore wind capacity. Out of the 36 GW some 9 GW are 20-24 years old and around 1 GW are 25 years or older. This creates a big market for decommissioning of onshore wind farms over the next decade.

However, an international standard for decommissioning wind turbines does not exist today. WindEurope therefore launched a Task Force for Dismantling and Decommissioning to produce guidelines for sustainable decommissioning. This document summarises that work with the aim of inputting the elaboration of an international standard through the International Electrotechnical Commission (IEC). As such, the document should be used as non-prescriptive general guidance, providing only high-level information on decommissioning and dismantling steps for onshore wind farms.

The Task Force identified the main regulations for dismantling onshore wind farms in key European countries - France, Denmark, Germany, Italy, Netherlands, Spain and the UK. The regulatory mapping includes identifying European and national legislation for waste management and site restoration. As the objective is circularity, we refer throughout the document to this as resources management (oils, rare earths, metals, composites, concrete, electric cables).

The decommissioning plan is the key document for the decommissioning of a wind farm. A decommissioning plan of a wind farm must reflect national and, in some cases, regional or local legislation. These guidelines provide key ones using an example of a German decommissioning plan as well as an example of a communication plan in France.

The dismantling of a wind farm is also dependant on different national guidelines for demolition. In the case of Germany, we present an overview of the DIN 18007 against which most common procedures are evaluated in terms of their suitability and impact depending on construction, component and building material. Cutting and separating methods as well as loading and transport steps are addressed in the dismantling chapter, together with the health and safety requirements, which are crucial for a sustainable decommissioning.

Wind turbines are a valuable source of resources that can be reintroduced into the circular economy. The aim should preferably be for use over the long-term, as this is the most sustainable application. However, at some point in time, wind turbines will reach the end of its life and valuable resources must be returned to the material cycle. The resource management chapter of these guidelines presents the key materials that can be found in a turbine (metals, oils, rare earths, composites and concrete) and recycling methods for rare earths, composites and concrete.

If not specified otherwise, once decommissioned, the wind farm will have to restore the site to a greenfield. Due to the residue-free removal of all operating fluids during the preparatory work for the dismantling, as well as the provision of binding agents, emissions into groundwater and soil are not to be expected, or only to a minimal extent. An example of site restoration to a greenfield in Germany is provided in the guidelines as well.

Health and safety requirements should always be a top priority throughout the whole process of decommissioning a wind farm. That, and a solid communication plan with the local authorities, are key factors for a sustainable decommissioning of a wind farm.

GLOSSARY OF TERMS

TERM	DEFINITION
Authority	A person or a company tasked by the national or local government as a supervisor that checks whether the public-law provisions of the decommissioning measure are being complied with.
Collection	The gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility.
Decommissioning	Removing a wind farm from service.
Dismantling	Taking a wind turbine apart into separate pieces.
Dismantling company	A company that has the responsibility of carrying out dismantling or removal work and choosing the type of demolition or the demolition method.
Disposal	Any operation which is not recovery even where the operation has as a secondary consequence such as the reclamation of substances or energy.
Hazardous waste	Waste which displays one or more of the hazardous properties listed in Annex III of the Waste Framework Directive (2008/98/EC).
Municipal waste	Includes household waste and similar commercial, industrial and institutional wastes including separately collected fractions (paper, metal, plastic and glass).
Operating company	A company that is tasked by the owner (in some cases the same company) with responsibilities for the planning, monitoring and disposal of one or multiple wind turbine generators.
Owner	One or multiple companies owning the wind farm in which one or multiple wind turbine generators need to be decommissioned.
Preparing for re-use	Checking, cleaning or repairing recovery operations, by which products, or components of products, that have become waste are prepared so that they can be re-used without any other pre-processing.
Prevent	Measures taken before a substance, material or product has become waste, that reduce: a. the quantity of waste, including through the re-use of products or the extension of the lifespan of products; b. the adverse impacts of the generated waste on the environment and human health; or c. the content of harmful substances in materials and products.
Rare earths	Rare earth elements belong in a group of 17 chemical elements with similar catalytic, magnetic, optical and other properties, which can be found in some wind turbine models.
Recovery	Any operation whose principal result is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.

TERM	DEFINITION
Recycle	Any recovery operation by which waste materials are reprocessed into products, materials or substances, whether for the original or other purposes.
Regeneration	Any recycling operation whereby base oils can be produced by refining waste oils, in particular by removing the contaminants, the oxidation products and the additives contained in such oils.
Repowering	The process of replacing wind turbines within a windfarm with newer turbines. Only if the majority of the components (including the foundation) are replaced can a project be considered as a repowering project.
Repurpose	Re-using an existing component or part of the component for a different application.
Re-use	Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.
Separate collection	The collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment.
Treatment	Recovery or disposal operations, including preparation prior to recovery or disposal
Waste	Any substance or object which the holder discards,intends to discard or is required to discard.
Waste broker	Any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste.
Waste dealer	Any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste.
Waste holder	The waste producer, or the natural or legal person, who is in possession of the waste.
Waste management	The collection, transport, recovery and disposal of waste, including the supervision of such operations and the aftercare of disposal sites and including actions taken as a dealer or broker.
Waste management company	A company that is responsible for the processes and activities that are subject to recycling or the disposal of waste/materials.
Waste oils	Any mineral or synthetic lubrication or industrial oil which has become unfit for the use for which they were originally intended, such as used combustion engine oils and gearbox oils, lubricating oils, oils for turbines and hydraulic oil.
Waste producer	Anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.

1. INTRODUCTION

1.1. CONTEXT

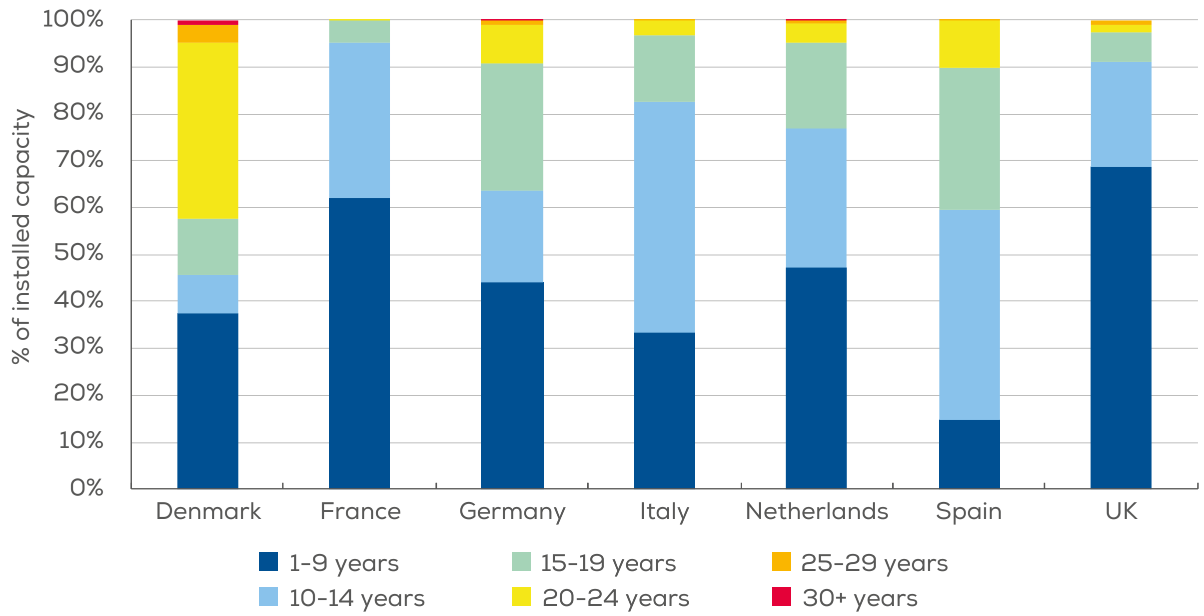
A growing amount of wind turbines will start to be decommissioned considering that:

- the standard lifetime of a wind turbine is approximately 20-25 years (with some wind turbines now reaching up to 35 years); and
- there are increasing repowering opportunities i.e. replacing old models with newer and more efficient models.

Today 34,000 turbines are 15 years or older, representing 36 GW of onshore wind capacity. Out of the 36 GW some 9 GW are 20-24 years old and around 1 GW are 25 years or older. Most of the ageing capacity is in Germany, followed by Spain, Italy and France. This is a significant volume that needs certain logistics in place to proceed with dismantling, collection, transportation, waste management treatment and finally site restoration in a sustainable way.

FIGURE 1

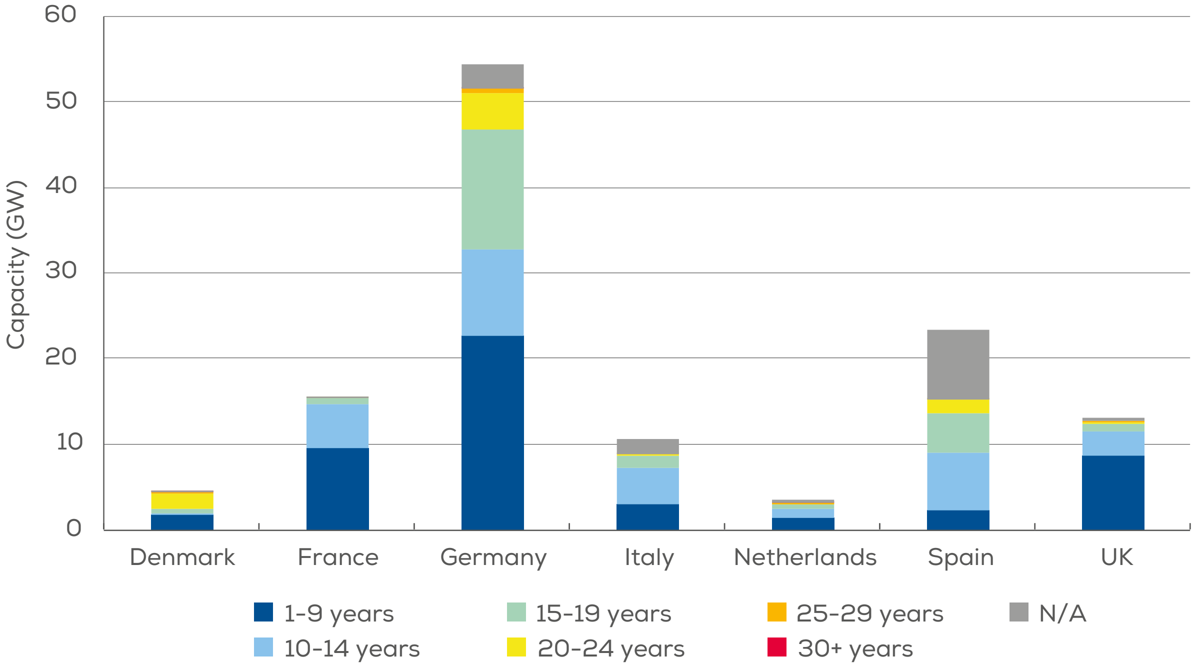
Age distribution of onshore wind capacity in seven European countries



Source: WindEurope

FIGURE 2

Age distribution of the onshore wind fleet in Europe in GWs



Source: WindEurope

1.2. PURPOSE

These guidelines were produced by WindEurope with the help of the WindEurope Decommissioning and Dismantling Task Force. The contents of these guidelines are only intended for submission to the International Electrotechnical Commission TC88 for Wind Turbines, to create an amendment to 61400-28 CD Technical Specification Wind energy generation systems – Through life management and life extension of wind power assets. This 61400-28 is currently in a Committee Draft (CD) version. The amendment intends to add the content for end-of-life.

The guidelines and foreseen Technical Specification are intended to be used as general guidance providing basic high-level information on decommissioning and dismantling arrangements for onshore wind farms. The guidelines are not to be perceived as prescriptive.

The intended audience for these guidelines is: decision-makers including asset owners, governments and customers. These guidelines aim primarily to provide direction for sustainable decommissioning and dismantling of wind turbines, by recognising existing legislation and adopting industry best practice throughout the European wind power industry.

Following industry-specific best practices will ultimately expedite national permitting procedures and reduce the cost of wind energy by having aligned procedures and joint acceptance. This will provide a better climate for companies to conduct their business within the European industry.

Following these guidelines does not relieve asset owners of their duty to ensure compliance with local legislation. Additionally, asset owners might need to take stricter measures depending on company policy.

2.
MAPPING OF REGULATIONS

2.1. DISMANTLING

Dismantling of wind turbines is regulated by national legislation as explained below:

DENMARK

The municipality typically sets the conditions for decommissioning in the building and operating permit initially issued. Decommissioning must start 1 year after the wind farm has stopped operating at the latest.

FRANCE

Decommissioning of wind turbines is regulated by the 'arrêté du 26 août 2011 relatif à la remise en état et à la constitution des garanties financières pour les installations de production d'électricité utilisant l'énergie mécanique du vent' and the 'code de l'environnement'. This regulatory framework has been amended by the 'arrêté du 22 juin 2020'[1,2].

Specific provisions are also provided under Article R 515-107 of the Environmental Code.

GERMANY

Decommissioning of wind turbines is regulated by the Renewable Energy Sources Act, 2017. Some provisions are also made in the Building Code.

ITALY

Decommissioning of wind turbines is regulated by the Ministerial Decree of 10 September 2010 titled "Guidelines for the authorisation of plants powered by renewable sources".

NETHERLANDS

The dismantling of wind turbines falls under the Building Decree 2012 (https://wetten.overheid.nl/BWBR0030461/2012-04-01#Hoofdstuk1_Paragraaf1.7).

SPAIN

There is no regulatory framework on decommissioning of wind turbines in Spain. Any decommissioning requirements are included in the Environmental Impact Assessment (EIA) for each project.

UNITED KINGDOM

Decommissioning requirements are set in the planning conditions for each project that has received permission.

Most projects will have agreed a 'decommissioning bond' with the local planning authority at the point of planning consent to cover the costs of decommissioning, usually in the form of a planning condition.

1. https://www.legifrance.gouv.fr/eli/arrete/2020/6/22/TREP2003954A/jo/texte#JORFARTI000042056139
2. https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=LEGITEXT000024514712&dateTexte=20200715
https://www.legifrance.gouv.fr/affichTexte.do;jsessionid=FB52D4508FA4524947D544FBA62933D8.tplgfr31s_1?cidTexte=LEGITEX-T000024514712&dateTexte=20210101

2.2. LEGISLATION FRAMEWORK FOR RESOURCE MANAGEMENT

GENERAL

The EU Waste Framework Directive (2008/98/EC) defines basic concepts related to waste management. It highlights the reduced availability of landfill and emphasises the need for extended producer responsibility and increased recycling. It requires that waste be managed without endangering human health and harming the environment. This also establishes the waste hierarchy.

The European Commission adopted the Circular Economy Package in July 2018, which included revised legislative proposals that Member States will need to transfer into national law. The following targets were set:

- A common EU target for recycling 65% of municipal waste (paper, metal, plastic and glass) by 2030;
- A binding landfill target to reduce landfill to a maximum of 10% of municipal waste by 2030;
- A ban on landfilling separately collected waste.

On 11 March the European Commission adopted a new Circular Economy Action Plan - one of the main blocks of the European Green Deal, Europe's new agenda for sustainable growth. The new Action Plan announces initiatives along the entire life cycle of products, targeting for example their design, promoting circular economy processes, fostering sustainable consumption, and aiming to ensure that the resources used are kept in the EU economy for as long as possible.

The new Circular Economy Action presents measures to:

- Make sustainable products the norm in the EU;
- Empower consumers and public buyers;
- Focus on the sectors that use most resources and where the potential for circularity is high, such as: electronics and ICT; batteries and vehicles; packaging; plastics; textiles; construction and buildings; food; water and nutrients;
- Ensure less waste;

Make circularity work for people, regions and cities,

- Lead global efforts on circular economy.

It does not contain legally binding legislation at this stage. Rather, it outlines future measures aimed at cutting waste in areas like textiles, buildings and electronic equipment, which have so far been unaddressed at the EU level.

As part of this legislative initiative, and, where appropriate, through complementary legislative proposals, the Commission will consider establishing sustainability principles and other appropriate ways to regulate the following aspects:

- improving product durability, reusability, upgradability and reparability, addressing the presence of hazardous chemicals in products, and increasing their energy and resource efficiency;
- increasing recycled content in products, while ensuring their performance and safety;
- enabling remanufacturing and high-quality recycling;
- reducing carbon and environmental footprints;
- restricting single-use and countering premature obsolescence;
- introducing a ban on the destruction of unsold durable goods;
- incentivising product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle;
- mobilising the potential of digitalisation of product information, including solutions such as digital passports, tagging and watermarks;
- rewarding products based on their different sustainability performance, including by linking high performance levels to incentives.

Priority will be given to addressing product groups identified in the context of the value chains featuring in this Action Plan, such as electronics, ICT and textiles but also furniture and high impact intermediary products such as steel, cement and chemicals. Further product groups will be identified based on their environmental impact and circularity potential.

The legislative framework for special resources used in wind turbines can be seen below, sorted by mass fraction within a wind turbine:

CONCRETE

Legislation pertaining to cement as a material: Common cements in Europe are specified by the European standard EN 197-1.

Legislation pertaining to recycling cement and concrete: Most European countries don't have explicit legislation pertaining to wind turbine foundations but concrete waste (EWC-number: 17 01 01) is one waste source in the EU's construction and demolition waste (CDW) category. Under the EU Waste Framework Directive (2008/98/EC), at least 70% by weight of non-hazardous CDW must be reused or recycled by 2020.

DENMARK

Article 2(2) of the Environmental Protection Act, 2016 states that municipalities must adopt regulations on sorting of building and construction waste, allocation of construction and demolition waste and notification of quantities thereof.

FRANCE

All demolition waste must be characterised depending on whether it is inert, non-inert but non-hazardous, or non-inert and hazardous, and be treated according to the waste hierarchy (Book V, Title IV Waste of the Environmental Code).

According to Article R. 515-106 of the Environmental Code, demolition and dismantling waste must be recovered or disposed of in the sectors duly authorised for this purpose.

According to the Arrêté du 26 août 2011 Section 7 Demantelement Article 29:

"The excavation of all the foundations up to the base, with the exception of any piles. By way of derogation, the lower part of the foundations can be kept in the ground on the basis of a study sent to the prefect demonstrating that the environmental balance sheet of the total disbursement is unfavourable, without the excavated depth being less than 2 meters in the land for forest use under the opposable town planning document and 1 m in other cases. Excavated foundations are replaced by earth with characteristics comparable to the land in place near the installation."

ITALY

The most important legislative pieces on CDW management are:

- D.Lgs 152/2006 (and amendements) « Norme in materia di ambiente (Codice ambiente)»;
- D.M. 5/2/98 (amended by Decreto 5/4/06 n. 186) "Individuazione dei rifiuti non pericolosi sottoposti alle procedure semplificate di recupero ai sensi degli articoli 31 e 33 del decreto legislativo 5 febbraio 1997, n. 22";

More info is available at the website of the European Commission[3].

NETHERLANDS

Under the Dutch legislation, lap 3, concrete from renovation or demolition of buildings, roads and other infrastructure must be recycled or reused.

SPAIN

The Royal decree 105/2008 of 1 February regulates the management of construction and demolition waste.

UK

There is no special legislation in place on the disposal of onshore wind turbine foundations in the UK.

METALS

Article 10(2) of the EU Waste Framework Directive (2008/98/EC) states separate collection shall be set up for paper, metal, plastics and glass by 2015. This means that metals that come from the wind turbines should be held separate from other waste streams. Article 11 of the EU Waste Framework Directive 2009/98 states that ''members states shall take measures to promote high quality recycling and, to this end, shall set up separate collections of waste where technically, environmentally and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors''.

3. https://ec.europa.eu/environment/waste/studies/deliverables/CDW_Italy_Factsheet_Final.pdf

DENMARK

Article 2(2) of the Environmental Protection Act, 2016 states municipalities must adopt regulations on sorting of building and construction waste, allocation of construction and demolition waste and notification of quantities thereof.

FRANCE

It is regulated according to Articles D543-282, R. 541-50 and R. 541-54-1 of the Environmental Code.

GERMANY

Germany follows the EU Waste Framework Directive (2008/98/EC) for the treatment of metals (Umwelt Bundesamt, 2014). This is transposed in the Commercial Waste Ordinance, 2002.

ITALY

The Legislative Decree n. 205 of 2 December 2010 transposes the EU Waste Framework Directive.

NETHERLANDS

According to Sectorplannen lap 3, sector plan 12, all metals (ferrous and nonferrous) should be brought to a recycling plant.

SPAIN

Spain follows the EU Waste Framework Directive (2008/98/EC) for the treatment of metals. This is transposed in the Law 22/2011 on Waste and Contaminated Land. Regions also have their own legislation.

UK

The UK follows the EU Waste Framework Directive (2008/98/EC) for the treatment of metals. From 1 January 2015, UK waste regulations require businesses to separate recyclable material from other waste (e.g. the Waste (England and Wales) Regulations 2011 as amended in 2015).

COMPOSITES

According to the European classification of wastes, composite blade waste is most often categorised as plastic waste from construction and demolition with the code 17 02 03.

To date, few regulatory requirements are in place for the composite waste sector. Nevertheless, there is a clear push towards more circularity in general at the European level as shown by the new EU Circular Economy Action Plan (2020)[4]. The European Strategy for Plastics in a Circular Economy (2018)[5] stresses that the low reuse and recycling rates (less than 30%) of end-of-life plastics is a key challenge to be addressed. It sets out the vision for 'circular' plastics with concrete actions at EU level. The strategy also stresses that the private sector – together with national and regional authorities, cities and citizens – will need to mobilise to fulfil this vision. So far, the focus has been on single-use plastics, microplastics, oxo-plastics and plastic packaging, and not on composite waste.

At the national level, four countries make a clear reference to composite waste in their legislation: Germany, Austria, the Netherlands and Finland. These countries forbid composites from being landfilled or incinerated.

FRANCE

Article 20 of the "Arrêté du 22 juin 2020 modifiant l'arrêté du 26 août 2011 relatif aux installations de production d'électricité utilisant l'énergie mécanique du vent […]" sets recycling targets for wind turbines as whole, and rotor blades in particular[6,7]:

- from 1 July 2022, a minimum of 35% of the rotor mass must be reused or recycled (for existing wind turbines).
- after 1 January 2023, 45% of the rotor mass must be reused or recycled (for wind turbines for which a planning application is submitted after this date).
- after 1 January 2025, 55% of the rotor mass must be reused or recycled (for wind turbines for which a planning application is submitted after this date).

4. https://ec.europa.eu/environment/circular-economy/index_en.htm
5. https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf
6. https://www.legifrance.gouv.fr/eli/arrete/2020/6/22/TREP2003954A/jo/texte#JORFARTI000042056139
7. https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000024507365&dateTexte=20200715

GERMANY

A ban on directly landfilling waste with a total organic content (TOC) higher than 3% came into force in 2009. Considering blades contain an organic part due to the resin that glues together the glass fibres, they cannot be landfilled.

NETHERLANDS

Under the 3rd edition of the National Waste Management Plan, landfilling of composite waste is banned 'in principle'. However, wind park operators can benefit from an "exemption" if alternative solutions are considered too costly i.e. where the cost of treatment is higher than the benchmark value of €200/t.

RARE EARTHS

Rare earth elements are a group of 17 chemical elements (cerium (Ce), dysprosium (Dy), erbium (Er), europium (Eu), gadolinium (Gd), holmium (Ho), lanthanum (La), lutetium (Lu), neodymium (Nd), praseodymium (Pr), promethium (Pm), samarium (Sm), scandium (Sc), terbium (Tb), thulium (Tm), ytterbium (Yb), and yttrium (Y)), categorised as specialty metals. The rare earth elements used in the production of permanent magnets are neodymium (Nd), terbium (Tb), dysprosium (Dy) and praseodymium (Pr). Neodymium–iron–boron (Nd2Fe14B) magnets are used in wind turbines. These magnets typically contain 29% of Nd and 1-1.5% of Dy.

Under the EU Waste Framework Directive (2008/98/EC), rare earth elements are listed as non-hazardous. To date, there is no specific European or national legislation related to rare earths.

ELECTRIC CABLES

The WEEE Directive 2012/19/EU article 2 section 4(c) states that ''this Directive shall not apply to the following EEE: large-scale fixed installations, except any equipment which is not specifically designed and installed as part of those installations". Under Annex VII of the EU Waste Electrical & Electronic Equipment (WEEE) Directive (2012/19/EU), external electric cables must be removed from any separately collected WEEE and be disposed of or recovered in compliance with the Waste Framework Directive (2008/98/EC).

OILS

The EU Waste Framework Directive (2008/98/EC) states that waste oils must be collected separately (where this is technically feasible) and treated in accordance with the waste hierarchy and without any harm to human health and the environment. Where feasible, waste oils of different characteristics should not be mixed to enable treatment. Member States may apply additional measures such as technical requirements, producer responsibility, economic instruments or voluntary agreements.

DENMARK

Denmark follows the EU Waste Framework Directive (2008/98/EC) for the treatment of waste oil via provisions in the Statutory Orders on Waste. Waste oils are primarily treated by regeneration and/or incineration with energy recovery.

FRANCE

Waste oil management is regulated by the Code de l'environnement Articles R543-3 to R.543-15.

GERMANY

Waste oil management is regulated by the Waste Oil Ordinance of 01.05.2002 and Article 19 of the Federal Water Act.

ITALY

The Legislative Decree n. 205 of 2 December 2010 transposes the EU Waste Framework Directive.

NETHERLANDS

The 'Sector plan 56 Afgewerkte olie' states that oil from wind turbines should be primarily treated by regeneration and/or incineration with energy recovery.

SPAIN

Spain follows the EU Waste Framework Directive (2008/98/EC) for the treatment of waste oil. This is transposed in the Law 22/2011 on Waste and Contaminated Land. Regions also have their own legislation.

UNITED KINGDOM

In Scotland, Wales and Northern Ireland waste oil management is regulated by the Pollution Prevention Guide under the section 'Safe storage and disposal of used oils (PPG8)'.

In England waste oil management is regulated by the 'Control of pollution (oil storage) (England) regulations 2001'. This legislation is similar to that of Scotland, Wales and Northern Ireland.

2.3. SITE RESTORATION

Site restoration is regulated by national legislation as explained below:

DENMARK

The municipality typically sets the conditions for decommissioning in the building and operating permit initially issued. A common requirement is to remove all equipment, including the foundation, as deep as 1m below the surface and rehabilitate the area.

FRANCE

Article 1 of the 'Arrêté du 26 août 2011' regulates decommissioning of wind turbines.

Proposed amendments to the current legal framework will require total excavation of foundations at the end of life except if an environmental impact assessment recommends not to do it.

According to Arrêté du 26 août 2011 Section 7 Demantelement Article 29, excavated foundations are replaced by earth with characteristics comparable to the land in place near the installation. The restoration of the site with the disbursement of the crane areas and access roads to a depth of 40 centimetres and the replacement by land of characteristics comparable to the land near the installation, unless the owner of the land on which is located the installation wishes their maintenance in the state.

GERMANY

Paragraph 35 (5) of the Building Code has the following provisions: "The operator has to issue a declaration of commitment to dismantle the installation and remove all soil sealing when permanently abandoning the site."

The Federal States Committee for Soil Protection has commissioned the development of guidelines on soil protection measures to be observed when dismantling wind turbines.

ITALY

The Ministerial Decree of 10 September 2010 requires producers to return the site to its original conditions.

NETHERLANDS

There is no specific legislation regulating the removal of wind turbine foundations in the Netherlands. Instead, any foundation removal requirements are set in the agreements between the landowner and the operator.

SPAIN

There is no regulatory framework on decommissioning of wind turbines in Spain. Any decommissioning requirements (including site restoration) are included in the EIA for each project.

UNITED KINGDOM

Decommissioning requirements are set in the planning conditions for each project that has received permission. The consenting authority can include requirements for restoration of land to an acceptable condition as part of the planning approval process.

3. DECOMMISSIONING PLAN

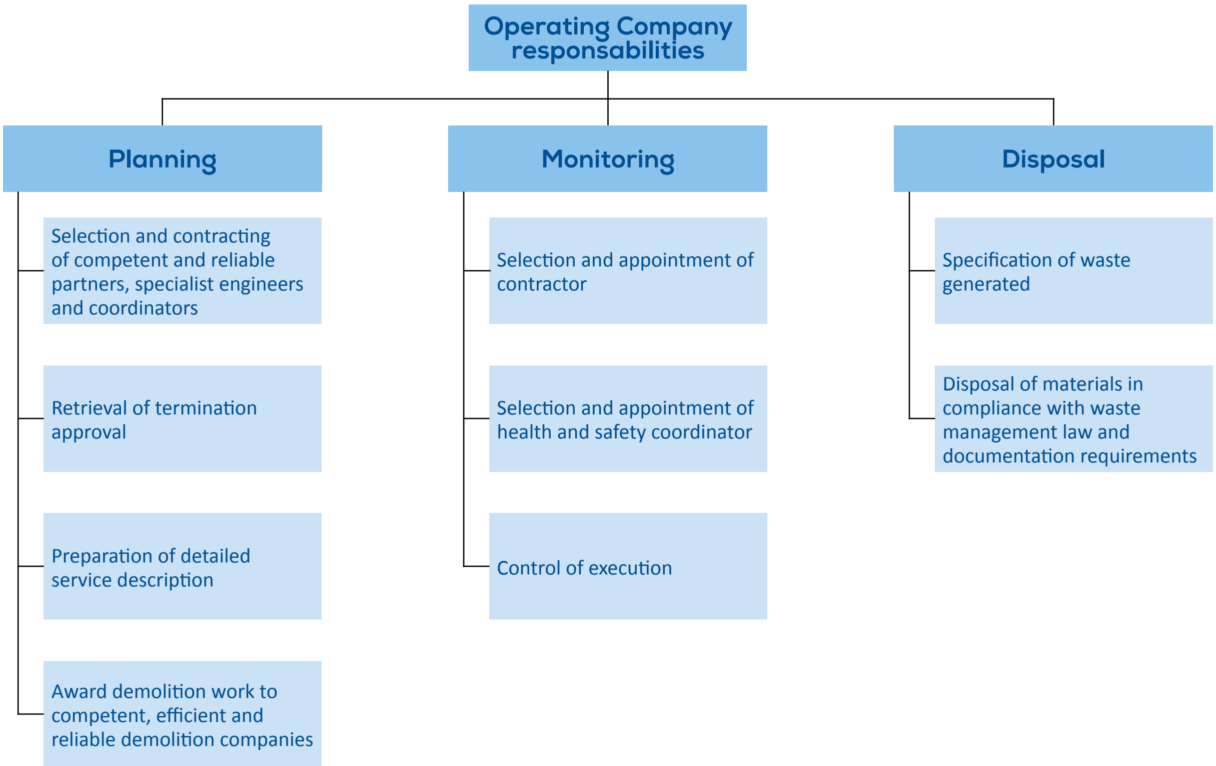
The decommissioning plan has to reflect national and, in some cases, regional or local legislation. This chapter reflects on a German example of a decommissioning plan and an example of a communication plan in France.

3.1. PROJECT MANAGEMENT

The preparation and implementation of the decommissioning and dismantling measures of individual wind turbine generators (WTGs) or the complete wind farm is divided into the following areas of responsibility by the parties involved:

- owner of the WTG or the complete wind farm;
- operating company of the WTG or the complete wind farm;
- dismantling company;
- waste management company;
- authority.

FIGURE 3
Overview of responsibilities of Operating Company



Source: WindEurope

3.1.1. OPERATING COMPANY

The owner of the WTG bears the overall responsibility for the decommissioning and dismantling measures to be carried out. The operating company of the WTG is usually the executing leg of an owner company (and in some cases the same company), which will be responsible for the planning, monitoring and disposal. If the operating company does not have its own expertise to fulfil the tasks in these areas, suitable expert persons or companies must be commissioned and the tasks delegated to them. However, the responsibility remains with the operating company.

The following overview (Figure 3) summarizes the responsibilities of the operating company. The areas of responsibility are assigned to exemplary - but not exhaustive - task areas.

3.2.2. DISMANTLING COMPANY

The dismantling company must prove its expertise in specific fields. The field of activity of the dismantling company comprises the following key areas, divided into general tasks and general and specific preparations for the dismantling project.

At the dismantling site, extensive waste categorisation should be in place in order to ensure the highest possible quality of recycling of the respective categories and to prevent an accumulation of pollutants in the material cycle. In accordance with the tender for the dismantling measure, the dismantling company selects the type of demolition or the demolition method to be used.

The dismantling company has the following responsibilities, among others, when carrying out dismantling or removal work:

- Checking the presence of the written dismantling or removal instructions on the construction site;
- compliance with health and safety regulations;
- verification of compliance with prescribed protective measures;
- control of the permanent presence of the supervisor (site manager);
- the obligation of coordination for all undertakings concerned;
- control of the proper execution in compliance with the generally accepted rules of technology and the approved demolition documents.

3.1.3. WASTE MANAGEMENT COMPANY

In Germany a waste management company is legally defined as a specialist waste management company in § 56 Para. 2 of the Closed Substance Cycle and Waste Management Act (Kreislaufwirtschaftsgesetz (KrWG)).

Disposal is a generic term for all processes and activities that are subject to recycling (to be differentiated in: reuse, recycling (material recovery) and energy recovery) or the disposal of waste/materials.

The waste management company is responsible for:

- the disposal of the materials and material flows resulting from the dismantling of the WTGs, foundations and infrastructure/balance-of-plant equipment;
- waste disposal logistics: all logistical measures for the preparation and implementation of waste disposal (this includes all corresponding planning and implementation activities);
- compliance with the requirements and conditions with regards to the proper and complete disposal of the various materials in terms of the KrWG;
- Issuing the corresponding qualified proof of disposal (incl. weighing slip)

3.1.4. AUTHORITY

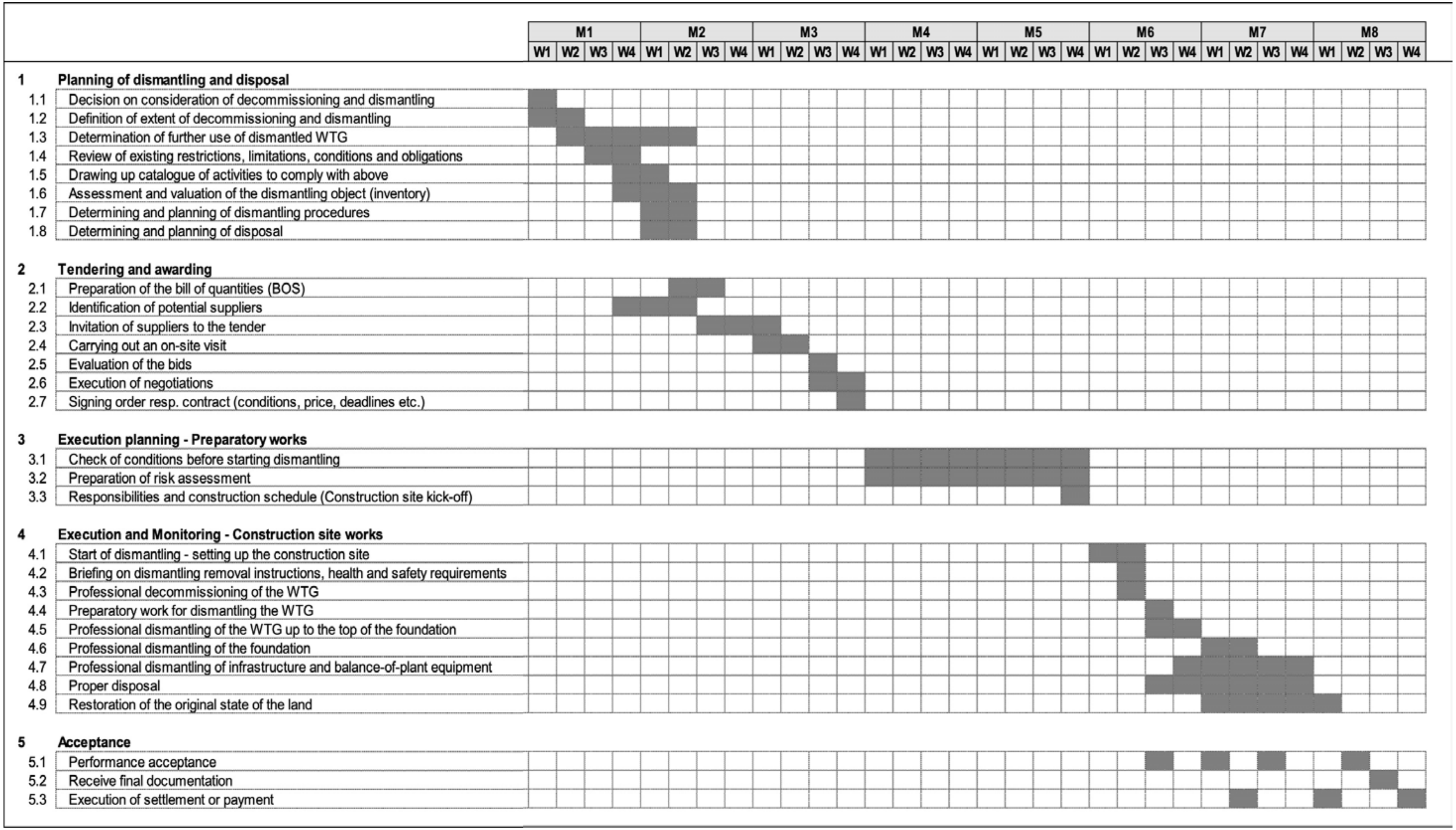
The authority has a responsibility as a supervisor; the representatives of the authority check that the public-law provisions of the decommissioning measure are complied with. This includes, among other things, compliance with the obligations for the disposal of hazardous waste. In addition, authorities may require the former operating company to submit appropriate documents to prove that the waste was disposed of properly.

PROJECT MANAGEMENT

It is advisable to plan decommissioning thoroughly and to carry it out systematically. This saves the operating company unexpected delays and additional costs. The individual process steps for successful project management of dismantling WTG are listed in an example time planner on the next page and described in the following section:

FIGURE 4

Timeline for individual processes in a decommissioning plan



Source: WindEurope

3.2. DESCRIPTION OF ACTIVITIES

3.2.1. PLANNING OF DISMANTLING AND DISPOSAL

3.2.1.1. DECISION ON CONSIDERATION OF DECOMMISSIONING AND DISMANTLING

The decision to dismantle a wind turbine or the complete wind farm can result from the following factors:

- a WTG has suffered damage compromising safe operations in the area and/or an accompanying total economic loss;
- the end of the land use contracts has been reached and they cannot be extended;
- expiry of the operating licence;
- (continued) operation is no longer economically viable;
- repowering.

3.2.1.2. DEFINITION OF THE EXTENT OF DECOMMISSIONING AND DISMANTLING

For the reasons mentioned above, it usually follows whether one or more individual wind turbines or the entire wind farm is to be decommissioned and dismantled. This determines which parts of the wind farm are to be retained or dismantled with regards to the infrastructure or balance-of-plant equipment and the grid connection point.

As for the extent of dismantling, especially foundations and infrastructure or balance-of-plant equipment such as crane assembly areas, access roads or cable routes, there are often no existing obligations under licensing law. However, almost all land use contracts usually contain provisions for the complete removal and restoration of the original state of the land after the permanent decommissioning of the WTG, so that this defines the scope of deconstruction.

3.2.1.3. DETERMINATION OF FURTHER USE OF THE DISMANTLED WTG

A distinction must be made whether the WTGs are to be marketed as a whole (without foundation) and, after dismantling, continue to be used as used WTGs, e.g. in a secondary market, or whether disposal is to take place in combination with a possible secondary use of individual components (e.g. rotor blade, gearbox or generator).

This further use or non-use of the WTG or individual WTG components determines the extent and manner of the dismantling measure. In order to define these services within the scope of the invitation to tender and award contracts, a potential buyer for a complete WTG, or for individual WTG components, must be irrevocably bound by contract as early as possible - at the latest before the start of the invitation to tender and request for a quotation.

3.2.1.4. REVIEW OF EXISTING RESTRICTIONS, LIMITATIONS, CONDITIONS, OBLIGATIONS

With regards to the dismantling and disposal of WTGs, the restrictions, limitations, conditions, obligations from the following sources must be examined:

- Land use contracts for WTG location, access route, cable route (internal and external);
- contracts concerning the grid connection point;
- approval of the WTGs, wind farm;
- conditions imposed by local authorities (e.g. soil, water, noise) from the building or demolition permit;
- EU legislation such as laws, regulations, rules, technical norms, standards, specifications, guidelines, directives.

3.2.1.5. DRAWING UP A CATALOGUE OF ACTIVITIES TO COMPLY WITH EXISTING RESTRICTIONS, LIMITATIONS, CONDITIONS, OBLIGATIONS

The restrictions, limitations, conditions, and obligations from point 1.4. Review of existing restrictions, limitations, conditions, obligations must be observed and implemented within the framework of dismantling and disposal. It is advisable to aggregate these points in an individual table or checklist so that all points are observed.

The question to be answered by the checklist in relation to point 1.4. Review of existing restrictions, limitations, conditions, obligations:

Who must implement what, when and how?

In this way, the responsibility, the way of implementation, and the time or deadline of a measure can be clearly tracked and checked for compliance. This catalogue of activities must be maintained throughout the entire dismantling measure and successively supplemented as new restrictions, limitations, requirements and obligations arise.

3.2.1.6. ASSESSMENT AND VALUATION OF THE DISMANTLING OBJECT (INVENTORY)

To ensure that the dismantling and disposal of the WTGs and infrastructure/balance-of-plant equipment can be implemented efficiently and safely, and that the relevant costs can be planned and determined, the material composition and the masses, weights, dimensions or volumes of the individual components of the WTGs and infrastructure/balance-of-plant equipment must be known.

For this purpose, the operating company must procure, compile and view the appropriate documentation from multiple documents and drawings. It is advisable to request the necessary data and documents from manufacturers and installers at an early stage, e.g. during commissioning. For this purpose, the WTG supply contract and the general contractor contract could include clear obligations of the WTG manufacturer/general contractor to hand over the relevant documents. During the operating phase, these documents should be backed up, data relevant for dismantling and disposal should be catalogued and, if necessary, e.g. when large components are replaced, updated as part of the plant life-cycle file.

The data required for the inventory can be generated from the following sources:

- As-Built documentation (of EPC), inter alia:
  - Building specifications; building permit application documents
  - Technical plans and drawings
  - Technical documentation; manufacturer specifications
  - Acceptance reports
  - Layout plans - (measured) cable route (internal and external)
  - Single-line diagram - internal cable route
- Technical specification and descriptions of the respective manufacturer of the component,
- Technical specification and descriptions of the WTG manufacturer,
- Service companies that have carried out operation and maintenance activities on the wind farm.

The concrete data for determining the types and quantities of materials required for the dismantling and disposal of the WTG, foundation and infrastructure/balance-of-plant equipment are given in Section 3.1.3 Data requirements. In this section, the definition of the components of the WTG, foundation and infrastructure, and balance-of-plant equipment is also included.

3.2.1.7. DETERMINING AND PLANNING OF DISMANTLING PROCEDURES

Details on this can be found in chapter 4 – Dismantling.

3.2.1.8. DETERMINING AND PLANNING OF DISPOSAL

The dismantled or disassembled components can be disposed of. For all groups of substances, the requirements and conditions pertaining to the proper and complete disposal of the various components are regulated nationally, which is in Germany in accordance with the KrWG. In addition, there are further specific requirements for individual groups of substances which must also be observed.

A detailed overview of materials that are relevant in the decommissioning process are explained in Chapter 5 – Resource Management.

The operating company should be able to provide proof of proper disposal on request within the scope of its responsibility for waste disposal. Some authorities already require proof of disposal (including weighing certificates). Thus, the relevant documents must be handed over by the commissioned dismantling company/disposer to the operating company at the latest with the acceptance of the services or as part of the final documentation. However, it must be ensured that this requirement for the handover of the proof of disposal (incl. weighing certificates) of all dismantled or disassembled components is included in the tendering process and is set out in writing as a service in the order/contract with the dismantling company/ disposal contractor.

In addition, the service "Creation of a disposal concept" can be integrated as an option in the tender, which must then be provided by the dismantling company/disposer before the start of dismantling. The waste disposal concept can serve the operating company and the commissioned contractor as an internal planning instrument and contains information on the expected quantities of the individual material flows, which are to be briefly described according to their nature and occurrence. In the waste disposal concept, the individual waste fractions arising are to be assigned to corresponding specialist waste management companies or operating facilities in a binding manner, with details of the acceptance criteria of the potential disposal companies if necessary. It is advisable that the transport and haulage companies involved are specifically named, but it limits the flexibility of the operating company.

3.2.2. TENDERING AND AWARDING

The process of tendering and awarding is initiated and carried out by the operating company. It can outsource a part of, or all of the process to experts or planners (e.g. engineering offices, other service providers). However, the responsibility for selecting a suitable dismantling and waste management company remains with the operating company.

3.2.3. EXECUTION PLANNING – PREPARATORY WORKS

3.2.3.1. CHECK OF CONDITIONS BEFORE STARTING DISMANTLING

Approximately three months before the start of the dismantling measure or the construction site, the operating company must ask the dismantling company about the necessary permits (including crane driving permit; road closures, accompanied traffic guidance, driving permit for heavy goods transport) and have these receipts verified for documentation purposes. The operating company also needs to announce the start of the dismantling measure to the authority. Depending on the county, this should be done at least one month before construction site kick-off.

In order to enable safe working with the main crane, certain soil mechanical properties of the sufficiently large crane assembly area are required. Depending on the location, it may be necessary to carry out additional preparatory work on the respective crane assembly area of the WTG before a crane is erected. Old WTGs often do not have (any longer) sufficient crane assembly areas, so a temporary crane assembly area, e.g. for laying out steel plates or placing ballast, has to be erected. If the access road is too narrow for the approach or departure of the main crane and for the heavy-duty transporters to be used, and the curve radius of the access routes are not (or no longer) available, the access routes must be temporarily extended in accordance with the specifications of the crane company. This can be done in the same way as for the crane assembly area, e.g. by placing ballast or laying out steel plates.

For this reason, the access roads (incl. curve radius) and the crane assembly areas must be checked for suitability, size and stability in an on-site appointment approx. 10 weeks before the start of the dismantling measure and, if necessary, the above-mentioned measures for preparing the crane assembly area and/or access routes (incl. curve radius) must be initiated.

3.2.3.2. PREPARATION OF RISK ASSESSMENT

The site-related risk assessment is prepared by the dismantling company before the dismantling work begins and must always be available on the construction site. It must be updated in the event of significant changes to the planned work sequence or in the event of hazards subsequently identified.

The accident insurance institutions will provide appropriate guidelines for the identification of hazards with measures to be selected to protect employees. At the latest before the start of dismantling or decommissioning, a risk assessment must be carried out to determine which protective measures are to be taken to prevent the release of pollutants and which requirements must be met with regards to disposal. When selecting the resulting protective measures, care must be taken to ensure that technical ones take precedence over organisational and personal protective measures.

The result of the risk assessment is included in the dismantling or removal instructions and is an important basis for the employee training to be carried out at the beginning of the dismantling measure.

3.2.3.3. CONSTRUCTION SITE KICK-OFF - RESPONSIBILITIES AND CONSTRUCTION SCHEDULE

All work must be carried out under the direction and supervision of a person authorised and responsible for the contractor on site, together with a representative.

With a lead time of approx. 8 weeks, the date "Construction Site Kick-off" takes place with all companies involved in the deconstruction. The responsibilities on site as well as a responsible person on the construction site are to be named in advance and presented at this date. This person should be authorised to give instructions to all employees of the companies involved on the construction site and should be the senior site manager and should also have assumed responsibility for the power plant. In addition, an external and independent person should be appointed to monitor the safety-related regulations and should be authorised to close the construction site in case of significant violations.

During this meeting, in addition to the responsibilities, the construction schedule and the time planning for the entire measure are discussed and, if necessary, adjustments are made based on comments from the companies involved. Finally, the construction schedule is bindingly determined and made available to all parties involved.

3.2.4. EXECUTION AND MONITORING – CONSTRUCTION SITE WORKS

3.2.4.1. START OF DISMANTLING - SETTING UP THE CONSTRUCTION SITE

A detailed overview of setting up the construction site is explained in chapter 4 – Dismantling.

3.2.4.2. BRIEFING ON DISMANTLING COMPLIANCE WITH REMOVAL INSTRUCTIONS, HEALTH AND SAFETY REQUIREMENTS

As a rule, the WTG manufacturer provides dismantling instructions. If this is not available, the dismantling company will prepare dismantling instructions. The dismantling instructions are based on the site-specific risk assessment.

The dismantling company must familiarise and instruct the employees on the construction site before starting their work on construction site-specific risk assessment and the dismantling or removal instructions (occupational safety). With their signature, the employees must confirm that they have been comprehensibly informed about possible hazards and protective measures. Within the framework of the transfer of duties, the dismantling company can delegate the implementation of the instructions to competent persons.

The respective applicable requirements and regulations regarding safety and occupational safety must always be complied with during the entire dismantling or removal of the wind turbines, infrastructure and balance-of-plant equipment. Proof of education and further training (e.g. height training, switching authorisation) or inspection stickers (e.g. for work equipment) must always be presented before (first) commencement of the respective work. In principle, the same standards should apply to dismantling as to assembly and be applied in practice.

3.2.4.3. PROFESSIONAL* DECOMMISSIONING OF THE WTG

In principle, the first step is to safely shut down and decommission the WTG intended for dismantling. In the second step, the WTG is physically separated from the internal cable route (usually the MV grid). For this purpose, the relevant cable harness to which the WTG is connected must first be disconnected. Depending on the extent and timing of the decommissioning or dismantling measures, these WTGs intended for dismantling can be decoupled in such a way that the remaining WTGs can continue to operate until they are decommissioned or removed.

With regards to the observance of safety and occupational safety, the disconnection of the grid must be carried out in the prescribed manner by an authorised person (with appropriate qualifications according to the existing voltage level (MS or HS)).

3.2.4.4. PREPARATORY WORK FOR DISMANTLING THE WTG

Connecting elements of the WTG

In the preparation phase, it is advisable to first loosen the individual connecting elements of the WTGs with torque wrenches and then to retighten them less strongly. In the dismantling phase to be carried out subsequently, this will minimise possible waiting times and thus downtimes for the comparatively expensive crane.

In total, about two days can be planned for the preparatory phase of dismantling, during which about 3-4 people work in parallel.

Special features for further use of the WTG

If the plant has been sold and the WTG will be used at another location, the dismantling preparation work must be carried out with the utmost care. This includes separation of cable connections (power cables and control cables) as well as the separation of tower installations (e.g. rail systems), which must be reassembled without any problems in case of a complete secondary use. Here, manufacturer-specific or plant-specific features must also be considered. In addition, detached connections must be labelled in detail so that no faulty assembly is possible when the WTG is assembled at the second location. Material traceability should be ensured as the dismantling and decommissioning responsibility lays with the owner of the re-used WTG.

3.2.4.5. PROFESSIONAL* DISMANTLING OF THE WTG UP TO THE TOP OF THE FOUNDATION

The steps of dismantling a WTG are shown in chapter 4 – Dismantling.

3.2.4.6. PROFESSIONAL* DISMANTLING OF THE FOUNDATION

The steps of dismantling foundations are shown in chapter 4 – Dismantling.

3.2.4.7. PROFESSIONAL* DISMANTLING OF THE INFRASTRUCTURE/BALANCE-OF-PLANT EQUIPMENT

The steps of dismantling of the infrastructure/balance-of-plant equipment are shown in chapter 4 – Dismantling.

3.2.4.8. PROPER DISPOSAL

The waste fractions resulting from the dismantling or after the dismantling of WTGs, foundations as well as infrastructure and balance-of-plant equipment (usually separately available) are transported in accordance with the waste management concept drawn up to the specialist waste management companies named therein, and disposed of (reused, recycled or recovered). Details of the disposal (reuse/recycling, energy recovery) of the individual waste fractions can be found in chapter 5 – Resource Management.

3.2.4.9. RESTORATION OF THE ORIGINAL STATE OF THE LAND

Site restoration is explained in chapter 6 – Site Restoration

3.2.5. ACCEPTANCE

3.2.5.1. PERFORMANCE ACCEPTANCE

Acceptance of the contractual services can be made for the complete service, or as a partial acceptance for self-contained partial services.

Acceptance shall be carried out at the request of the Customer, or the Contractor. Acceptance is intended to ensure that there is an agreement at the time of acceptance, and that any differences are clearly formulated.

For acceptance, the operating company checks the contractual condition of the plots. Among other things, it must be checked that:

- the foundations have been removed in accordance with the contract
- the infrastructure and balance-of-plant equipment have been removed in accordance with the contract
- the backfilling of the excavation pits meets the contractual requirements
- all work, in particular waste disposal, has been carried out in accordance with the contract

3.2.5.2. RECEIPT OF FINAL DOCUMENTATION

The final documentation includes inter alia:

- Systematic summary of the results of the deconstruction and renaturation of the areas documented in the construction diary
- Documentation of mass and material flows
- Proof of proper disposal

For preparation of the waste balance sheet, the dismantling company compiles the measurements and quantity determinations. The operating company, as the waste producer, is responsible for the obligations to provide evidence under waste law. This also includes keeping the register. The operating company can delegate the obligations to provide evidence under waste law to the dismantling company or to the specialist waste management company.

However, as a waste generator, the operating company is responsible for the proper and harmless disposal of all material flows. This responsibility of the operating company continues until the final disposal of the materials.

It is therefore important for the operating company to ensure that all documentation obligations are fulfilled correctly and that all proof of disposal (incl. a weighing slip) is collected in full so that it can be presented to the authorities on request if necessary.

3.2.5.3. EXECUTION OF SETTLEMENT OR PAYMENT

Invoicing takes place on the basis of the service description in conjunction with the contractually agreed remuneration, and usually after acceptance and final documentation.

3.3. DATA REQUIREMENTS

Not all the data that is necessary for decommissioning can be obtained from a wind turbine manufacturer. Data regarding WTG type, rated output, rotor diameter, hub height, weight of the hub, nacelle weight, generator type, towers, operating materials, lubricants, and gear oils is relatively easy for wind turbine manufacturers to share for newer wind turbine models. However, for old models it is necessary to find the data on the weight of the hub and the nacelle, generator type and operating materials from wind turbine manuals or from service companies that performed operation and maintenance on the wind farm.

Data on local distribution of composites within a blade and in reference to industrial magnets and their type not shared.

Data related to foundations, drawings of crane parking areas and access roads, drawing of cable routes and type and quantity of operating fluids is site-specific and usually not within the responsibility of a wind turbine manufacturer – rather of the owner of the WTG.

In some cases, even the insurance companies of the wind farm have the necessary data available.

The following template indicates which fields need to be filled for decommissioning (in cases where an owner is not the operating company, the details of the owner need to be added as well):

FIGURE 5

Data requirements for decommissioning of a wind farm

Checklist data requirements			
Common data			
Operating Company			
Company			
Address			
Zip Code, Location			
Contact Person			
Name			
Phone			
E-Mail			
Plant location			
Name			
Address			
Zip Code, Location			
Geographical Coordinates			Longitude
			Latitude
WTG / Wind farm			
Manufacturer			
WTG Type			
Serial number			
Rated capacity			MW
Rotor diameter			m
Hub height			m
Number of WTG		#	
Commissioning date		*DD.MM.YYYY*	
Material specific data			
Rotor blade			
Length			m
Weight per rotor blade			tons
Material composition		*pure GRP or GRP/CFRP*	
		Local distribution of CFRP within the rotor blades	
Manufacturer			
Hub			
Weight			tons
Dimensions		*Length x Width x Height*	m
Material composition		*Steel / other*	
Nacelle (Gondola)			
Weight	*in total (incl. power train)*		tons
Dimensions		*Length x Width x Height*	m
Material composition	*Casing*	*GRP / Aluminum*	
Generator	*Type*		
	Labelling		
	Manufacturer		

Gearbox	*Type*			
	Labelling			
	Manufacturer			
Operating fluids, lubricants, gear oils	*Labelling*			
	Volume			Litres
	instructions for drainage			
Industrial Magnets (SEE)	*type*			
Tower				
Tower type	*Concrete tower*			
	Tubular steel tower	*(x)*	*number of segments: 3*	
	Hybrid tower			
	Lattice tower			
Manufacturer				
Material composition	*Concrete*			m^3
	Reinforced steel			tons
Height				m
Weight				tons
Dimensions			*Length x Width x Height*	m
Technical drawing				
Foundation				
Foundation type	*Standard flat foundation*	*(x)*		
	Pile foundation			
Material composition	*Concrete*			m^3
	Reinforced steel			tons
Foundation plan (technical drawing)		*(x)*		
Infrastructure				
Crane assembly area				
Material composition	*Technical structure*		*Gravel / .....*	
Dimensions			*Length x Width x Height*	m
Specifications of the WTG manufacturer	*Technical drawing*	*(x)*		
Access routes to WTG				
Material composition	*Technical structure*		*Gravel / .....*	
Dimensions			*Length x Width x Height*	m
Specifications of the WTG manufacturer	*Technical drawing*	*(x)*		
Internal and external cable route				
Material composition	*Cable Type*		*Aluminum / Copper*	
Number / cross section / product labelling			*3 X 1 X 185² NA2XS(F)2Y*	
Length			*complete cable route*	m
As-built plans - (measured) of cable route		*(x)*		
Single-line diagram - internal cable route		*(x)*		
Transformer of WTG	*in nacelle*			
	at tower base			
	external transformer station	*(x)*		
	Type			
	Labelling			
	Manufacturer			
Transfer station (substation)	*Type*			
	Labelling			
	Manufacturer			
Grid connection point				
Own transformer station	List of components			
MV control panel	*Type*			
	Labelling			
Others				
Operating fluids				
Type	*for each operating fluid*			
Labelling	*for each operating fluid*			
Volume	*for each operating fluid*			Litres
Instructions for drainage	*for each operating fluid*	*(x)*		

Source: WindEurope

3.4. PERMITTING FORMALITIES

Decommissioning and dismantling are usually regulated by ancillary provisions in the building permit of the wind farm. Usually, the permit contains a requirement for dealing with decommissioning.

For a wind farm in Germany being decommissioned there is no general deconstruction obligation for permanently abandoned structural facilities in the Federal Immission Control Act (BImSchG) or in building law.

The local building authorities are in charge of monitoring compliance with the requirements in the permit.

An example of ancillary provisions concerning decommissioning/dismantling:

Upon commissioning of the wind turbines, the following facts must be reported to the permitting authority in writing without delay, including when the intended termination of operation will be.

The Building Law regulates that the wind turbines, with their auxiliary facilities and access roads, are to be dismantled within one year of the final cessation of use, and the ground sealing is to be permanently removed.

An obligation to dismantle exists for the operator, which is responsible for the following:

- A deconstruction guarantee must be deposited with the permitting authority at the time of approval;
- Fulfilment of the requirements of the permit under the Federal Immission Control Act (see above);
- Generally, land lease contracts include an obligation of deconstruction;
- This is tied to a cancellation of the public easement for the wind turbines in the land register after dismantling.

Scope of the decommissioning obligation:

The scope of the deconstruction obligation is framed in the permit, e.g. deconstruction depth (of the foundation), removal of the soil sealing and establishment of a natural state.

Permitting formalities:

- Notification to permitting authority according to § 15 (3) of the Federal Immission Control Act
- General information on the project (location, name of the installations, reference to the permit for the old installations);
- Description of the termination of operation (decommissioning).
- Applying for a demolition permit with the building authority (different regulation in the federal states; in Lower Saxony: § 60 para. 3 NBauO)
- Application with official form of the building supervisory authority;
- Site plan;
- Description of the dismantling;
- Description of the restoration of the site.

3.5. COMMUNICATION PLAN

Site inspections with relevant parties including Planning Authority officers, Statutory Consultees and Landowners during decommissioning, restoration and aftercare (as appropriate) are recommended in order to ensure ongoing communication and to provide for a responsive approach to the decommissioning of the site and its restoration. Such sustainable communication plans help to head off potential problems and achieve better long-term results.

As dismantling operations can raise concerns, the communication plan with the main local stakeholders is a key success factor. Even if operations are conducted according to the regulations, and in line with the best practices of the sector, a lack of communication on this sensitive issue could generate controversies that could be used not only at a local, but also at a national level.

Beyond the compulsory requirements, the dismantling operators should pay particular attention to:

- Sharing the timing of the operations:
  - > Dismantling operations generate noise, dust, light (during night/dark season) and traffic around the site;
  - > As soon as the operation schedule is set up, it might be useful to identify and gather the main stakeholders (including neighbours, people living along the main transportation route, users of the transport route and people whose view from their dwelling will change) and present when and where nuisances can be expected;
  - > For many wind farms, a "stakeholder's committee" already exists.

- Answering key questions around the management of the waste, especially regarding:
  - > The turbine itself:
    - In some countries such as France, recyclability rates have been made compulsory for existing and new installations (integrated blades in the total mass of the wind turbine);
    - One key question regards not only the rate, but the actual waste management (how and where waste is treated);
    - In France, the wind sector (SER) discussed the possibility of having a transparency platform. This platform aims at communicating which part of – and how - the wind turbine has been treated (recycled or valued);
    - For the first dismantling operations, this kind of information has been provided through a press release[8].
  - > The foundations:
    - Removing the foundations is both an environmental and economical challenge, as it is not proven that removing the whole foundation is environmental-friendly;
    - However, the complete removal is often requested by the stakeholders, or even the landowner at the development stage in the lease agreement;
    - If the regulation leaves room for discussion to the stakeholders, including the operator of the wind farm, but also environmental specialists and representatives of the residents, a public dialogue could be set up.
      - » For instance, in France, the regulation now provides that if an environmental assessment establishes that removing the whole foundation is "environmentally unfavourable", part of the foundations could be maintained in the ground;
      - » The assessment must be shared with the public authorities but could also be used as a starting point for the discussion with the stakeholders.

The recommendation is that this dialogue happens through a "stakeholder's committee". Its ambition is to collectively assess the pros and cons of total removal of the foundations, based on neutral, scientific studies.

Involving stakeholders through a communication plan is crucial not only for decommissioning projects but also for repowering projects, which could increase the local acceptance of the repowering project.

3.6. ENVIRONMENT, HEALTH AND SAFETY

Health and safety requirements must be included according to national legislation. The decommissioning plan should address the following health and safety points[9]:

- Risk Assessment and Method statement for the operation;
- Lifting plan in place to guarantee suitability of the crane, to include wind speed limits for each component movement considering drag factors;
- Equipment technical documents and inspections;
- Soil test, crosschecking the capacity of the terrain to sustain the crane pressure while operation;
- Waste/disposal/reusing management plan in place for the disassembled components;
- Emergency response plan/details for the operation.

8. https://www.engie-green.fr/app/uploads/2019/11/CP_D%C3%A9montagePLN_2019-ENGIEGreenVF.pdf
9. The list is not exhaustive as information regarding skills requirements, incident reporting and environmental mitigation measures still need to be verified.

4. DISMANTLING

For the demolition of buildings and structural facilities, there are various procedures, machines and equipment to choose from. In Germany the DIN 18007 “demolition methods" [“Abbruchverfahren"] provides information about terms, procedures and areas of application for the demolition of buildings or structural facilities. Appendix A of DIN 18007 is helpful in selecting suitable demolition methods. In this, the most common procedures are evaluated in terms of their suitability and impact depending on construction, component and building material.

For the WTG, the foundation, the infrastructure, and balance-of-plant equipment, the following assessment criteria for the selection of the dismantling procedure can be listed and evaluated with regards to their suitability (preferably applicable, partially applicable or non-applicable dismantling procedure):

- Hub height of the WTG;
- Tower type (concrete tower, tubular steel tower, hybrid tower and lattice tower);
- Foundation type (standard flat foundation (with or without buoyancy control), pile foundation);
- Accessibility and environment of the WTG (open space, forest, mountains, etc.);
- Availability of areas for storage, construction site equipment (open space, forest, mountains, etc.);
- Location of cables and of the external cable route (e.g. under a river); and
- Time schedule.

The dismantling procedure to be applied and its ultimate concretisation for the respective sub-areas must also take into account the following aspects:

- Environmental compatibility;
- Avoidance of damage to the land;
- Safety considerations;
- Minimisation of environmental pollution (noise, dust, vibrations);
- Appropriate cost-benefit ratio.

Depending on the dismantling procedure to be applied, the concrete sequence of dismantling and the individual dismantling steps are determined as follows, as part of the dismantling planning:

1. Rotor star (rotor blades and hub);
2. Nacelle (gondola);
3. Tower;
4. Foundation;
5. Crane assembly area/access routes.

The dismantling of other components of the infrastructure and balance-of-plant equipment (possibly external transformers of the WTG, transfer station, internal cable route, external cable route, grid connection point, e.g.MV control panel, own transformer station, etc.) can be carried out in parallel or after the dismantling of sections 1-5, depending on the circumstances on site.

Start of dismantling - setting up the construction site

Before starting the construction site installation, it must be ascertained that the measures for the preparation of the crane assembly area and access routes, including the curve radius, have been implemented and that the area meets the requirements of the crane company.

The dismantling company must create safe and healthy working conditions on the construction site with the construction site equipment.

Regarding the construction site equipment:

- The dismantling site must first be secured in accordance with the agreed site installation plan, e.g. by a site fence and by signage;
- The water supply as well as the wastewater disposal and power supply must be set up, e.g. by connecting to existing networks or by operating fresh water and wastewater tanks and installing a power generator;
- Offices, recreation rooms and sanitary facilities must be set up and equipped, including first aid facilities;
- Fire extinguishing equipment must be provided for certain work, e.g. flame cutting;
- Traffic areas, including escape and rescue routes, must be provided. If it becomes necessary to close off public roads, the order of a traffic restriction according to §§ 44 f StVO must be applied for at the responsible road traffic authority;
- Sufficient operating areas shall be provided for the lowering, handling, disassembling and splitting as well as for the interim storage of components of the WTG and for the sorted collection of waste/material flows;
- When installing heavy equipment, waste containers etc. - especially the main crane - care must be taken to ensure that the underground is sufficiently strong.

Due to local conditions, special requirements may be placed on the construction site equipment, e.g. for reasons of environmental protection (noise, dust, vibrations).

4.1. DISASSEMBLY

Professional* dismantling of the WTG up to the top of the foundation

The following lays out the individual steps for a professional* dismantling of a WTG up to the upper edge of the foundation (i.e. excluding the foundation component), which is to be used at another location for the purpose of further use of the WTG (the further steps shows an example of dismantling a WTG with tubular steel tower):

<u>Further use of the WTG as a whole</u>

1. Yawing the turbine to an orientation that allows crane boom manoeuvring,
2. Pitching the blades to a position suitable for dismounting - for full-rotor disassembly, this is with the trailing edge forward pointing to ensure ground clearance once the rotor star is on the ground.
3. Successive disconnecting power and information cabling;
4. Where needed, de-energise energy storage devices to reduce risk during the process, such as batteries, pressure vessels, etc;
5. Erecting the main crane on the crane assembly area;
6. Dismantling the rotor star as a whole and lowering it in one operation. If the turbine is designed for Single Blade Installation only, adhere to the disassembly instructions from the supplier of the wind turbine;
7. (Flat) placing the rotor star on the ground;
8. Disassembly of the rotor star into its individual parts (3 individual blades and hub);

9. Direct loading of the rotor blades onto heavy duty transporters (suitable transport racks);
10. Transport of the rotor blades to the agreed destination of the buyer of the WTG;
11. Direct loading of the hub onto heavy-duty transporters (suitable transport frame);
12. Transport of the hub to the agreed destination of the buyer of the WTG;
13. Dismantling of the nacelle entirely (incl. power train) and lowering;
14. Direct loading of the nacelle onto heavy-duty transporters (suitable transport frame);
15. Transport of the nacelle to the agreed destination of the buyer of the WTG;
16. Successive dismantling of the individual steel tower sections after loosening the relevant connections and lowering each steel tower section in one operation;
17. Direct loading of the individual steel tower sections onto heavy-duty transporters (suitable transport frame);
18. Transport of the individual steel tower sections to the agreed destination of the buyer of the WTG;
19. Dismantling of the WTG components that may still be in the tower base;
20. Direct loading of these remaining WTG components onto vans (suitable transport frame);
21. Transport of these remaining WTG components to the agreed destination of the buyer of the WTG.

The following lays out the individual steps for a professional* dismantling of a WTG up to the upper edge of the foundation (i.e. excluding the foundation component), which is to be disposed of completely (the illustration shows an example of a WTG with a tubular steel tower):

<u>Disposal of the WTG</u>

1. Yawing the turbine to an orientation that allows crane boom manoeuvring,
2. Pitching the blades to a position suitable for dismounting - for full-rotor disassembly, this is with the trailing edge forward pointing to ensure ground clearance once the rotor star is on the ground;
3. Successive disconnecting power and information cabling;
4. Where needed, de-energise energy storage devices to reduce risk during the process, such as batteries, pressure vessels, etc.;
5. Erecting the main crane on the crane assembly area;
6. Dismantling the rotor star as a whole and lowering in one operation. If the turbine is designed for Single Blade Installation only, adhere to the instructions to disassembly from the supplier of the wind turbine;
7. (Flat) placing the rotor star on the ground;
8. Disassembly of the rotor star into its individual parts (3 individual blades and hub);
9. Temporary lateral storage of the individual blades and the hub;
10. Cutting of the rotor blades into transportable pieces (the disposal companies have special requirements regarding the maximum size of acceptable pieces);
11. Loading the rotor blade pieces onto standard vehicles;
12. Transport of the rotor blade pieces to the specialist waste management company;
13. Loading of the hub onto heavy-duty transporters;
14. Transporting the hub to the specialist waste management company;
15. Dismantling of the nacelle entirely (incl. power train) and lowering in one operation;
16. Direct loading of the nacelle onto heavy-duty transporters (suitable transport frame);
17. Transport of the nacelle to the specialist waste management company;
18. Successive dismantling of the individual steel tower sections after loosening the relevant connections and lowering each steel tower section in one operation;
19. Temporary storage of the individual steel tower sections on a storage area provided for this purpose (securing against lateral rolling away);
20. Shredding the individual steel tower sections on site into transportable sizes, for example with the aid of cutting torches;
21. Loading the shredded steel tower parts into containers and transporting to the specialist waste management company;
22. Dismantling of the WTG components that may still be in the tower base;

23. Direct loading of these remaining WTG components onto vans (suitable transport frame);
24. Transport of these remaining WTG components to the specialist waste management company;

Disposal of the WTG with a possible secondary use of individual components

In the case of disposal of the WTG in combination with a possible secondary use of individual components (e.g. rotor blade, gearbox or generator from the nacelle), the relevant individual steps regarding the corresponding component(s) must be replaced following the corresponding individual steps from the procedure "Further use of the WTG as a whole".

Dismantling procedures of the tower

The tower of a WTG can be designed as a concrete, steel tube, hybrid (concrete tower in the lower section and steel tower in the upper section) or lattice tower. In the following, the dismantling and deconstruction of these tower variants is briefly described:

The deconstruction of concrete towers is irreversible, so that the reconstruction of a deconstructed concrete tower and the concrete tower section of a hybrid tower is not deemed possible. Due to the current lack of alternative deconstruction methods, concrete towers are currently dismantled in segments or destroyed in a targeted manner. The dismantled concrete tower can be separated into its components and recycled in a subsequent process. For this purpose, excavators are usually used to crush the concrete tower so that the reinforcing steel is separated from the reinforced concrete. The concrete demolished during the dismantling process is either processed or recycled directly on site as required, e.g. during repowering, or is transported to special companies for recycling.

The tubular steel tower, consisting of individual steel sections arranged one above the other, is connected at the base of the tower to the foundation component, which provides the connection with the foundation. The corresponding dismantling and handling of the material was described in detail above.

The connecting elements of a lattice tower can be easily loosened so that individual sections (consisting of a certain number of lattice bars) can be lowered from the main crane and disassembled on the ground. The lattice bars are collected on site in containers and transported to the waste management companies.

In addition to concrete and steel (depending on the tower concept), the dismantling of a tower generally also produces non-ferrous metals such as aluminium from the tower components and copper from the cut power cable in the tower, which are also supplied to specialist waste management companies.

Professional* dismantling of the foundation

After complete dismantling of the WTG, the foundation is dismantled. Here, a basic distinction must be made between a standard flat foundation (with or without buoyancy protection) and a pile foundation. Pile foundations are similar in structure to standard flat foundations, but pile foundations do not stand directly on the ground, but rest on piles previously inserted into the ground.

Specification of the scope of dismantling

With regards to the general obligation to dismantle the foundations, there are different requirements as to whether the foundation is to be completely dismantled or only to a certain depth below the top edge of the terrain. Especially in older permits, there are often provisions that require the foundations to be removed only to a depth of e.g. 1.50 m below the top edge of the terrain. The reason for the deviations is the different interpretation of the requirement "restoration to the original condition". However, the complete dismantling of the foundations is recommended with a view to the unrestricted subsequent use of the area. In the case of pile foundations made of concrete driven piles or even loose piles, their removal would lead to a disproportionate disturbance of the soil structure. The piles therefore usually remain in the deep soil layers, in which case the flat foundation resting on the piles is completely removed.

Dismantling procedures

The actual dismantling of a foundation can be done either by means of an excavator or by blasting.

Foundations can be dismantled using an excavator. To do this, the foundation is first broken up using a hydraulic chisel and the exposed fragments are then dredged out. Due to the vibrations during chiselling, the reinforcing steel can be separated from the concrete relatively easily, or is already predominantly present separately during excavation.

For foundation depths of more than two metres, blasting (also known as loose blasting) is a sensible option that should be agreed upon with the local population. The competent authority must be notified in advance, stating, among other things, that the blasting cannot cause any damage to neighbouring installations, houses or even supply lines. After loose blasting has been carried out, concrete and the reinforcing steel are mostly available separately and can be removed from the foundation pit using excavators.

The reinforcing steel and concrete are transported separately to special plants for further recovery or recycling.

For direct connection of the foundation with the WTG tower, there is also (depending on the tower concept) a larger steel installation part (anchor cage - foundation installation part) in the centre of the foundation. If the WTG is to be used again, this foundation component is carefully removed from the foundation in some cases and, once the fault-free condition has been established, it can be reused in a new foundation to be constructed at the second site. If the wind turbine is to be disposed of, the foundation component is transported to a specialist waste management company.

Professional* dismantling of the infrastructure/balance-of-plant equipment

The infrastructure and balance-of-plant equipment shall consist of the following elements, where applicable:

- crane assembly area at WTG;
- access routes to WTG with the associated curve radius;
- external transformers of the WTG;
- transfer station;
- internal cable route, external cable route;
- grid connection point (MV control panel, own transformer station, etc.);

The size and dimensions of the required crane assembly areas as well as access routes with the corresponding curve radius result from the technical installation specifications of the WTG manufacturer. They typically consist of rock ballast, and sometimes also a separating layer of geotextile or geogrid, whereby the exact type of ballast is partly specified or restricted by the responsible authorities.

The rock ballast brought in is picked up by an excavator and can in principle be used as ballast in new projects (after screening if necessary). However, the quality and composition of the ballast must be considered. Older wind farms may also contain gravel materials from slag. Presently, this may not be installed at a new site depending on the local regulations or project specifics. If no new project is planned, the ballast is transported by truck to a company for the processing of construction waste for recycling.

In addition to the ballast, geotextiles or geogrids may also be present, which were originally used to clearly distinguish the different layers.

External transformers of the WTG, transmission station and the grid connection point must be properly and professionally* disassembled. Loading and transport of these components to the specialist waste management company must be carried out in compliance with the safety regulations with regards to any hazardous substances (including PCBs, SF6) contained in the components. The usually small individual foundations must also be completely dismantled. The concrete produced can be transported by truck to a company for the processing of building rubble for recycling.

When dismantling the cables, a distinction must be made between site-specific, park-internal cabling (internal cable route) and the cabling connecting the wind farm to the grid connection point (external cable route). As a rule, the internal cable route must be completely dismantled. The extent to which the external cable route must also be completely dismantled must be examined and weighed up in each individual case according to the respective existing boundary conditions under legal, ecological and economic aspects.

4.2. CUTTING AND SEPARATING

4.2.1. ROLES AND RESPONSIBILITIES

Usually, blade cutting activities are outsourced to contractors e.g. regional waste handlers. They should be consulted to obtain more specific information on facility requirements e.g. FRP taxes, FRP bans, dimensional requirements of blade sections, available capacity/ volume. It is crucial that cutting and separating activities are carried out under high health and safety requirements as regulated by national legislation.

4.2.2. EXECUTION TECHNIQUES

Regardless of the tool, sectioning by means of a mechanical process (saw/cutter affixed to an excavator) is best practice compared to a manual process (handheld tools).

Where possible, cutting should occur in an enclosed environment (e.g. temporary tent) to minimise dust and noise emissions.

Water jet cutter

This method uses a very high-pressure jet of water, or a mixture of water and an abrasive substance. It can cut different blade materials, including metals. The process is somewhat environmentally friendly, regarding dust and noise emissions, but the use of water is high in comparison to the other methods listed below.

Wire saw

The method uses a water-cooled steel wire with diamond particles/teeth, which is wrapped around the wind turbine blade. The wire can cut different blade materials, including wood and metals. It can also section all blade sizes and is only limited by the length of the wire which can be extended indefinitely. The process is relatively environmentally friendly, regarding dust and noise emissions. The cooling water can be recycled, and the cuttings can be collected. Additionally, the cuts are relatively smooth and well defined. The disadvantage is that the method is time consuming and the blade must be firmly affixed during the cutting to avoid pinching the wire.

Circular saw

Different types and sizes of diamond tipped circular saws can be used. Sizes range from handheld saws to hydraulically driven saws with blade sizes up to 2 meters in diameter. The saw can make any size section, but it is usually necessary to make several cuts. This increases the amount of dust/cuttings/emissions that are produced for each section. If done properly, the circular saw will produce relatively fine handling friendly cuts. It can be combined with different dust collecting systems, either by vacuum or water. The key advantage is that it is possible to make independent cuts in all directions. This gives the possibility to extract selected materials, like the main laminates or balsa for special purposes.

Jaw cutter

The jaw cutter is the most common method for sectioning wind turbine blades. The hydraulically driven jaw produces a very rough cut through the material, and the material is crushed in the cutting zone. It is difficult to control the dust and fibre emissions – therefore a water fog is needed to control the dust. It is also necessary to sanitize the area after completion. The sections are prone to emit dust and fibres during transport, which increases the demand for proper stowing, covering and/or wrapping on the lorries.

4.3. LOADING AND TRANSPORT

4.3.1. ROLES AND RESPONSIBILITIES

The loading and transport of Wind Turbine Components are normally outsourced to specialist contractors e.g. crane contractors, transport contractors/hauliers, who have unique expertise and equipment specifically designed for this purpose. They should be consulted on a case-by-case basis to obtain more specific information on requirements e.g. equipment type and capacity, route management, lift management requirements and documentation such as lift plans, Rope and Marine Services, permit needs etc.

The Wind Turbine Manufacturer usually can provide all component data such as weights and dimensions, specifications and drawings detailing the centre of gravity & lifting points/arrangements.

4.3.2. PERMITTING PROCEDURES

A special loads application will be required for submission to the local authorities/agencies in advance of the planned operation for permission to perform the transport. Consultation must be sought with the appointed transport logistics provider for guidance on permit application. The transport logistics providers and subcontractors must be appointed well in advance of planned delivery to allow enough time to conduct route planning, risk assessment and transport management plan.

Public Interface – The effect/impact of the operation on the safety and convenience of other road users and stakeholders must be considered. All options and alternative roads must be evaluated.

4.3.3. EXECUTION TECHNIQUES

Loading – Detailed planning and risk assessment must be performed by the Crane Contractor and Logistics contractors in conjunction with the Wind Turbine Manufacturer to determine the safest method to lift and load the components onto transport. The outcome must be documented in the form of a lift plan providing detailed drawings of crane configurations and steps necessary to safely lift, load and secure the components.

Escorting Arrangements – Authorities may stipulate specific escort requirements for the transport of abnormal loads. Road transport exceeding legal weights or minimum dimensions may require an accompaniment of escort vehicles - this can include police escort and/or a private escort vehicle solution.

Travelling Position of Vehicles – There are a combination of positions adopted in a convoy. The positions may change when the abnormal loads are under police escort - otherwise the recommended combination is one vehicle at the front of the convoy and one at the rear. This third vehicle can take on a surveillance role ahead of the convoy to provide advance warning and information about oncoming traffic.

Radio Communication – Each abnormal load vehicle and all accompanying escort vehicle drivers should have a facility to allow effective communication with each other. Often, the police may also be involved during some stages of the convoy, and it is therefore important to keep spare radios for police command vehicles to enable them to effectively communicate with all parties. Spare batteries and a few extra radio handsets should always be available.

4.3.4. HEALTH & SAFETY REQUIREMENTS

Risk Management – In the EU, an abnormal load is defined as a vehicle or vehicle combination having either no load or an indivisible load, which can only be transported by exceeding at least one of the dimensions and/or axle, bogie or total weights authorised by Directive EC 96/53 and national legislation. For the renewables sector, it refers to wind turbine components and transformers which meet these criteria.

Competency:

- Only trained, certified and competent personnel may be deployed during loading/unloading/stacking and transportation. The spheres of responsibility of the personnel for the operation of tools must be clearly defined;
- A responsible person who monitors safety during the loading/unloading/stacking and prevents any work which compromises safety from being carried out must be appointed. All personnel who observe an unsafe working conditions are empowered to stop the job until the situation is rectified.

Transport Equipment - General Requirements:

- All transport units must be maintained and serviced in accordance with national rules and manufacturer’s requirements;
- All operators must be trained and medically fit to work in this environment;
- All parties engaged in transportation must be able to provide a risk assessment/method statement/work plan that relates to these operations.

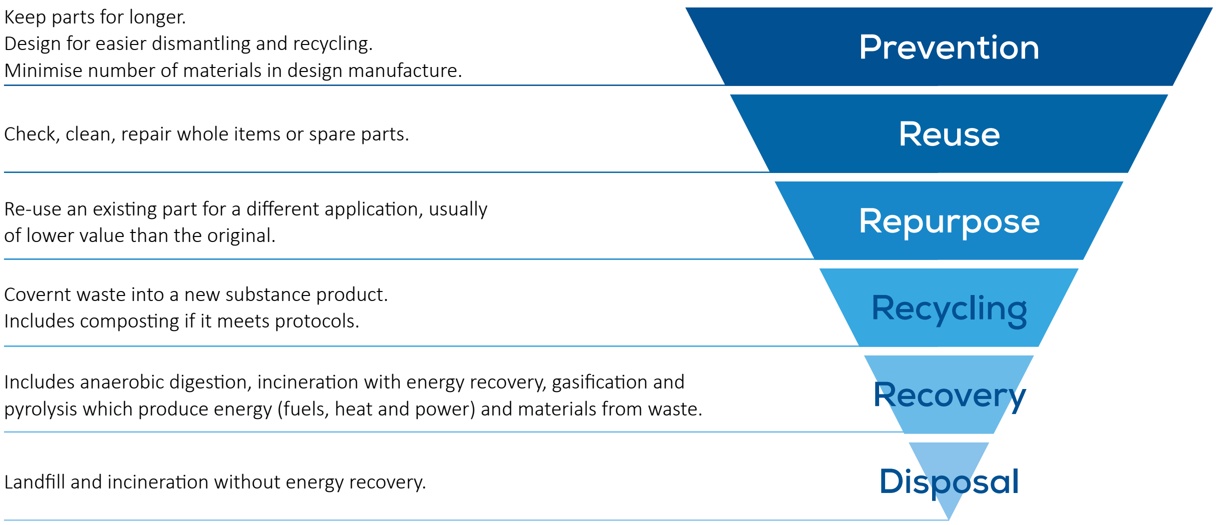
5. RESOURCE MANAGEMENT

5.1. OVERVIEW

Wind turbines provide valuable resources that can be reintroduced into the circular economy. The prerequisite for this is a clean separation of materials and innovative recycling processes. An efficient use of resources (and material avoidance) is the highest level of the waste hierarchy. A preferably long-term use should be aimed for, as this is the most sustainable use. However, at some point in time, wind turbines will reach the end of their life and valuable resources must be returned to the material cycle.

Methods in the following waste hierarchy should be considered:

FIGURE 6
Waste treatment hierarchy



Source: ETIPWind - How wind is going circular

In the following sections specific recycling methods (following the waste hierarchy) of materials used in wind turbines are described.

The materials used in a wind turbine depend on different models and turbine manufacturers, as well as requirements by the customer. ENERCON's life-cycle assessment of its E-115 wind turbine with a hybrid tower shows a component weight of 356 tonnes (excluding the tower) in which 60% of the weight is represented by steel and iron materials, while polymer materials (such as rotor blades, PET foam and cable ducts) represent 27% of the weight[10].

According to a report from the International Renewable Energy Agency, roughly 90% of the weight of a 2 MW Gamesa turbine (excluding the tower) is from steel, iron, castings and fiberglass.

FIGURE 7

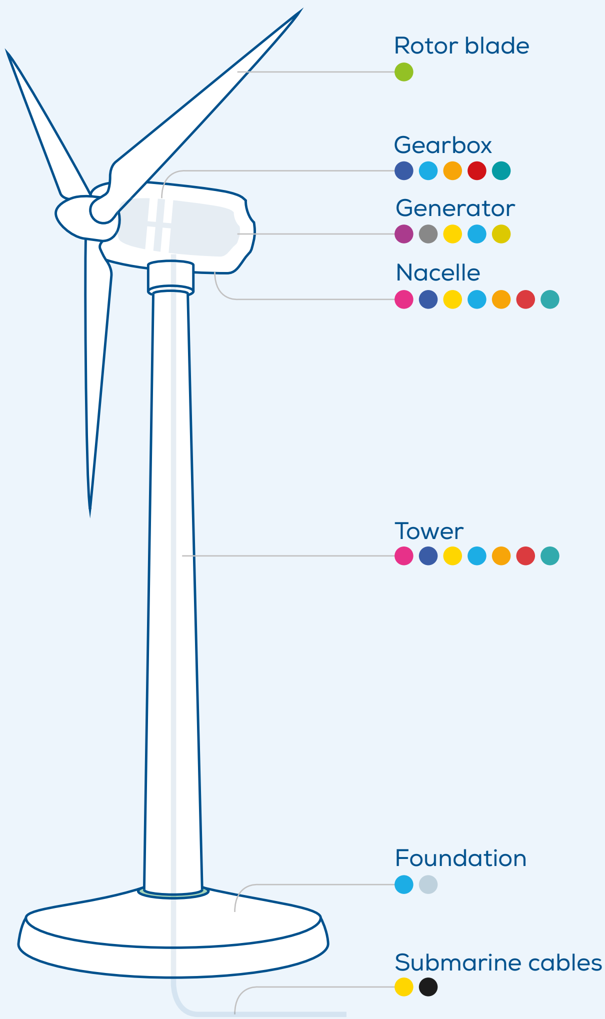
Raw materials used in wind turbines

- Aluminium
- Boron
- Chromium
- Cobalt
- Composite
- Copper
- Iron
- Lead
- Manganese
- Molybdenum
- Nickel
- Rare Earths*
- Concrete

* Dysprosium, neodymium, praseodymium, terbium

Sources: European Commission Materials Information System (MIS) Wind Energy, April 2016 and European Commission Raw Materials Scoreboard 2016.

The source does not specify the wind turbine on which the above information is based.



Source: Somo 2018 – Human Rights in Wind Turbine Supply Chains

10. ENERCON, 09/2019, Life Cycle Assessment E115, HT 135m

According to the JRC report - Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, the materials that represent the biggest part of the weight of a wind turbine are:

- Concrete (243,500 - 413,000 t/GW),
- Steel (107,000 – 132,000 t/GW),
- Cast Iron (18,000 – 20,800 t/GW).

5.2. CONCRETE

Construction and demolition waste (CDW) are one of the heaviest and most voluminous waste streams generated in the EU. 380 million tons is being produced in the EU each year, and this accounts for approximately 25-30% of all waste generated in the EU (European Commission 2020, European Commission 2019). CDW consists of numerous materials including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. The range in composition of concrete in CDW waste ranges between 20-70% across EU Member States (Migliore, Talamo & Paganin 2020).

According to WindEurope's estimates, some 3.7 million tons of CDW could be created by decommissioning 9 GW of wind farms by 2030.

There is a high potential for recycling and re-use of CDW, since some of its components have a high resource value. There is a re-use market for aggregates derived from CDW waste in roads, drainage and other construction projects. Technology for the separation and recovery of construction and demolition waste is well established, readily accessible and generally inexpensive (European Commission 2019).

5.2.1. PREVENT

The possibility for a reduced concrete use in onshore wind farms can be achieved through hybrid or steel towers for wind turbines, instead of concrete turbines.

5.2.2. RE-USE & REPURPOSE

It is not economical nor environmental to transport concrete over long distances to be re-used in similar applications when there is a recycling option for a different application available locally e.g. as road base (CEMBUREAU 2016).

5.2.3. RECYCLE

Like steel and aluminium, concrete can be repeatedly recycled (or re-recycled). The recycled concrete product is commonly crushed into aggregate and can be re-used in many ways e.g. cement replacement, concrete levees for flood protection, backfilling and filler.

Recycled concrete has several benefits:

- It replaces other materials such as gravel that must otherwise be mined and transported for use.
- It reduces waste in landfills and avoids disposal or tipping fees.

Despite its potential, the level of recycling and material recovery of CDW varies greatly (between less than 10% to over 90%) across the EU (European Commission 2019). CEMBUREAU (2016) indicates that on average, only one third of CDW is recycled and it's not technical difficulties that prevent a higher recycling rate.

There are fixed recycling centres and mobile crushing and sorting plants for CDW (European Commission 1999).

Best practice would be to separate CDW at source in order to avoid mixing waste types (including hazardous ones) that pose environmental risks and can hamper recycling (European Commission 2019).

One of the main obstacles cited for greater reuse and recycling of CDW is the technically acceptable use of recycled materials for higher-grade applications, and a lack of trust in products made from recycled materials. Certification schemes are one potential solution referenced to ascertain that recycled products can be trusted (European Commission 2020).

5.2.4. RECOVERY

There are currently around 210 kiln-operated cement plants distributed across the EU. Kiln-operated cement plants can provide a co-processing solution, including energy recovery of waste, for a certain amount of the waste currently being landfilled (CEMBUREAU 2016).

5.2.5. DISPOSAL

Concrete was once routinely trucked to landfills for disposal, but because it is such an essential, mass-produced material, much effort has been made to recycle and conserve it. Further, with the rising costs and regulations associated with landfills, disposing of certain materials including concrete, is becoming more difficult. Further, many of these landfills can no longer accommodate the size and volume of concrete waste. CEMBUREAU believes that more should be done to ban the landfilling of recyclable and recoverable waste, including concrete (2016).

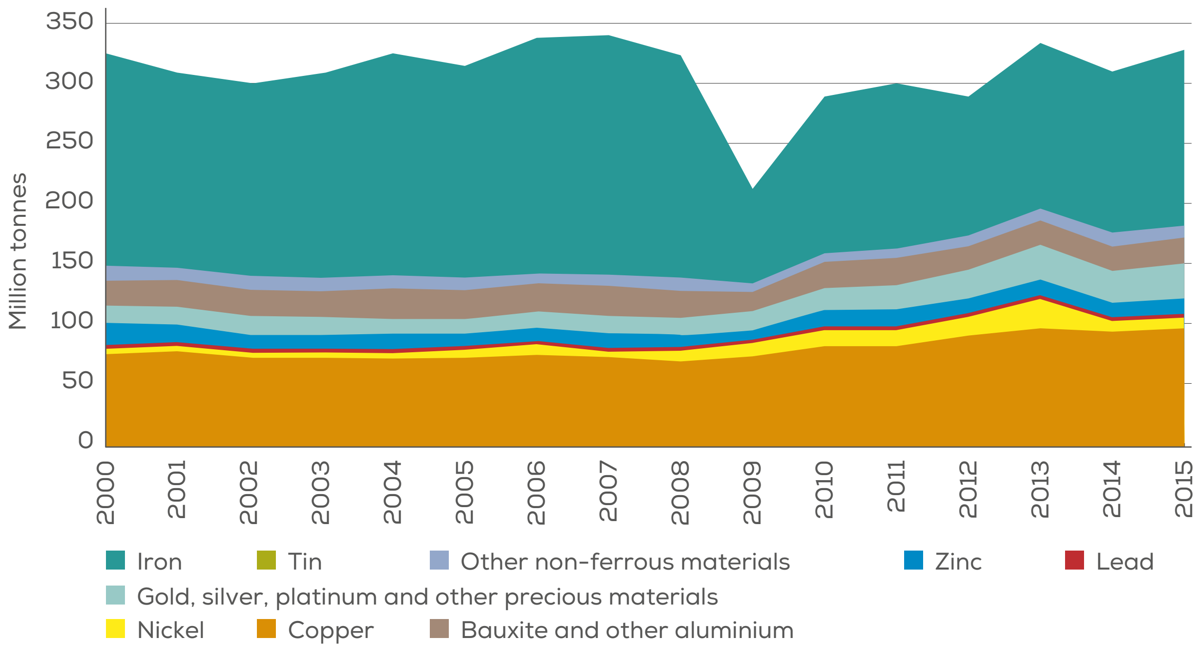
5.3. METALS

Metals are elementary resources used in wind turbine, which can be reused and recycled. According to the JRC report - Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, steel (107,000-132,000t/GW) and cast iron (18,000-20,800t/GW) represent substantial parts of the weight of a wind turbine.

As seen in Figure 8, there is a high demand on iron and copper in Europe. Since metals in wind turbines are easily recyclable, those metals would be re-used domestically in Europe.

FIGURE 8

Domestic material consumption of metals (EU-28, 2002-2016)



Source: Raw material Scoreboard - European Commission 2018

According to the World Steel Association, about 85% of wind turbines around the world are manufactured primarily from steel. However, concrete towers, concrete bases with steel upper sections and lattice towers are also used (IRENA, 2012).

Aluminium - Across turbine types and models, the range of possible values for aluminium is large, varying from 500 to 1 600 t/GW. The lower estimates apply to direct-drive turbines where copper is the preferred material and possibly stem from different requirements for onshore and offshore wind turbines. In addition, they might also represent to a certain extent the selective replacement of copper with aluminium in the cast-coil transformer in the nacelle or in the tower design. While this option presents some challenges, Vestas for example has adopted aluminium cast- coil transformers in its turbines. In cases where the whole nacelle casing is made of aluminium, the use of this material can exceed 3 500 t/GW. Aluminium is used in the production of resistant but lightweight components, such as the turbine tower and nacelle. Besides the turbine itself, aluminium is also used in the production of cables at the plant site.

Copper values differ across turbine types and models. The range of possible values for copper is large, ranging from approximately 950 to 5,000 t/GW, with the median value being around 2,100 t/GW. The higher estimate is for direct-drive turbines. It is the consensus that direct-drive generators can use three times more copper than gearbox configurations. According to Månberger and Stenqvist (2018) and references therein, the difference is however lower for the power plant as a whole. Copper is predominantly used in the coil windings in the stator and rotor portions of the generator, in the high-voltage power cable conductors, transformer coils and earthing (Copper Alliance).

Steel and cast iron (Fe). Steel and stainless steel are used in the manufacture of several components, including the tower, nacelle, rotor and foundation. Besides the tower, manufactured primarily of plate steel, the gearbox, generator and turbine transformer also mainly consist of structural steel and stainless steels. Onshore foundations are made up of large concrete and steel platforms, whether they are gravity- or rock-anchored systems. Cast iron is used in the nacelle foundation, main shafts, gearbox, generator and blade hub. Different cast grades are available. Cast iron usage is very similar for different turbine types. Iron is also used in the permanent magnets: the lower estimate is for high- to medium-speed turbines with a gearbox (around 30 t/GW); the higher estimate is for direct-drive turbines (around 300 t/GW). However, the material intensity for this is about two orders of magnitude lower than the cast iron requirements, so it has been neglected.

Recycling methods for steel and cast iron will be added in a later stage.

Other materials are explained in the JRC report - Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, 2020.

5.4. COMPOSITES

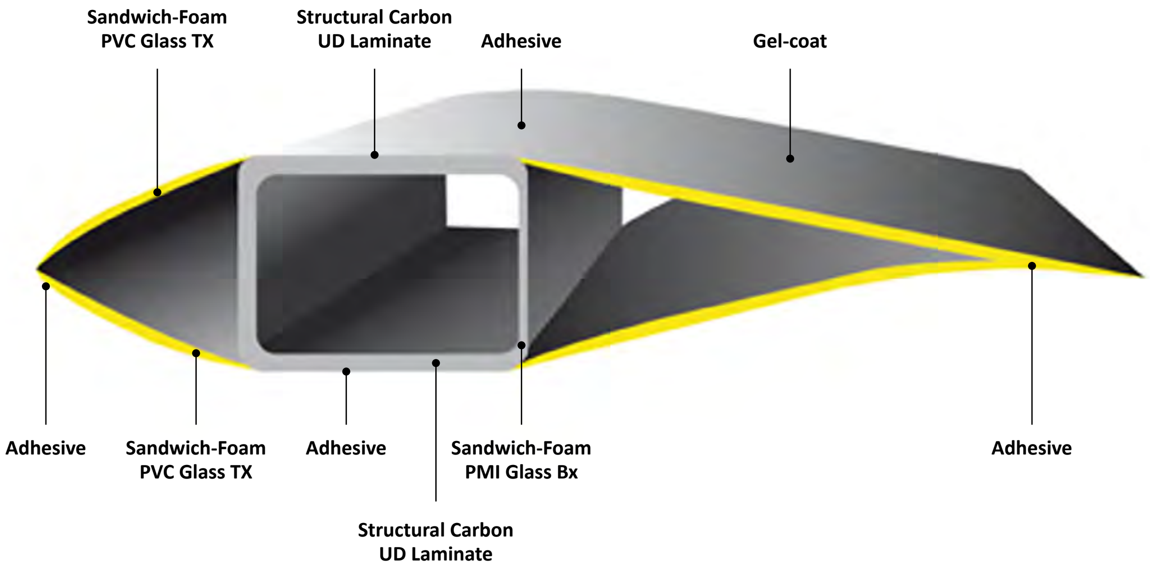
Wind turbine blades are made of composite material that boost the performance of wind energy by allowing lighter and longer blades. Although material compositions vary between blade types and blade manufacturers, blades are generally composed of the following (see Figure 9):

1. Reinforcement fibres e.g. glass, carbon, aramid or basalt. Glass fibre represents the primary material in wind turbine blades. Carbon fibre is also used in wind turbine blades, but to a lesser degree. Carbon fibre's superior strength and higher stiffness offer many advantages over glass fibre, but its higher cost per volume is a key barrier to further deployment in the wind power industry;
2. A polymer matrix e.g. thermosets such as epoxies, polyesters, vinyl esters, polyurethane, or thermoplastics;
3. A sandwich core e.g. balsa wood or foams such as polyvinyl chloride (PVC), polyethylene terephthalate (PET);
4. Structural adhesives e.g. epoxies, polyurethane (PUR);
5. Coatings e.g. polyethylene (PE), polyurethane (PUR);
6. Metals e.g. copper wiring, steel bolts.

The combination of fibres and polymers, also known as fibre reinforced polymer (FRP) composites, represents most of the blade's material composition (60%-70% reinforcing fibres and 30-40% resin by weight).

FIGURE 9

Generic composition of a rotor blade



Source: ETIPWind

5.4.1. PREVENT

Blade waste can be prevented through reduction and substitution efforts in design. For example:

- Mass reduction resulting in less material to recycle;
- Decreasing failure rate and extending design lifetime. Testing and certification play a crucial role here; and
- Designing for easy upgrade of existing blade to new versions, e.g. segmented/modular blades. However, these are not standard design yet.

5.4.2. RE-USE

The blade should be used and reused for as long as possible before waste treatment is needed. Routine servicing and repair are required to achieve a blade's design lifetime. For lifetime extension, a 'remaining useful lifetime assessment' (i.e. fatigue load analysis using SCADA data or types of data) combined with site inspections and review maintenance actions performed since commissioning of the blade must be conducted. This might lead to repair actions and reinforcement in certain areas. DNV-GL has developed a standard for lifetime extension of wind turbines (DNVGL-ST-0260), and the International Electrotechnical Commission (IEC) is developing a standard for the through-life management and life extension of wind power assets (IEC TS 61400-28). Finally, a number of European and North American companies have established businesses for selling refurbished wind turbines and components.

5.4.3. REPURPOSE

Repurposing is the next step in the waste hierarchy. This means re-using an existing part of the blade for a different application, usually of lower value than the original.

Examples include:

- Re-using the blades for playgrounds or street furniture;
- Specific structural parts can also be repurposed for building structures e.g. bicycle shelters, bridge in Nørresundby, Denmark (yet to be built), walkways, architectonic reuse.

However, to date many of the repurposing examples represent demonstration projects that are unlikely to be a large-scale solution for future expected volumes. Where repurposing is not possible, recycling is the next option.

5.4.4. RECYCLE & RECOVER

Recycling means the blade becomes a new product or material with a different functional use. Recycling requires energy and other resources in order to convert the blade waste into something else.

Recovery means turning waste into a fuel for manufacturing processes after removing all individual components that can be used again. Cement co-processing, incineration with energy recovery and fluidised bed fall under the category of recovery.

Today, the main technology for recycling composite waste is through the cement kiln route, also known as cement co-processing. Composite materials can also be recycled or recovered through mechanical grinding, thermal (pyrolysis, fluidised bed), thermo-chemical (solvolysis), or electro-mechanical (high voltage pulse fragmentation) processes, or a combination of these. But these alternative technologies are at different levels of maturity and not all of them are available at industrial scale. The processing methods also vary in their effects on the fibre quality (length, strength, stiffness properties), thereby influencing how the recycled fibres can be applied.

The table below summarises some of the key properties of each of the technologies mentioned above. For a detailed description of each of these technologies, please refer to WindEurope, Cefic and EuCIA's joint report 'Accelerating wind turbine blade circularity' (available here).

5.4.5. DISPOSAL

Disposing blades via landfill or incineration without energy recovery are the least favoured waste treatment methods because there is no material or energy recovery.

The best strategy for wind blades is one that combines design, testing (according to latest standards to decrease repair and failure rates), maintenance, upgrades (e.g. reinforcement) and the appropriate recycling technology to ensure the maximal value of the material is retrieved throughout its lifetime. It should also allow (where possible) the re-use of materials for the same or similar purposes (e.g. allows polymer matrices to revert to monomers and avoids fibre damage during the process). Having a good understanding of the environmental impacts associated with the choice of materials during design and of the different waste treatment methods at end-of-life through life cycle assessments will also help define the appropriate strategy.

TABLE 1
Comparison of recycling and recovery technologies

	RECYCLING TECHNOLOGY	TYPE	MATURITY LEVEL (TECHNOLOGY READINESS LEVEL)	COST
GLASS FIBRE	Cement co-processing	Thermal	9	Low
	Mechanical grinding	Mechanical	9	Low
	High Voltage Pulse Fragmentation	Electro-mechanical	6	High investment and running costs
CARBON FIBRE	Pyrolysis & Micro-wave Pyrolysis	Thermal	Pyrolysis: 9 Microwave pyrolysis: 4/5	High investment and running costs
	Solvolysis	Chemical	5/6	High investment and running costs
	Fluidised Bed	Thermal	5/6	High investment and running costs

5.5. RARE EARTHS

Rare-earth elements and boron are essential for turbine designs that employ permanent magnets. Most direct-drive turbines, but also to different extents certain technical designs with gearboxes, are equipped with permanent magnet generators, which typically contain neodymium and smaller quantities of dysprosium. On average, a permanent magnet contains 28.5% neodymium, 4.4% dysprosium, 1% boron and 66% iron (2) and weighs up to 4t (Rabe, Kostka and Smith Stegen, 2017). There is also some minor use of rare-earth elements in magnets within the turbine tower for attaching internal fixtures (Vestas, 2018a).

5.5.1. PREVENT

Making rare earth content magnets takes vast amounts of energy in mining, processing, melting and machining. It also creates a lot of environmental pollution in decreasing order at the mine, processing, melting and machining sites. By re-using and recycling used rare earth content magnets, Europe's environmental pollution footprint will shrink and reduce the dependency on single sources.

5.5.2. RE-USE

Storage as replacement parts. Unlikely outside the generator, as the magnets are unlikely to fail. Storage as a fitted part in a generator, for example, would be the only exception to the above recycling recommendation, but it must be controlled, or storage may be used as a recycling obligation avoidance scheme.

5.5.3. REPURPOSE

The installation of used magnets in a different application. Possible individually, but not really practicable at scale.

5.5.4. RECYCLE

The reclaimed magnets can be re-cast as new magnets with the same composition.

Rare earth elements recovered by dissolution/depletion can be used to change the composition of the other recovered magnets in a melt. Re-combination of materials in different combinations is thus possible, but far more costly than simply recasting the removed magnets from solid item/powder form, which are the most environmentally acceptable solutions. It may thus be best to simply re-melt them in the same composition and leave different compositions to the totally new goods market.

5.5.5. RECOVERY

a. **Manual dismantling and segregation:** Expensive and labour intensive, probably uneconomical at scale.

b. **Mechanical recovery:** Robotic disassembly and segregation line: Possible and potentially quite efficient at scale, given sufficient investment and a good market for recovered magnets.

c. **Melting**: High temperature separation:
   - **I.** Melting the whole magnet containing item is possible due to different melting temperatures, which allows some segregation, but this is not so environmentally efficient or effective.
   - **II.** Possible to totally remove the magnets from the scrap and melt them, but unless it is stripped completely and one ensures that only similar magnets are melted together, it may be better to simply deliver them as they were to the manufacturer for melting & re-casting, as this would be greener.

d. **Dissolution / depletion:** This involves grinding to a powder and dissolving one element of the magnets with a fluid and then filtering it off, leaving a depleted powder. Not very effective and very energy intensive. However, it does allow recovery of one the majority of one rare earth element at a time (usually neodymium), which could be useful in the future.

e. **Disintegration:** Hydrogen atmosphere degradation and demagnetisation (the most environmentally efficient so far):
   - **I.** Putting neodymium, boron and iron magnet-containing items in a hydrogen gas environment leads to the magnets

being demagnetised and breaking down to a powder in a few minutes. This powder can then easily be separated from the waste, which can then carry on for further recycling. The collected powder can be used to re-form more magnets. This seems, by far, the greenest and easiest way to recover the magnets from scrap, but the scrap will need to be mechanically disassembled first to ensure best recovery rates.

II. The University of Birmingham received a Horizon 2020 grant to develop a European supply chain for their SUSMAGPRO (Sustainable Recovery, Reprocessing and Reuse of Rare-Earth Magnets in a Circular Economy) process for neodymium, boron and iron magnets recovery. This prototype process is planned to include robotic rare earth in waste concentration, followed by melting and casting of new magnets.

III. One obvious issue that this hydrogen disintegration process raises is the essential use of hydrogen fuel cells in long range / high payload EVs, where a hydrogen leak could leak to instant dissociation of the magnets on board if unventilated (high concentrations are needed).

5.6. OILS

Operating fluids or lubricants are used in WTGs in the generator, converter, gearbox, hydraulic system, rotor bearings and in the transformer. Contamination of the soil during the dismantling or removal of the WTG, also due to unforeseeable events, is to be avoided or minimised as much as possible. During the preparatory work for dismantling, therefore, the operating fluids (especially the oils and hydraulic fluids used in the plant) or lubricants, i.e. the substances hazardous to water, are drained off.

The operating fluids are usually extracted by trained specialist personnel with the aid of special machines, which are also used in the maintenance process when changing the oil in the systems, and are collected in special containers in order to recycle them accordingly, e.g. by refining and reconditioning them as base oil.

Although it is generally not possible to remove all operating fluids without leaving any residue, so that usually individual small quantities of fluids remain in the plant, the resulting risk of soil contamination is significantly minimised. As an additional measure against residual risk, demolition permits for WTGs sometimes contain ancillary provisions which stipulate that binding agents must be kept available during demolition in order to prevent the introduction of water-polluting substances into the soil and thus, if necessary, into the groundwater.

5.7. OTHER MATERIALS

Polymers are used together with aluminium, copper and steel in the production of cables for the plant.

Separately, electric and electronic components incorporated in the turbine make up around 1% of its mass (Vestas, 2017). It is estimated that around 9,500 electronic parts form the wind turbine controller units. These consist of electronic signal and power components such as resistors, capacitors and integrated circuits. Aluminium, tin, zinc, tantalum and precious metals, in various amounts, are among their main constituents.

5.8. MATERIAL TRACEABILITY

Thorough product documentation (material specifications) must also be well maintained for traceability if waste is to be used as a resource after a long lifetime of turbine operation, especially when considering the complexity of composite materials and the differences between OEMs in a component's material composition. Such an adequate flow of information from manufacturers to recyclers is crucial to ensure and potentially enhance high quality recycling. Furthermore, traceability of materials and the substances they contain plays a crucial role in reducing regulatory risks such as compliance with the EU's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Directive.

Rare earths:

Labelling and data acquisition: Recording composition of the magnets in the item is essential to segregate them carefully, so the new magnets made from reclaimed and recycled materials are consistent and thus controllable in foundry, and the end product is stable and more easily quality controlled. Uncontrolled composition in = uncontrolled composition out = massive reject magnets.

Blades:

Existing certification standards include IEC 61400 and DNV GL-ST-0376.

Note: Global Fiberglass Solutions (GFS) developed 'BladeTracker' which provides serial-number level tracking of blade material from collection to product manufacturing. This enables blade waste tracking at every stage of a blade's life but still does not predict the amount of blades reaching the recycling facility. GFS also collects FRP volumes from other industries e.g. boats, automobiles, etc.

5.9. HEALTH & SAFETY CONSIDERATIONS

Health and safety requirements must be included according to national legislation and risk assessments are recommended. The Health & safety considerations for the Resource Management chapter should address the following health & safety points[11]:

- Do not mix different categories;
- Wastes to be retired only by legal registered qualified vendor;
- Generate disposal documentation (which amount of what type of waste to be recycled/re-used disposed, by whom (Waste management vendor) and where).

11. The list is not exhaustive. Additional information is missing that still needs to be validated.

6. SITE RESTORATION

In order to minimise the risks to soil and groundwater from material inputs during construction site operations, organisational and technical measures (care in handling hazardous materials, checking cranes, transport vehicles and machines for leaks with regard to lubricant and fuel losses, etc.) must be defined and compliance with these measures must be checked during dismantling. Due to the residue-free removal of all operating fluids during the preparatory work for the dismantling as well as the provision of binding agents, emissions into groundwater and soil are not to be expected, or only to a minimal extent.

After completion of deconstruction measures of the wind turbines and the infrastructure and balance-of-plant equipment, it must be ensured that the plots of land again fulfil the natural soil and original use functions. In order to achieve this, measures may be necessary, such as unsealing of the used areas, removal of sustainable compaction in the topsoil and subsoil and the creation of a suitable subsequent use.

The pits resulting from the dismantling of the foundation and removal of the crane assembly area and access routes, and if necessary, also the cable routes, are to be filled with material. In principle, material is to be selected that will enable the future management of the areas. In addition, some requirements regarding the properties of the soil (e.g. bio-soil) and the general soil function, such as seepage capacity, must also be accounted for.

6.1. RESTORE SITE TO GREENFIELD

An example of a site in Germany being restored to a greenfield can be seen below. The process describes the activities after all structural works have been removed, including the wind turbine, foundation, infrastructure (roads, crane site, cables), transmission station and others.

Steps:

1. Assessment if, before construction of the wind farm, any evidence was created (possibly including photo documentation), signed by the landowner and tenant, and exists as an annex to the lease agreement;
2. Assessment of the former building permit and the dismantling permit whether they contain special requirements for wind turbine removal and the design of the surroundings. There might also be additional requirements from other authorities regarding environmental protection etc.;
3. Planning how the former wind farm area should look after dismantling, possibly with the support from special planning offices (for complex circumstances);
4. Discussing the design with private and public landowners/tenants (in Germany, plots of land with road sections often belong to the municipality);
5. Discussing the design with experts for environmental construction monitoring, the forest administration, regional agriculture organizations and other stakeholders;
6. Assessment if planting is necessary after earthwork: a separate planning is necessary;
7. Assessment if typical local topsoil and soil for filling is available; Finding out what happened to the topsoil removed during construction (was it stored locally?);
8. Tendering and assignment of construction works;
9. Execution of the construction works including supervision and documentation;
10. Site inspection with the landowner/local authority and hand-over report of the finished area including photo documentation.

6.2. DAMAGE MINIMISATION

Once a wind farm is decommissioned the restoration of the site should aim to achieve the greatest improvements with the least disturbance and impacts on landscape fabric, character or visual amenity of neighbouring receptors through careful control of the works. The Scottish Natural Heritage report No. 591 suggests the following recommendations for infrastructure removal techniques:

- The restriction of working widths;
- protection of adjoining areas from vehicle incursion and stockpiling;
- weather/seasonal timing to avoid damage of substrates;
- control of working hours to minimise night-time intrusion in the countryside;
- dust suppression measures to avoid damage to vegetation and creation of visible dust plumes;
- avoidance or careful design and siting of stockpiles/ storage mounds;
- rapid and progressive re-soiling and restoration of the site with an appropriate substrate.

6.3. VISUAL REMEDIATION

Already in the initial design of a wind farm it is crucial it is recommended to have a sensitive design to achieve good landscape and visual fit for the wind turbines. Design innovations in foundation design, and the potential use of temporary access tracks, laydown areas and crane pads which utilise geotextiles to increase strength) generated during the early stage may also provide for mitigation of decommissioning impacts and may make removal of infrastructure cheaper and easier. If the restoration would take place in phases it could minimise the extent of landscape disturbance.

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