

# Chapter 22

## ODIN-WIND: An Overview of the Decommissioning Process for Offshore Wind Turbines

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**Abstract** The oldest offshore wind farms in Europe are now well over 2 decades old. Considering this fact, and the technological advancements in wind turbine technology, it is evident that decommissioning of wind farms will soon become a crucial topic of discussion. NIRAS have been at the forefront of offshore wind farm decommissioning, and have developed extensive expertise in the area. Recently, they released a tool—ODIN-WIND—to assist stakeholders with the decommissioning process. The current chapter describes the decommissioning process for wind farms, the inherent challenges that may be faced, and potential solutions. It also provides an overview of ODIN-WIND tool.

### 22.1 Introduction

Decommissioning has previously been seen as simply the reverse procedure of the commissioning of an offshore wind farm (OWF). In recent years the sector has seen a shift from looking at the challenge in this simplified way to viewing it as a more diverse and complex challenge. It is considered prudent to address the future challenge of offshore wind farm decommissioning in a much more detailed manner in order to avoid the situation currently being experienced in the Oil and Gas industry where the failure to consider the potential requirements for decommissioning at an early stage has resulted in significant underestimation of the costs associated with decommissioning.

This chapter presents the processes relevant for decommissioning of offshore windfarms. This is done from a planning/management perspective and a on a high level. It is briefly discusses when it is recommended to make such a decommissioning plan in order to be in due diligence and the obvious results from such an assessment are presented.

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Finally the ODIN-WIND tool is presented. ODIN-WIND is a decommissioning management tool that, in large, covers the phases of decommissioning as explained in this chapter.

## 22.2 Decommissioning Management

The planning and management of a decommissioning project must address the issue of decommissioning as a whole, considering the full process and all the associated sub-processes. By addressing and understanding the processes it is also possible to identify where there is a lack of knowledge and where contingencies and assumptions (known unknowns) should be made. Herby it is also possible to address the unknowns as they become known. The typical decommissioning process is explained further in Sect. 22.2.1, and can be seen in Fig. 22.1.

### 22.2.1 *The Decommissioning Assessment*

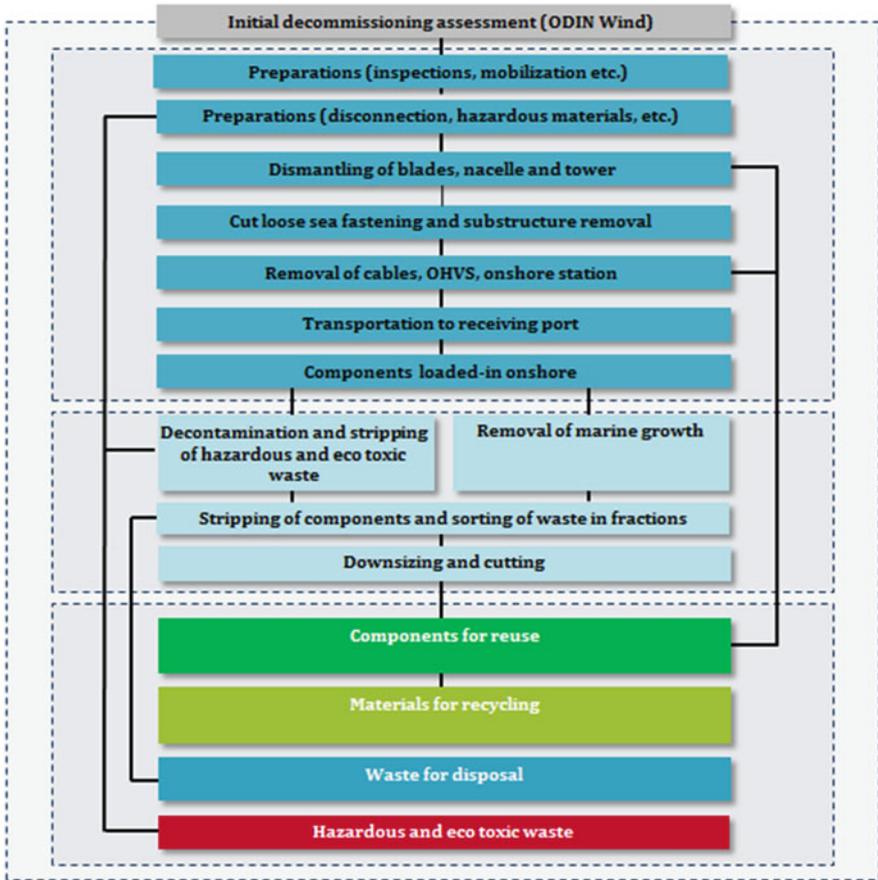
The assessment of the decommissioning process requires consideration on many levels and of many sub-processes. The typical processes of a OWF decommissioning which should be assessed are shown in Fig. 22.1. The assessment consists of three parts.

At the top, Fig. 22.1 shows the planning process which should asses all the process of decommissioning—i.e.—the decommissioning planning which is the work explained as a whole in this chapter.

Next, Fig. 22.1 illustrates the typical process of decommissioning: preparation, dismantling methods including cutting, lifting and detachment. Also included are considerations such as the used-vessels' capabilities and restraints; these restraints for vessels include weather on the site, challenges with transportation to the port and what the port capabilities are. All in all, this is essentially the offshore operation with an interface of the structure being lifted ashore.

In the middle part of the figure, the onshore operations are addressed, e.g. the treatment of the structural items including decontamination, stripping and waste management.

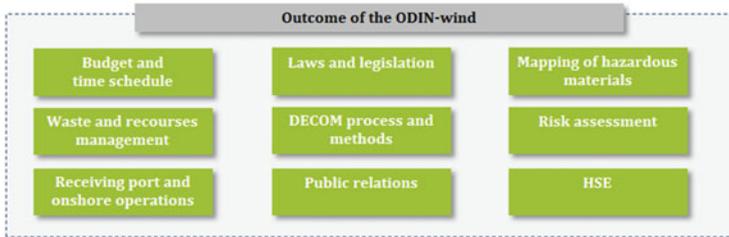
The bottom part of Fig. 22.1 shows the main components of waste and recourses that are produced. The hierarchy of the four fractions—reuse, recycling, disposal and hazardous waste—is deliberate. The top two fractions are in favour while waste for disposal should be avoided as well as hazardous materials which should be minimised as far as possible.



**Fig. 22.1** Typical process decommissioning of an OWF from the ODIN-WIND tool (Gjørdvad 2015)

After assessing the specific decommissioning project, the project should produce project output that can be used by the owner and the stakeholders involved. The focus and details of the output can vary, depending on which state the OWF is in: design, operation, or end of life. Typical outputs from such an assessment can be seen in Fig. 22.2.

It is of course the case that inadequate knowledge on the subject and equally inadequate or insufficient data, when using a tool as ODIN-WIND (Gjørdvad 2015), obviously will result in results of equally poor quality.



**Fig. 22.2** Typical output from a decommissioning assessment the ODIN-WIND tool (Gjørdvad 2015)

The mentioned method, considerations and other key elements of the decommissioning assessment are described in detail in Sects. 22.3–22.8. Starting with the actual decommissioning process including perpetrations, details on WTG (Wind turbine generator) and tower removal, substructure and OHVS (Offshore High Voltage Station) removal, cables removal, met mast removal followed by the vessel and port, weather and removal sequence, HSE and risk, waste and material management and finally cost estimation including budgeting and time schedule.

Managing an offshore decommissioning project requires involvement at an early state. This means the inclusion of a decommissioning assessment into a given offshore windfarm project as early as possible. The involvement of decommissioning in the different phases of an OWF is described shortly below.

### 22.2.2 *Decommissioning During the Design Phase*

The decommissioning assessments in the design phase can commence early—ideally during the selection of substructures, arrays, location etc. This would mean that a decommissioning analysis is made considering different scenarios with variations of the variables and thereby feedback into the decision of what type of substructure, array type and installation and even location is optimal. Although experience shows that the input from decommissioning is not as important as other considerations—such structure, installation scenarios, etc. . . .—the decommissioning input can still have an important impact on the final decision.

If not included from the beginning the decommissioning analysis can be based on a selected scenario with defined parameters including substructures, arrays, location etc., taken into account. Here the decommissioning assessment feeds back in to the project with cost reductive design adjustments taking the future decommissioning in

to consideration. This means that the existing design can be optimised by including the decommissioning input.

### ***22.2.3 Decommissioning During the Operation Phase***

A decommissioning plan can also be produced during the operation phase of an OWF. Making a plan at this stage can be done regardless of the existence of an decommissioning assessment from the design phase. It is recommended that the assessment should commence half way through the expected life time, typically 12–13 years after commissioning. If a decommissioning plan was made during the initial phases the assessment during the operation phase will naturally be an update. Otherwise the assessment should be made from scratch.

During the operation phase of the OWF, the estimation can be an important tool for the owner to decide what to do after end of operation; this enables the owner to set aside funding and also get a better picture of when the OWF should be taken out of operation. Furthermore the estimate can also be used for the purposes of life-extension and re-powering of the OWF.

The assessments will naturally be more detailed than the one made during the design phase. This is primarily because details of the OWF are actual ‘as-built details’, along with operation and maintenance information.

### ***22.2.4 Decommissioning Prior to the End of Life***

The final decommissioning assessment should be updated in good time prior to the actual decommissioning of the wind farm. The final assessments should be more detailed than the previous assessments, not only with actual details of the OWF in place. The final assessment also includes actual conditions at the time of decommissioning.

Even though such ‘final assessments’ get more precise the closer it is made to the planed time of decommissioning, it should not be left too late—and needs to be made at least 2–4 years ahead, depending on the quality of the previous decommissioning assessments made. As the time of decommission comes closer the assessment can then be used for EIA analysis, permitting and regulatory compliance as well as the actual tendering process.

Not only should the final assessment include details on the actual decommissioning, but also include plans for a post survey and a project close-out report.

### **22.2.5 *The Regulatory Process for Decommissioning***

Depending on which part of its life cycle the OWF is in—design, operation, or end of life—the regulatory process is a little different. Obviously the countries which first established offshore windfarms are most likely to be the ones that are furthest on the matter of decommissioning. This, combined with the level of environmental awareness that the respective countries holds, determines the state of regulations.

For the North Sea and most of the European waters, the regulations and guidelines that need to be fulfilled are international (from organizations such as IMO—International Maritime Organization), regional (from, for instance the OSPAR agreement), and national.

Regulations for the design phase, are at the present, only general rules of design such as Eurocode and environmental rules. Additionally, general rules of vessel operations and such should also be upheld. However, no *actual* rules of assessment of decommissioning of OWF or design input currently exist.

In many cases it is an authority requirement that decommissioning is considered during design, but the actual authority demand and the quality of the required assessment is very variable—and in most cases poor. Regulations for decommissioning assessments during operations are often driven by the fact that most European states require that the owner sets aside funding for the future decommissioning of the offshore structure.

The actual decommissioning for most of the European OWFs is at the present some time away, and therefore only few countries have actually made a fixed set of rules and procedures for decommissioning of offshore windfarms. Existing rules on O&G (oil and gas) are considered as starting points, and of course general regulations on HSE (Health, Safety & Environment) are to be upheld as well as general regulations on vessel operations.

## **22.3 The Decommissioning Process**

For all the assessed methods the process should be considered with regards to HSE (Health Safety and Environment). The considerations of HSE requirements are equally as important as the cost and time consumption. Thus, potential risks related to offshore decommissioning projects must be understood and addressed. The mentioned considerations are as important as managing the project in a cost effective way. Indeed, addressing these matters can actually help to make the project more cost efficient.

### 22.3.1 Preparations

Comprehensive preparations are necessary prior to the commencement of the dismantling and removal operations both onshore and offshore. With regard to vessels, this includes providing sea-fastening, lifting yokes, mobilization of vessel in general, amongst other tasks. An upgrade of the receiving port is also often required—e.g.—reinforcement of quays.

Preparatory work at the site depends on the removal concepts. Prior to the WTG and tower dismantling, preparations usually include jack-up footing assessment of seabed, disconnecting of high voltage system and other installations, securing non-fixed structures, and structural integrity checks.

Preparatory work for substructures, topsides and cable recovery include tasks such as dredging prior to cutting operation, preparing access inside the piles for tool deployment and ROV's (Remotely Operated Vehicles), and removal cables and other equipment.

### 22.3.2 Wind Turbine and Tower Dismantling

The options of removal concepts typically considered are shown in Table 22.1:

These options follow the typical installation options, but in reverse order. Thus, the installation process for a wind farm should be properly documented during the installation stage, and studied closely in the decommissioning planning phase.

Typically WTIVs (Wind Turbine Installation Vessels) and HLVs (Heavy Lift Vessels) are used for installation of wind turbines, and the obvious choice for the dismantling is to use the same or a similar vessels. For minor near shore wind turbines other solutions are possible such as jack-up platforms or barges with a mobile crane.

**Table 22.1** Wind turbine removal concepts

Removal concept	Description of lifts
Bunny ear and tower in 2 pieces	Single blade, nacelle, hub and two of the blades, tower in 2 pieces
Bunny ear and tower in 1 piece	Single blade, nacelle, hub and two of the blades, tower in 1 piece
Rotor and tower in 2 pieces	Hub and three blades, nacelle, tower in 2 pieces
Rotor and tower in 1 piece	Hub and three blades, nacelle, tower in 1 piece
Five pieces separately	All three blades individually, nacelle and hub, tower in one piece
Six pieces separately	All three blades individually, nacelle and hub, tower in two pieces
Removal in 1 piece	Blades, hub, nacelle and tower in one single lift

### 22.3.3 *Transition Piece and Substructure Removal*

The key factor to be considered removing substructures is whether the installation is to be removed entirely or if any parts are to be left behind. The baseline of international law and obligations—e.g.—OSPAR convention and UNCLOS—is complete removal of offshore installations, with exceptions according to the IMO guidelines. The IMO guidelines list 6 key components that should be considered when making decommissioning decisions regarding how much—if any—of a platform or a structure should be left on the seabed.

The substructure design and installation concepts must be taken into consideration when planning the decommissioning. Typical substructure designs include: Monopile, 4 legged jacket, 3 legged jacket, tripod, gravity based. Typical installation and design concepts include: transition piece grouted onto top of pile, driven or drilled (grouted), or suction bucket (monopod).

#### 22.3.3.1 *Monopiles, Jackets and Tripods*

The common practice for removal of monopiles, tripod and jackets at other offshore installations has been to cut piles just under the seabed. Concepts for complete removal are yet to be field tested in full scale. The feasibility of the concepts and methods vary depending on the installation method—namely suction buckets and type of pile installation used. Various decommissioning concepts for monopiles, jackets and tripods are shown in Table 22.2.

**Table 22.2** Decommissioning concepts for Monopiles, Jackets and Tripods

Decommissioning concept	Description
Partial removal	Substructure with TP in one piece cut below seabed level
Partial removal	Substructure and TP in separate pieces cut below seabed level and TP
Complete removal	Removal of monopiles, tripod or jackets with suction buckets by reversing the suction process. Field proven on met mast leaving the seabed unmarked
Complete removal	Removal of the monopile, tripod and jacket piles in its full height using water pressure. Novel concept which not yet have been field tested
Complete removal	Removal of the monopile in its full height by removing sand around the pile. Considerable impact on the benthic ecologic and challenging. The impact and challenge increase proportional with the substructure depth

If the substructure is to be partially removed selecting the correct cutting concepts and methods is crucial for the operation to be successful. There are several cutting methods concepts, including:

- Internal pile cutting tool. The cutting tool is lowered inside the MP after clearance of internal parts and necessary seabed excavation
- External cutting. The cutting tool is installed after dredging soil around piles

The best solution of cutting tool and dredging method depends on the site conditions. In many cases it is preferable to minimize the use of divers which can cause safety risks and long downtimes. Cutting tools include flame cutting (oxy-fuel cutting); wire cutting; abrasive water jet cutting; cutting using linear shaped charge (explosives); blade sawing; and laser cutting. Explosives can be placed and detonated safely in regard to personnel health but are usually wrongly counted out due to environmental concerns.

### 22.3.3.2 Gravity Based Substructures (GBS)

In the Oil & Gas sector partial removal or leave wholly in place (reefing) are conceivable solutions in some case for large concrete GBS situated on deep waters. GBS for wind turbines are in most cases situated at shallow water depths and typically minor constructions than the ones used for oil rigs. GBS' are not piled and therefore they do not have the issue of cutting and leaving the piles partly in the seabed hence most likely complete removal is the only acceptable solution. Decommissioning concepts for GBS are shown in Table 22.3.

The weight of GBS' is substantial by design, and moving the GBS is a challenging operation. Conceivable options are shown in Table 22.4.

### 22.3.4 Substation (Offshore High Voltage Station) Removal

Substructure concepts for substations are the same as for wind turbines and can in general be decommissioned applying the same measures as for wind turbines

**Table 22.3** Decommissioning concepts for GBS

Decommissioning concept	Description
Offshore disposal	Moving the GBS further off shore and dumping it on greater depth
Demolition at other location	Moving the GBS inshore at location with wider and cheaper options for deconstruction
Demolition on site	Demolition on site and removal of debris/pieces
Onshore demolition	Moving the GBS onshore for conventional demolition

**Table 22.4** Options for moving GBS

Options for moving GBS	Description
Single heavy lift in one	The lift requires very large vessels with large draughts for the heavy lift. The feasibility of the solution is dependent on the water depth and the weight
Heavy lift in two pieces	Dividing the GBS by wire cutting or sawing will reduce required lifting capacity significantly and enabling more vessels do carry out the lift. The cutting operation is very sensitive to weather conditions due to underwater operations. Feasibility is dependent on the GBS design
Floating	Floating the GBS supported by salvage pontoons and filling it with ballast on site is usually used for the installation and it is obvious to reuse the method if the design allows pumping out sufficient ballast weight to enable buoyancy.

**Table 22.5** Overview of removal concepts for substation topsides

Removal concept	Description
Single heavy lift	Removal of topsides by heavy lift vessels.
Float-over	Float-over is the removal by lifting the topside of the substructure with semisubmersible heavy lift vessels or dual barges with jack-up systems. No crane lift is required for this method.
Skidding	The method is the reverse of skid-on where the topside is transferred to a vessel by drifting on rails from the substructure.
Modular	Lifted in modules reverse of the installation process.

substructures. The substructures for substations however, are typically bigger than wind turbine substructures. The logical solution for removing the topside is using the same concept as is used for the installation. Self-installing (jack-up) concepts have been used at other offshore installations but most offshore high voltage station (OHVS) topsides have been installed using the single full topside concept. The concepts for removal of substation topsides are shown in Table 22.5.

Independent of the removal concepts, the separation of the topside and substructure requires a cut at stabbing pipe sleeves and all welded connections. A OWF typically only includes one OHVS and therefore opting to use a lifting vessel already at the site is likely to be cost-effective.

### 22.3.5 Cable Removal

The installation concepts for inner array cables and export cables are given in Table 22.6.

At the time of decommissioning seabed conditions may have change dramatically from the installation phase due to current and sand waves. Hence a thorough

**Table 22.6** Installation concepts for offshore cables

Installation concepts	Description
Buried	Typically buried 1–2 m under seabed in a trench and possible partly scour protected
Covered	Typically covered with 0.5–1.0 m of rock boulders

**Table 22.7** Overview removal methods for cables

Recovery	Storing on CLB or CLV
Jetted up on seabed (if buried) and pulled on board	On drums On an on-board turntable Cut in sections
Directly “Brute forced” (if rock covered)—the cable is pulled free first from the J-tube and then from the rock layer	On drums On an on-board turntable Cut in sections

inspection is required prior to decommissioning planning. The decommissioning concepts for cables are:

- Complete removal of all cables
- Leave all in place
- Partial removal.

The solution depends on the regulatory obligations and/or the economical balance between the cost of recovery and the scrap value. In some cases, it the possible repowering and reuse of cables will determine the best solution. An overview of removal methods for cables is given in Table 22.7.

The best solution for storing the cable is interdependent of transport distance and offload facilities and if direct load-in to scrapyard is relevant. The main vessels used are CLV (Cable Laying Vessel) or CLB (Cable Laying barge). For the jetting operation and attaching the cable to the crane hook a ROV can be applied. Divers are often preferred in shallow waters, or used when the ROV is not applicable.

### 22.3.6 *Met Mast*

Wind farms usually have one or more met masts. The design of met masts varies a great deal. Met masts with lattice tower mounted on monopiles are a quite common design. The towers can often be dismantled without crane use. The substructure is more likely to be removed totally—and removing a mono suction bucket substructure totally, by reversing the suction process, has been field proven.

## 22.4 Vessels and Ports

This section describes the challenges that may arise during the decommissioning process due to inadequate vessel technology or port facilities.

### 22.4.1 Vessel Types

Many vessels are used in the process of decommissioning. The main vessel types are listed in Table 22.8.

Beside the main decommissioning vessels a fleet of support vessel is required. This includes work boats, construction support vessels, diver operation vessel, ROV operation vessels, anchor handling tug and crew boats for transit.

### 22.4.2 Vessel Suitability

The vessels used for the wind farm installation will by nature be capable of decommissioning. However the market for installation vessels is constantly developing

**Table 22.8** Main decommissioning vessels

Vessel type	Description
Jack-up barge	Barge or platform equipped with legs and a jacking system allowing the barge to self-elevate when operating. Used for installation of blades, hub, nacelle and tower. The components are transported to the site by a barge.
WTIV	Purpose build jack-up vessel for the installation of blades, hub, nacelle and tower. WTIV is self-elevating similar to a jack-up barge but transport the components on the its own deck.
Heavy lift vessel (HLV)	Designed to lift very large loads and used for installation of topsides and substructures. There are several types and variations of HLV e.g. floating sheerleg cranes, monohull crane vessel, catamaran cranes, semi-submerging vessels lifting with-out the use of cranes.
Semi-submersible crane vessel (SSCV)	Designed with increased stability allowing very large crane capacity. Used for topside installation.
Barge	Capacious flatbottom vessel used for transportation of wind turbines, substructures and OHVS topsides etc.
Cable laying vessel (CLV) and cable laying barge (CLB)	Used for cable recovery by pulling the cable on drums or turntables.

to increasing installation performances—and at the time of decommissioning the original installation vessels could be decommissioned themselves.

The physical character of the structures and the proposed method for removal will result in a number of requirements for the vessels to be used. Parameters to be considered include lift capacity, cargo load capacity, etc. As a key factor in the planning stage the vessels operational limits in regard to environmental loads must be taken into account. Furthermore the logistic planning must take cargo area, transportation/transit speed, length, draft, breadth, and other such factors into account in order to line up port requirements and get realistic cost estimations.

### **22.4.3 Ports**

The receiving port should be able to meet the requirements derived from the load-in and the downsizing activities. Examples of physical requirements for the port include water depth, load capacity, storage facilities, and load-in facilities. The lesser the port restraints, the more vessels are available—leading to increased completion in the tendering process. Other port requirements that should be considered are environmental approvals for emissions, noise, dust, and facilities for the specific hazardous materials. Matching the requirements with vessel performance, port capacity and methodology should be done in an iterative process.

## **22.5 Removal Sequence and Weather Windows**

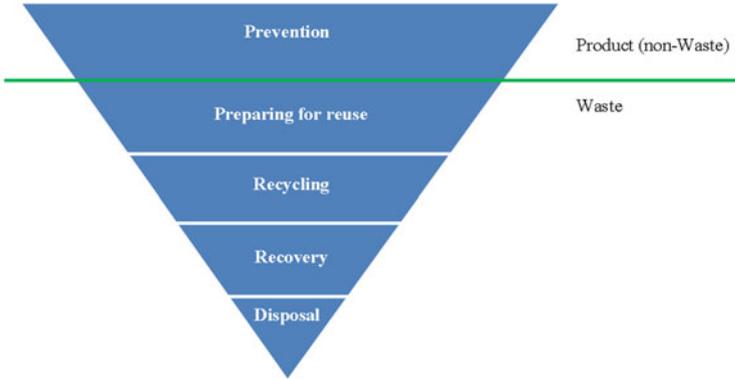
The removal process must be broken down in a removal sequence to analyse the downtime for the decommissioning operation duration.

The time schedules for offshore operations are based on a weather model or met-ocean data. A common approach to the weather model used for the estimation of operation duration is to combine the planned offshore decommissioning activities (removal sequence)—defined as a combination of duration, required weather windows and weather restrictions specific for selected vessels—with the assumed future weather conditions of wind speed, significant wave heights and peak wave periods. In this manner, the time schedules can include vessel downtime due to weather restrictions.

## **22.6 Waste and Material Management**

The policy for waste treatment is a waste hierarchy, shown in Fig. 22.3.

The EU Waste Framework Directive (EU, 2015) specifies that companies involved in the production of materials, construction, demolition, renovation,



**Fig. 22.3** Waste hierarchy

buildings and public works will improve the sorting and recycling of their waste to achieve performance in terms of material recovery of 70 % in 2020. The material received onshore from the wind farm will, as far as possible, be re-used, alternatively recycled or incinerated for energy recovery. If none of these alternatives are possible, for instance, due to content of environmentally hazardous compounds, the material will be deposited at landfills. The trend of circular economy will also influence the offshore wind industry and the design of the modules will by time be easier to dismantle, refurbish and reuse.

### **22.6.1 Reuse of Components**

The nacelle with hub and blades can either be reused completely, or be disassembled in major components and sold as spare parts. The reuse of substructures, towers and sea cables is less attractive. This aftermarket business of selling old turbines is developing as the wind industry is coming to a mature state.

### **22.6.2 Recycling**

The majority of the materials are fit for recycling. All metals, electronics, batteries, gears and motors can be recycled through re-melting. Concrete can be crushed and recycled as secondary construction materials. Oils can be refined and that way upcycled to new oil products. For rubber, plastics and glass fibre, or other composites and epoxy, recycling is possible, but depending on the quality and compositions of the specific products.

Marine growth on the subsea parts will consist of algae, barnacles and mussels. Due to the anti-fouling agent on the substructure they might be contaminated with the active components of the anti-fouling agent. Due to the organic content in the material, it is possible that the material can be used as other types of sludge.

### **22.6.3 Incineration**

If rubber, plastics and glass fibre, or other composites and epoxy, cannot be recycled it is possible they can be incinerated for energy purposes. For glass fibre it is known that a large amount can cause challenges for the incineration plants filtration system, and that the emission of dioxin can rise.

PVC is a problematic compound, because it can contain phthalates or heavy metals—and if incinerated in a waste incineration plant, the amount of slag produced will increase significantly. This slag is classified as hazardous waste and has to be landfilled. Although a method exists for the recycling of mainly hard PVC, it is not feasible for OWFs. In wind turbines, PVC is sometimes used as cores in the blades and has to be split from the glass fibre, before it can be recycled, which currently is quite difficult. It can therefore be expected that PVC in current blades will be incinerated.

### **22.6.4 Deposit**

Currently, the recycling of composites is quite limited. It is a field of innovation, as presently, these materials are mainly incinerated or landfilled depending on their content. If the marine growth on these materials is highly contaminated by anti-fouling agents the composites will have to be deposited.

Some fractions of hazardous waste must be expected. In some cases, this can be treated (through the use chemicals, for instance); otherwise depositing is the only option.

## **22.7 Cost Estimation**

The cost estimate should include the proposed decommissioning measures described earlier in this chapter (Sect. 22.3). The estimation should have a budget covering:

- Planning and engineering
- Decommissioning design
- Offshore removal and transportation

- Clearance of site
- Onshore dismantling
- Waste and recourse handling
- Assumptions and contingencies

The budget should be accompanied by a time schedule which naturally will appear as the methods are assessed. The schedule should show the different phases of the decommissioning work which naturally would be undertaken in the most suitable part of the year in regards to weather, based on the implementation of sequence and removal windows.

## 22.8 ODIN-WIND: The Tool

The ODIN-WIND project is a Danish development program under EUDP (energy technological development and demonstration program) supported project NIRAS has, together with its partners, Vattenfall, TWI (Technical Welding Institute), DTU (Technical University of Denmark) and Maersk Broker, created the ODIN-WIND modelling tool.

The ODIN-Wind modelling tool is based on a standard estimation of decommissioning procedures. This includes an input phase where the user is guided through the process of establishing the model. This aids the user in inputting the initial data after which the modelling tool preselects the next steps based on the provided data. Preselection is based on logical choices from what is possible with the previously given input. The user can also update the model to achieve different end results by improving data input, or making different selections. Finally the end result is computed, and results from each iteration can be saved separately for future use. In other words the user can iterate and justify the built model to retrieve the optimised result.

The model is built up in stages and at any time a user can return to previous stages and make changes. However, it is not possible to move on to a later stage unless the previous stage is completed.

The input function part of the modelling tool includes the steps below:

- Log in
- Initial study
- Mapping of Hazardous materials
- Deconstruction
- Receiving ports
- Supplier selection

The end result is presented to the user as a summary of the model with a listing of estimates and relations linked to: the installation details, selected methods, suppliers, geography etc. The end result is presented to the user as relevant information regarding:

- Cost estimation (budget and time schedule)
- Applicable laws, legislation, regulations and standards
- Mapping of Hazardous materials
- Waste and recourse management
- Decommissioning process and methods
- Risk assessments/analysis
- Receiving ports and onshore operations
- Public relations
- HSE

The ODIN-WIND tool is described in more details in the EWEA paper “Preparing for the future—the full process of decommissioning” (Gjørdvad 2015).

## 22.9 Conclusions

As OWFs become increasingly common, there will—inevitably—be a need to decommission obsolete turbines. Decommissioning is a process that has not been explored or researched widely until now, as the need was not so pressing. NIRAS, being at the forefront of technology have anticipated the needs of the industry and developed a comprehensive tool to address the decommissioning process, as described in this chapter.

It is expected that this tool, and indeed the decommissioning process, will be updated and adapted in the future, as wind turbine technology continues to evolve.

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## Reference

Gjørdvad J (2015) Preparing for the future – the full process of decommissioning. Paper presented at the EWEA Offshore 2015 Conference, Copenhagen, 10–12 March 2015