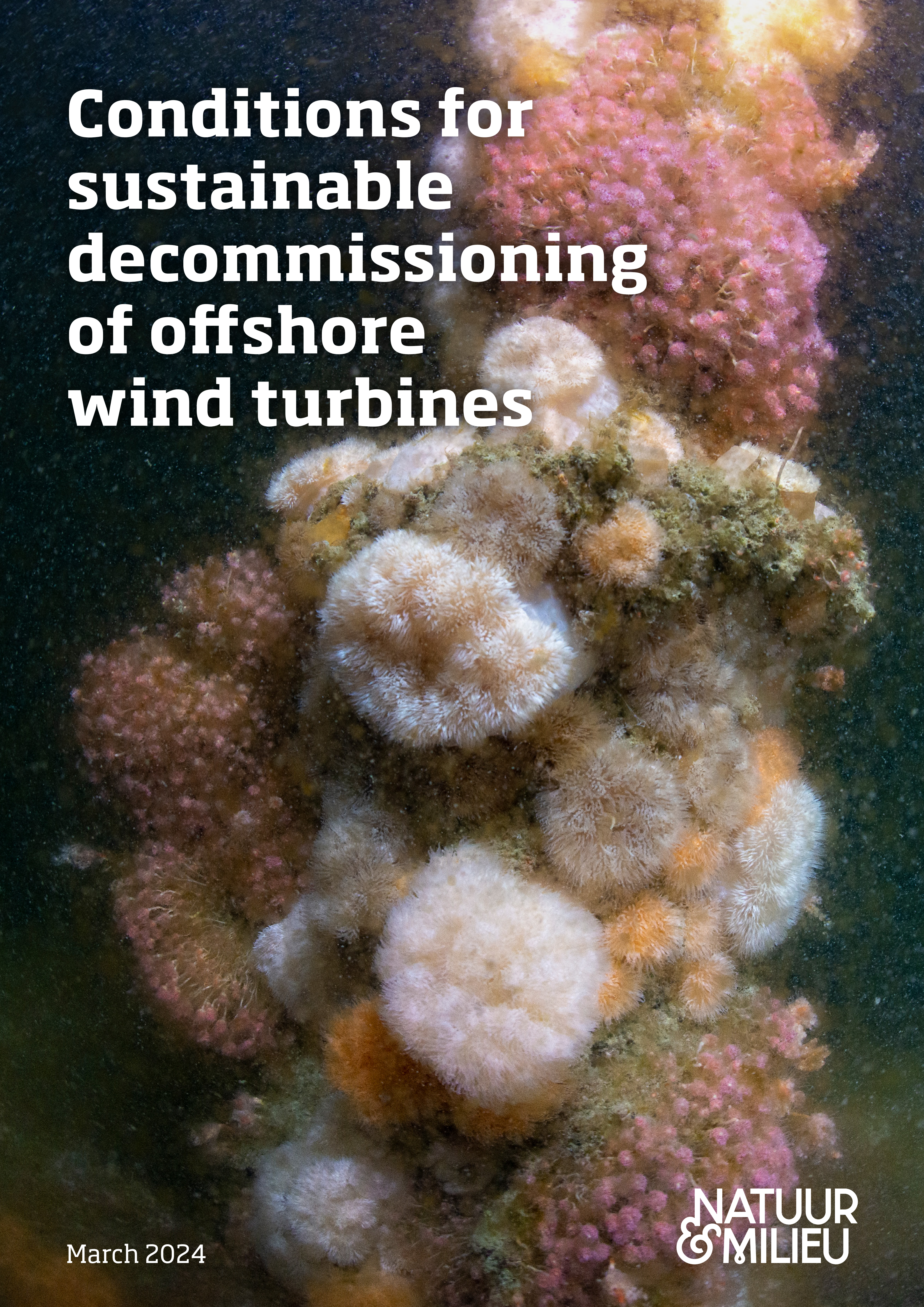
Conditions for sustainable decommissioning of offshore wind turbines



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Index

1. Introduction

Offshore wind energy is developing rapidly and is becoming one of the main focal points for the generation of renewable electricity in Europe. The installation of offshore wind turbines in the EU is growing exponentially, with a European ambition of 111 GW in 2030 and 300 GW in 2050 for the North Sea alone. Consequently, offshore wind energy plays a crucial role in phasing out fossil fuels (Appendix 5.1).

To achieve significant progress in upscaling offshore wind energy and reducing the costs for offshore wind turbines, the spotlight has been primarily on new windfarm deployments. The critical issue of decommissioning offshore windfarms (OWFs) and related infrastructures such as cables at the end of their lifecycle has been relatively overlooked.

Given the knowledge that all the thousands of wind turbines, including cables, which are being built should also be decommissioned, it is important to investigate how this can be done without compromising on other targets such as those set for nature restoration and circularity. It is crucial to take a comprehensive approach to the decommissioning issue and retain a long-term perspective. In doing so, environmentally friendly and circular dismantling go hand in hand, but this is not adequately encouraged holistically by the business case and the pressure for the rapid implementation of offshore wind.

The main challenge this paper is addressing is the need to strike a balance between decommissioning and meeting nature conservation, restoration and circularity targets. In order to do so, **sustainable decommissioning** should be the norm. In this paper, we define sustainable decommissioning as a decommissioning process that integrates principles of nature conservation, restoration and circularity.

Aim of this paper

This paper highlights the dilemmas surrounding current decommissioning practices and the legislation and steps necessary to achieve sustainable decommissioning. We describe challenges with respect to nature inclusivity and circularity that arise when decommissioning offshore wind farms. We consequently define a set of policy recommendations for the EU and Member States to improve the conditions for enhancing the sustainable decommissioning of OWFs. We translate this into a first draft of decision-making principles that need to be considered during the design phase of an OWF in order to include the aspects of nature inclusiveness, the life span and the circularity.

Through all this, we aim to start a discussion that will lead to a decision-making framework on decommissioning offshore wind farm infrastructure with respect to nature and circularity. We believe that this framework must be developed in collaboration with relevant stakeholders such as offshore wind farm developers, manufacturers, marine ecologists, NGOs and scientists.

Ultimately, our goal is to make sure that industry is motivated to develop comprehensive plans for sustainable and nature-inclusive design which includes a sustainable decommissioning plan ensuring minimal impacts on marine ecosystems and maximum circularity when decommissioning offshore windfarms.

Scope and reading guide

This paper is addressed to policymakers in the EU and its Member States. It focuses on the impact of decommissioning on nature and material use, and on the changes in policy conditions necessary to reduce negative impacts of offshore windfarm decommissioning.

This paper considers the implications of decommissioning offshore windfarms built with monopiles. It also addresses the turbine and associated infrastructure within the wind farm such as inter-array cables and offshore transformer substations for electricity transport are included. Geographically, we focus on the North and Baltic Sea area. Gravity-based foundations, floating wind, onshore wind farms and oil and gas assets are beyond the scope of this paper.

The paper starts with Chapter 2 on the relationship between OWFs and biodiversity, and the impacts that decommissioning can have on this. In addition, we discuss how to minimise the impacts of decommissioning on nature and how circularity contributes to sustainable decommissioning. In this chapter we also elaborate on the legal conditions concerning decommissioning. In Chapter 3, we will discuss some alternatives for full decommissioning and introduce the necessary steps towards sustainable decommissioning. These steps result in policy recommendations that are introduced in the concluding chapter 4.
As a follow-up to this paper, we will discuss the importance of life span extension, standardisation and a focus on circular design in order to further decrease the negative impacts of OWF decommissioning. This paper can be downloaded here.

2. A focus on decommissioning

The challenges involved in decommissioning encompass the absence of practical experience but also the potential impact on biodiversity and circularity needs. As the offshore wind sector scales up, informed considerations and decisions on decommissioning must be made before and during the design phase of new projects.

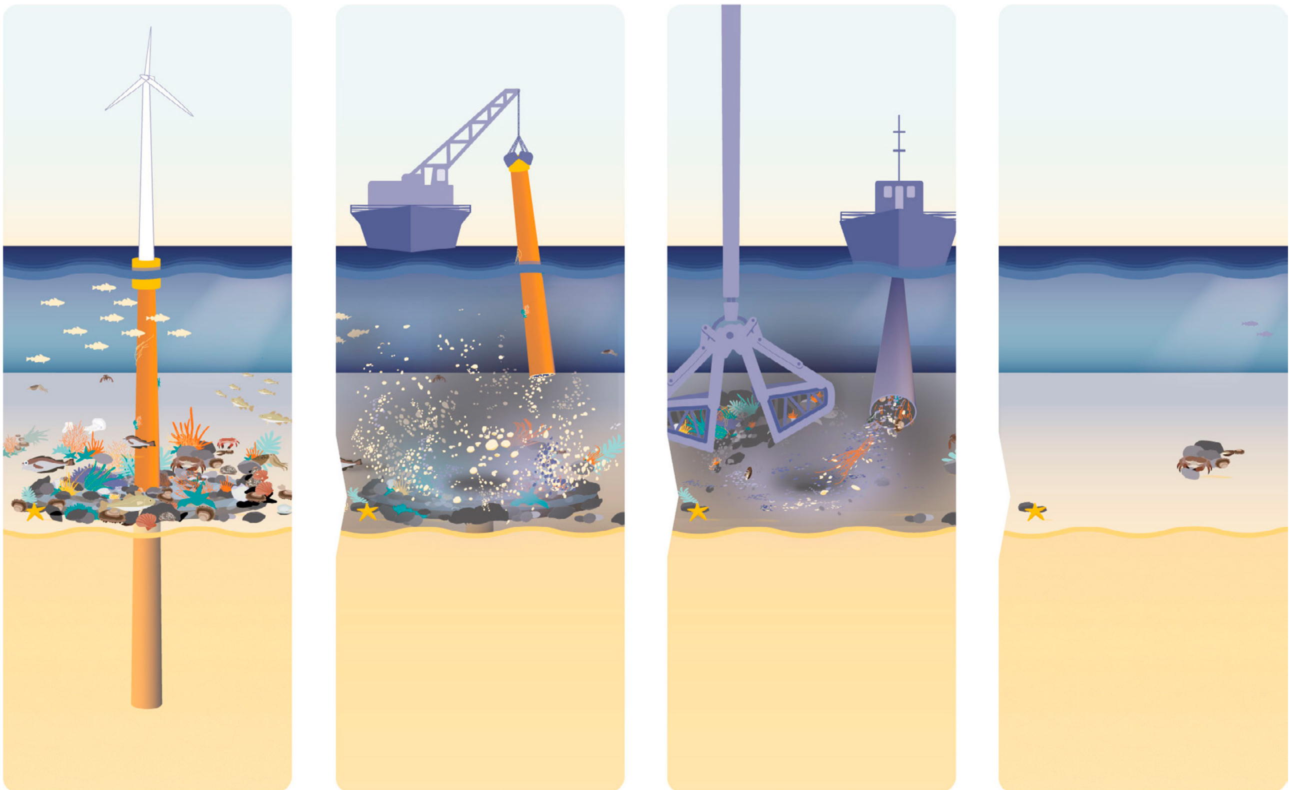
With the scale-up of wind energy and the advent of innovations, there have been cost reductions that have made it possible to develop offshore wind farms without the need for subsidies. This is one of the success stories of the energy transition. However, the current market situation for offshore wind has changed. Wind developers in the EU are no longer competitive on price due to high inflation, commodity prices and access to raw materials, amongst other things[1]. It is crucial to work on other aspects that are important when scaling up wind energy. The amount of space and materials needed for offshore wind energy is substantial, and negative impacts on marine ecosystems may occur when scale is achieved. [2, 3, 4] In the complete offshore wind lifespan and value chain, steps should be taken to avoid and mitigate these negative effects and strive to achieve a positive impact on nature.[5, 6, 7]

OWFs can offer possibilities for nature. The Dutch North Sea Agreement states that *'objects and installations create new habitats and can contribute to nature'*. Marine species use these newly introduced hard substrates to settle, spawn, forage and take refuge, thereby increasing local biodiversity and biomass, the so-called 'artificial reef effects'[8]. Offshore wind structures have also been found to induce artificial reef effects[9]. Additionally, some OWFs (Netherlands, Belgium) prohibit trawl fisheries and heavy vessels, consequently protecting the area from bottom-disturbing activities. This reinforces the opportunity for environmental flourishment[10]. We have seen the same effect with oil and gas platforms which can significantly enhance local biodiversity and biomass.[11] Ecological research shows that the species communities that have developed around human-introduced hard substrate and those around natural hard substrates such as stones and biogenic reefs can display certain similarities. On the contrary, platforms create different habitats than natural reefs and cannot offer compensation for the previous destruction of the hard substrates of oyster beds[12, 13, 14]. Always taking the intrinsic value of naturally occurring habitat into consideration, artificial reefs can increase local production and native biodiversity, potentially making these ecosystems valuable and worth maintaining.

1) *Press release, European Commission, 2023.* *https://ec.europa.eu/commission/presscorner/detail/en/ip_23_5185*
2) *Garthe, S., Schwemmer, H., Peschko, V. et al. Large-scale effects of offshore wind farms on seabirds of high conservation concern. Sci Rep 13, 4779 (2023).* *https://doi.org/10.1038/s41598-023-31601-z*
3) *Deltares, 2018. Assessment of system effects of large-scale implementation of offshore wind in the southern North Sea* *https://www.deltares.nl/en/expertise/publicaties/assessment-of-system-effects-of-large-scale-implementation-of-offshore-wind-in-the-southern-north-sea*
4) *Slavik, K., Lemmen, C., Zhang, W. et al. The large-scale impact of offshore wind farm structures on pelagic primary productivity in the southern North Sea. Hydrobiologia 845, 35–53 (2019).* *https://doi.org/10.1007/s10750-018-3653-5*
5) *The Mitigation Hierarchy* *https://www.thebiodiversityconsultancy.com/our-work/our-expertise/strategy/mitigation-hierarchy/*
6) *IUCN, Nature Positive:* *https://www.iucn.org/resources/file/summary-towards-iucn-nature-positive-approach-working-paper*
7) *World Economic Forum: What is 'nature positive' and why is it the key to our future?'* *weforum.org/agenda/2021*
8) *Birchenough & Degraer, 2020; Coolen, et al., 2020; Fowler A. M., et al., 2018; Teunis, et al., 2021;Langhamer, 2012)*
9) *Degraer, et al., 2020. Offshore wind warm artificial reef affect ecosystem structure and functioning.* *httsp://edepot.wur.nl/541008*
10) *Van Duren, et al., 2016; Ounanian, van Tatenhove, & Ramírez-Monsalve, 2020*
11) *Coolen et al., 2020. Ecological implications of removing a concrete gas platform in the North Sea* *https://edepot.wur.nl/534846*
12) *IMSA Amsterdam. Ecosystems associated with North Sea oil and gas facilities and the impact of decommissioning options.* *https://ecoeffective.biz/wp-content/uploads/2016/02/LNS214_Ecosystems-and-North-Sea-oil-and-gas-facilities_LiNSI_DEF-copy.pdf*
13) *Underwater footage reveals abundant marine life in the Blauwwind offshore wind farm:* *https://natuurenmilieu.nl/nieuws-artikel/onderwaterbeelden-laat-veel-zeeleven-zien-in-windpark-van-blauwwind/*
14) *Other steps to reduce negative impacts or yield positive impacts of offshore windfarms on species is to incorporate best practices for all newly constructed wind farms, such as black blade tips, providing underwater habitats and limiting the maximum and minimum height of the wind turbine.*

The construction, operation, and decommissioning of wind turbines naturally result in physical alterations of their surroundings. Distribution and abundance of certain bird and bat species may change. Additionally, marine mammals, fish, and fish larvae are significantly disrupted during construction due to the noise generated during piling[15]. The decommissioning of OWFs is expected to have a similar effect on the surrounding areas of the wind farm as the installation. However, the actual impact of decommissioning is unknown as there have not yet been any examples of offshore decommissioning on a large scale.

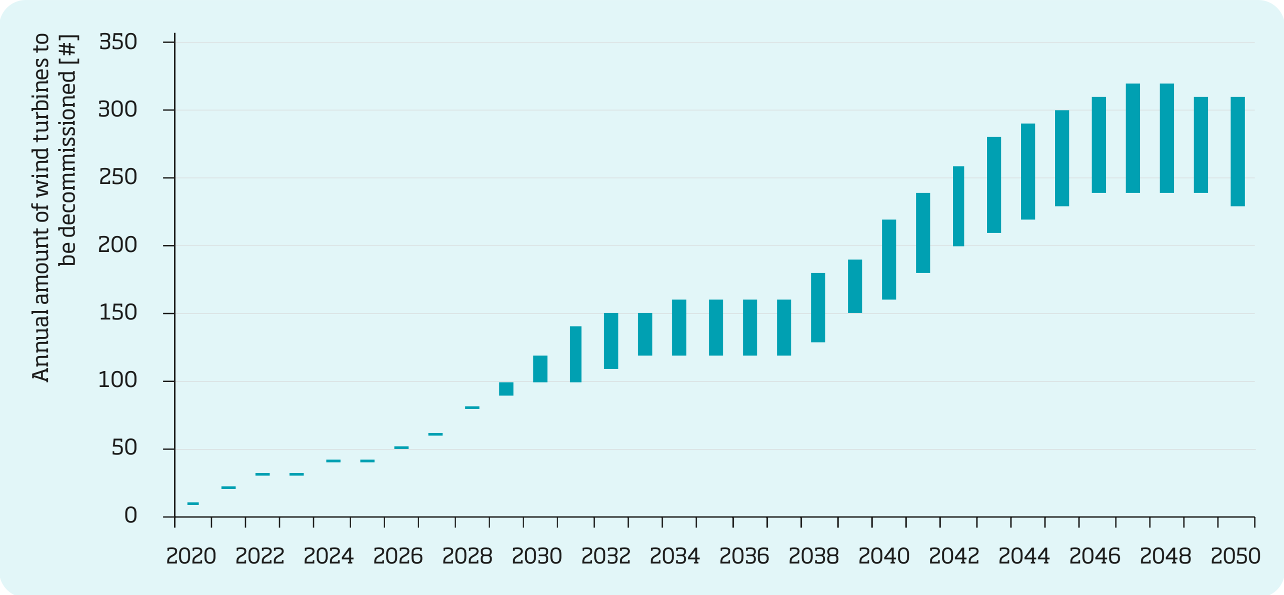
Figure 1: The environmental impact of full decommissioning of an offshore wind turbine



There are currently only two examples in Europe of offshore wind farms that have been decommissioned. The first of these is the Vindeby windfarm in Denmark. The other wind farm was a demonstration project close to the English coast. As a result, there is not much experience to draw on when it comes to the large-scale decommissioning of OWFs, let alone sustainable decommissioning, as these two OWFs were completely removed.

15) *Radical changes in the North Sea due to the growth of wind farms require more research. North Sea Foundation. https://megavind.greenpowerdenmark.dk/files/media/document/Strategy%20for%20Extending%20the%20Useful%20Lifetime%20of%20a%20Wind%20Turbine.pdf*

Figure 2: Projection of annual amount of wind turbines to be decommissioned



As can be seen in Figure 2[16], from 2030 onwards, a much larger number of wind turbines in OWFs are going to be decommissioned. Currently, at the wind farm's end-of-life stage, all assets are legally required to be removed. Both the OSPAR treaty as well as international law prescribe that all structures that were added to the marine environment must be removed at the end of life (Appendix 5.2). Decommissioning is an expensive component when applying for tenders since developers are asked to include a budget reservation for this purpose. Decommissioning is taken into account for the Levelized Costs of Energy (LCOE) part of a tender bid and the implications for cost reductions by changing decommissioning policy for OWFs might be significant. However, there are currently no criteria for the design and production phase that include stringent requirements for decommissioning and end-of-life phase (Appendix 5.2). Tenders do offer a good opportunity to set new standards in the offshore wind sector.

With the current laws and regulations, sustainable decommissioning is not possible. There is no option for assessing whether the nature arisen during the lifespan of a wind farm is of ecological value and need to be preserved by partial decommissioning. The full removal obligation now ensures that no proper assessment can be made regarding sustainable decommission. With the number of wind turbines that are going to be decommissioned in the near future, it is important that an integral consideration can be made between the preservation of materials, the value of arisen nature, and the impact on nature.

16) *Hajonides van der Meulen, T., Bastein, T., Krishna, D., Saraswati, N., Joustra, J. (2020). Offshore windpark decommissioning - Een oriëntatie van mogelijke economische activiteit in de regio Zuid-Holland en het havengebied Rotterdam. Report by TNO, TU Delft and commissioned for SmartPort*

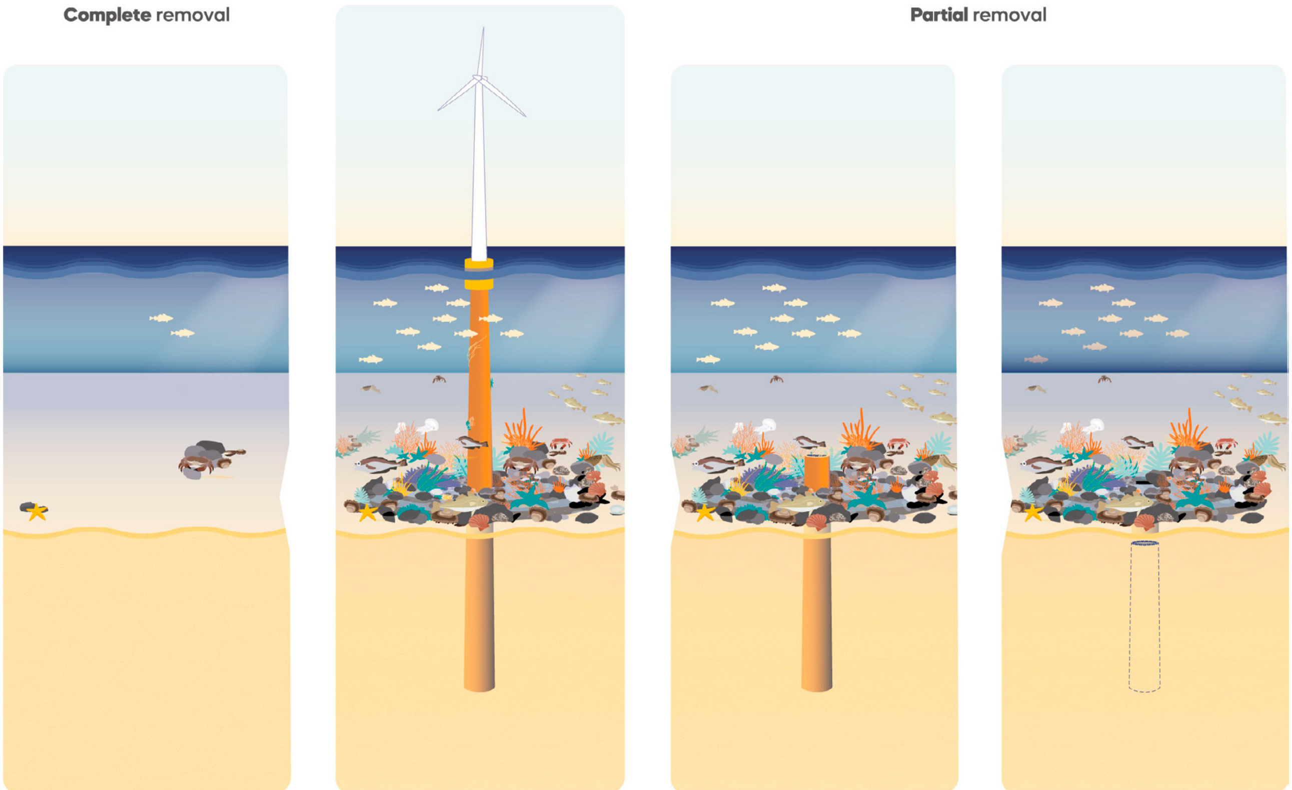
3. Steps towards sustainable decommissioning

When sustainable decommissioning is in place a dilemma arises: leaving behind certain elements can be better for nature, but then you lose materials for reuse and recycling. One of the dilemmas that arises in the decommissioning process is deciding if and which infrastructure to leave behind in order not to disturb the natural values that have developed.

From a technical standpoint, there are many possibilities to protect nature in and around OWFs and use resources efficiently. The current European regulatory framework mandates the complete removal of all structures post-operation phase, restoring the seabed to its original state. However, this overlooks the potential impacts on local biodiversity. The challenge is to strike a balance between decommissioning and meeting biodiversity and circularity targets.

For OWFs, there are several alternatives for complete removal, in which the seabed is 'left as it's found', such as partial removal in the form of *topping or only scour protection left*[17, 18] *(see Figure 3 and Appendix 5.3)*. There is no practical experience with these types of removal yet, meaning that the options described here are only theoretical. It is not possible to say that there is a one-size-fits-all best solution for nature, as this is dependent on external factors such as local biodiversity, type of seabed and other underwater circumstances and therefore demands a case-by-case assessment.

Figure 3: Schematic visualisation of complete and partial removal



17) *Jurrius, L., Providing room for nature in the decision making process. https://assets.vu.nl/d8b6f1f5-816c-005b-1dc1-e363dd7ce9a5/fbbad5e9-5e89-49f7-b092-035d8b413fb5/IVM_EE_2021_Jurrius.pdf*
18) *Lobregt, Amersfoort, van Leeuwen. Decomissioning of offshore wind farms. The nature-based business case of scour protection. ECHT Communicity & de Rijke Noordzee.*

A solution for minimizing the negative impacts of decommissioning on marine ecology is to extend the lifespan of the offshore wind farm as long as possible[19]. However, at the unavoidable end of life for an OWF, a decision needs to be made with respect to decommissioning. Ideally, exemptions for full removal of infrastructure are allowed when justified by the ecological value that the infrastructure offers. This should be evaluated and decided by an independent, scientific committee on a case by case basis. In this case, providing structure for deciding whether to fully decommission, partially decommission or leave infrastructure in place is crucial. This is outlined in the following steps:

1. During the design phase, **circular material use** that takes sustainable decommissioning into account should be the starting point.
2. **Implement a standardised evaluation procedure near End of Life.** Outcomes of this evaluation should give clarification on the possibility of extended life span, the ecological value and the material value.
    a. Identify steps taken to **extend the life** of the wind turbine. At the end of the permit term for an OWF it might be possible to further extend the life of the assets.
    b. Evaluate the ecological and raw material value of the end-of-life offshore infrastructure and of the area as a whole, such as its reusable materials and its role in supporting local biodiversity and ecosystem functions. Take local, naturally occurring habitat into consideration. If the ecological value provided by the infrastructure is insufficient to warrant leaving behind infrastructure, it must be removed in its entirety. Research by the SeeOff Consortium found that leaving the scour protection and cables in situ, where the monopile is cut off above seabed, is best for biodiversity[20]. What this means for the reuse of materials such as for cables should however also be evaluated.
3. **Assess decommissioning impact on ecologically important species and habitats.** When the ecological importance of species on and around the infrastructure is high, the next step is to identify the species and habitats that may be affected by the decommissioning process and assess their **vulnerability to disturbance**. If all ecologically important species are unaffected by the decommissioning process, then the infrastructure must be removed whilst applying mitigation measures for species that are harmed or disturbed by the decommissioning process.
4. **Conduct a cost-benefit analysis of the repurposing of infrastructure.** When relocation (of infrastructure including the settled marine life) is expected to result in loss of ecological value, the feasibility of **repurposing the infrastructure** as an artificial reef or a different type of marine habitat needs to be assessed[21]. In this case, infrastructure components possessing ecological value may remain, and those with insufficient ecological value must be removed. Leaving the infrastructure in place may also affect other aspects, such as marine safety, or the potential release of hazardous materials or chemicals. Therefore, it is important for clear agreements to be made in advance about who is **responsible** for the abandoned infrastructure after the operational phase. Monitoring should take place. If it turns out that complete decommissioning is still required, the infrastructure will be completely removed. There should be a clear body responsible for this.
5. **Mitigate impact on ecologically important species.** When the identified ecological importance is impacted by the decommissioning process, mitigating steps need to be taken to preserve the ecological value on and around the infrastructure.
6. If the decision is made to leave parts of the infrastructure behind due to high ecological value, steps should be taken to **legally protect the area** from other disruptive activities.

19) The importance of life span extension is further stressed in paper [link]
20) SeeOff Decommissioning handbook: https://www.seeoff.de/data/publications-20220621-1-kNEpoY1G.pdf
21) Another option could be to replace permanent materials in non-constructive items (for example NID designs) with biodegradable or natural materials. Implement legislation that these materials do not need decommissioning.

4. Recommendations

We need to embed the subject of sustainable decommissioning interdepartmentally and internationally in laws, regulations, and plans to ensure that the goals of restoring nature and promoting circularity become achievable. To achieve the necessary conditions for the offshore sector to develop plans for sustainable decommissioning, we make the following appeal to policymakers in the EU and member states:

- Enhance **legal flexibility for partial decommissioning** to avoid ecological damage related to full decommissioning.
- Set up a decision-making framework to facilitate the **case-by-case assessment of ecological value** on infrastructure in offshore wind farms.
- Integrate decommissioning requirements in tenders to ensure that sustainable **decommissioning is incorporated in the design phase** of offshore wind farms.
- Take advantage of the decommissioning processes of the Dutch Egmond Aan Zee OWFs (2027) and Prinses Amalia wind farm (2028) to gain valuable insights and **practical knowledge** for implementing partial decommissioning strategies.
- Ensure that **ecologically valuable areas are protected** from harmful activities after assets have been decommissioned and the area is no longer an OWF.
- Ensure that valuable and scarce materials can be extracted from the wind farms with **minimal impact on nature.**

5. Appendix

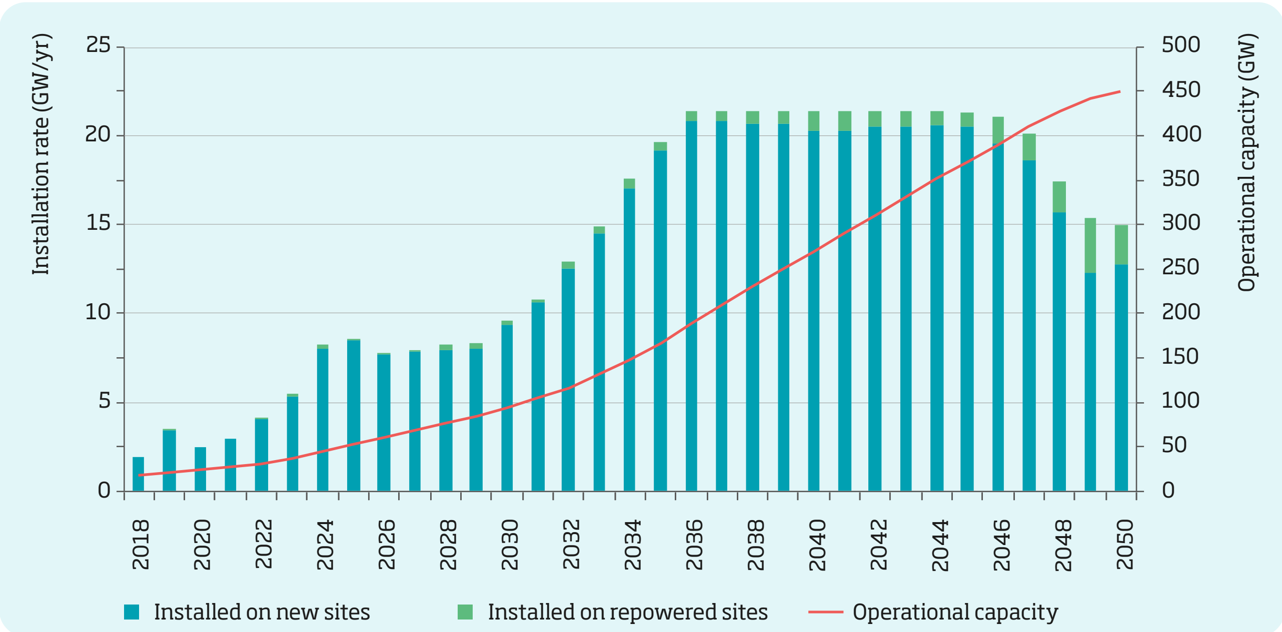
5.1 Background: scale-up of wind energy

The European Green Deal describes the goals for offshore wind in 2030 and aims to reduce greenhouse gas emissions by 55% compared to 1990 levels. Offshore renewables will make a key contribution to attaining the EU's ambitious energy and climate targets for 2030 and 2050 and reduce dependency on imported fossil fuels. Offshore renewables are set to become an indispensable part of the energy mix that will be necessary to decarbonise and achieve climate neutrality. This is reflected in Member States' ambition to achieve 111 GW of offshore renewables by 2030[22]. Member states formulate their own offshore wind targets. For example, in the Esbjerg Declaration[23], Germany, Denmark, Belgium and the Netherlands have set ambitions for 65 GW of installed offshore wind capacity in 2030 and at least 150 GW in 2050. In 2022, the heads of state and energy ministers of the eight countries around the Baltic Sea committed to increase the current 2.8 GW to 19.6 GW by 2030. They plan to consider a 2040 target at a later stage.[24] In April 2023, following the Esbjerg Declaration, France, Ireland, Luxembourg, Norway and the United Kingdom joined the Ostend Declaration, setting combined targets for offshore wind of about 120 GW by 2030 in the North Seas and 300 GW by 2050[25].

Achieving these goals would require the installation of a significant number of OWFs and associated infrastructure in the North Sea and Baltic Sea, which are considered a prime location due to strong winds and shallow waters.

WindEurope's market prediction states a necessary installed capacity of 24 GW between 2023 and 2028. This means that in the final three years leading to 2030 ('28 – '30), the industry should be installing 20 GW each year. With the current innovation curve, we can assume that we will have turbines of 20MW by then. This means that at least 1,000 turbines, hundreds of kilometres of cables, and many platforms will be built by 2030. The growth after 2030 will be even more substantial. However, at some point in the distant future, all this infrastructure will have to be decommissioned under current legislation.

Figure 4: Installation rate required to achieve 450 GW by 2050. Source: BVG Associates for WindEurope.



22) *https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023DC0668. This is excluding the UK*
23) *https://windeurope.org/wp-content/uploads/files/policy/position-papers/the-esbjerg-declaration-north-sea-as-green-power-plant-of-europe.pdf*
24) *https://windeurope.org/newsroom/press-releases/baltic-sea-countries-sign-declaration-for-more-cooperation-in-offshore-wind*
25) *https://windeurope.org/wp-content/uploads/files/policy/position-papers/20230424-Ostend-Declaration-Ministers.pdf*

5.2 Policies with regard to decommissioning

To assess the practical improvements needed in the decommissioning phase of OWFs, it is important to have a global understanding of the current policy context surrounding it.

OSPAR-treaty

First of all, decommissioning of offshore infrastructure in various European countries is regulated by the OSPAR-treaty[26]. This treaty describes the steps that need to be taken when decommissioning occurs. In short, all structures that were added to the marine environment must be removed. This applies to the wind turbine components but also to grid infrastructure, scour protection and any other associated structures added during construction. The idea behind this regulation is to leave the marine environment as it was found, but removal of offshore wind farms can have a significant effect on local biodiversity. Marine soil is significantly disturbed during the removal of scour protection, and any settled marine life will be displaced at best but generally destroyed in the process. This raises the question of whether it is always desirable to completely decommission infrastructure from an ecological point of view, or if it may be beneficial to leave (part of) the added infrastructure.

International law

Regarding offshore wind turbine decommissioning, there could be more policy flexibility. International law[27] allows a coastal state to decide to leave an artificial reef intact and to justify it legally. It is important for a distinction to be made between objects placed in between wind turbines (i.e. stand-alone artificial reefs) and objects that are placed on, or made part of, the monopile and scour protection of a wind turbine, and thereby legally designating part of the wind turbine as a single installation. For both categories of objects, the conclusion is that international law and EU law do not impose an absolute obligation to fully remove the objects. It should be noted that coastal states in principle enjoy a wide measure of discretion under international and EU law to determine whether or not to have the object removed or to leave all or part of it in place[28].

Tender procedures

Current regulations offer little in terms of decommissioning incentives: although OWF decommissioning must be addressed in tender procedures, there is no direct reason to optimise or make concrete investments before starting the projects (plans are only specified shortly before the decommissioning phase).

At present, there are **no requirements for the design and production phases that include stringent requirements regarding the decommissioning and end-of-life phase.** Without regulation and mandatory tender requirements, adjustments in this area will generally lead to so-called 'split incentives' in which different players in the value chain are affected by the costs and benefits of adjustments. Only by including the requirements in tender packages will they lead to different choices in design, material composition and decisions regarding nature and biodiversity. This is currently done in the Dutch tenders for wind farms, and it accelerates innovation on nature enhancement inside wind farms.

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26) *The fifteen European governments are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.*

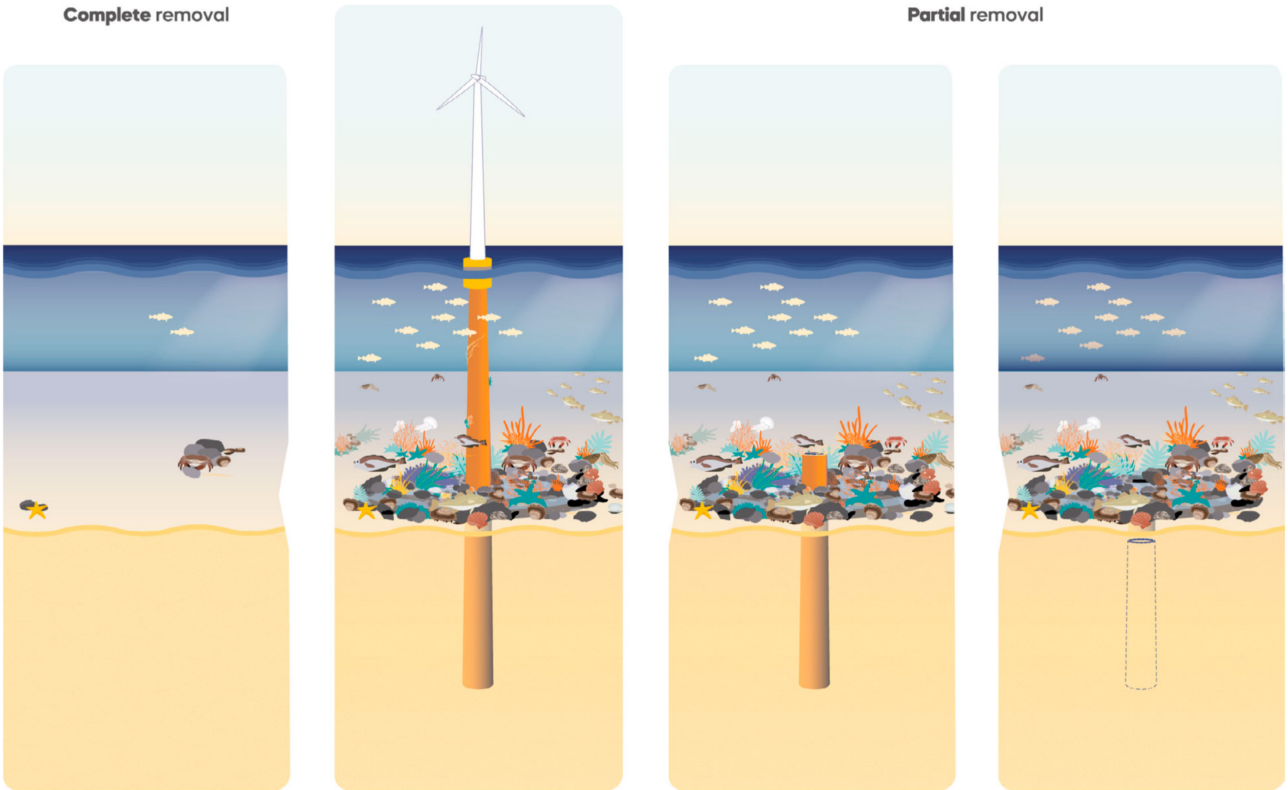
27) *https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf*

28) *Rapport-UU_Juridische-vragen-t.a.v.-opruimplicht-Internationaal-en-Europees-recht_final.pdf (de-rijke-noordzee-production.s3-eu-west-1.amazonaws.com)*
See UN Convention on the Law of the Sea (UNCLOS), articles 60(3), 56(2) and 80; IMO Resolution A.672(16) adopted on 19 October 1989, Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone; 2009 LC/LP/UNEP Guidelines for the Placement of Artificial Reefs; 2012 OSPAR Guidelines on Artificial Reefs in Relation to Living Marine Resources.

5.3 Types of decommissioning

When it comes to decommissioning, a distinction can be made between complete removal, where the entire structure and all the materials of the wind turbine and its scour protection are fully removed, and partial removal.

Figure 5: Schematic visualisation of complete and partial removal



For partial removal there are different options:

- **Topping:** Here, the monopile is cut down to two metres above the seabed. Also, the scour protection is left *in situ*.
- **Only scour protection left:** This alternative involves cutting below the seabed but leaving the scour *in situ*.
- **Designated reefing area:** The monopile is cut below the seabed and the retained steel and scour are deposited in a designated reefing area[29].

29) *Jurrius, L. (2021). Providing room for nature in decision-making for decommissioning offshore wind foundations.*

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