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Mitigation and management across wind energy and other sectors

Sustainable development in protected areas

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Contents

Summary

We are currently in a twin climate and biodiversity crises. Marine renewable energy provides an opportunity to benefit climate change production, whilst simultaneously protecting and minimising impacts to biodiversity.

Mitigation is a mechanism that helps to prevent and minimise potential impacts to biodiversity, such as increasing wind turbine height to reduce bird collisions. If there are still significant residual impacts to biodiversity after mitigation has been exhausted, then compensation may be considered. This involves measures that offset the impact, for example, the creation of artificial habitat.

Across the North Sea, offshore wind is a rapidly expanding industry. The Netherlands is one of the key drivers of this expansion and is also at the forefront of embedding positive measures for nature.

My study visit to the Netherlands focused on nearshore wind farms located within or nearby protected areas, to better understand innovative mitigation techniques, potential compensation measures and examples of nature-inclusive design. I visited three nearshore wind farms – Eemshaven wind farm, Fryslân wind farm and Maasvlakte II wind farm. Various novel mitigation methods and biodiversity positive measures are being used, including: trialling black turbine blades to reduce bird collisions; use of radar to track bird movements and temporarily stop turbines, again to reduce collisions; and the creation of an artificial island to act as a nature reserve for wildlife.

Additionally, I hoped to learn more about how these approaches are applied at offshore wind farms in the Dutch North Sea, drawing comparisons to offshore wind energy in Scotland. To achieve this, I visited two specialist locations – University of Amsterdam and the Offshore Expertise Centrum (OEC).

Finally, I was interested in lessons learnt from other industries. I visited the Voordelta Natura 2000 site and learnt about the formal fisheries-based compensation associated with the expansion of the Port of Rotterdam. In this case, the compensation could not be deemed as effective and further measures need to be secured. I also visited a water treatment plant and the dune reserve managed by the water company to better understand how other industries implement sustainable development in protected areas.

This report presents the findings of my visit, including recommendations for the offshore wind sector, with a particular focus on relevance to Scotland.

Introduction

About the author

Graduating from the University of Southampton in 2019, I have an integrated master's degree in marine biology and have studied internationally at the University of North Carolina, Wilmington (UNCW) also. Whilst I have various experience in fundraising and public outreach across the charity sector, my current role is at NatureScot[1] – a statutory nature conservation body in Scotland.

I first joined NatureScot on a project placement, assessing the Scottish blue carbon evidence base, including producing a literature review (Cunningham & Hunt, 2023). Following this, I completed a short-term trainee role in the marine energy team and later moved into my current role as a Marine Sustainability Adviser.

This role involves co-ordinating and delivering casework advice for offshore wind developments and other marine renewable energy sites (i.e. tidal, wave) in Scottish waters. Casework advice focuses on natural heritage interests, including protected areas, and also takes account of seascapes, landscapes and visual impacts. Thus, I have a deep interest in innovative approaches in the renewables sector that better protect biodiversity.

Figure 1. Caitlin Cunningham (the author) in front of a large photograph of an offshore radar platform in the Dutch North Sea, taken at the Offshore Expertise Centrum (OEC).

Twin climate and biodiversity crises

Human-induced global temperature rise has already reached 1.1°C above pre-industrial levels and we need to cut global greenhouse gas emissions by 43% before 2030 to limit warming to 1.5°C (IPCC, 2023). We are already witnessing changes to our climate, including sea level rise, more extreme weather events and rapidly disappearing sea ice. These impacts pose widespread risks to people and ecosystems and are only set to increase with future warming. In April 2019, the Scottish Government declared a climate emergency and shortly after set a target date for net zero emissions of all greenhouse gases by 2045 (Scottish Government, 2019).

According to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, more than 42,100 animals worldwide are threatened with extinction (IUCN, n.d.). However, this is likely an underestimate, given only 28% of species have been assessed globally.

[1] NatureScot is the lead public body responsible for advising Scottish Ministers on all matters relating to the natural heritage.

This has been deemed an ongoing sixth mass extinction event (Ceballos, Ehrlich, & Dirzo, 2017) and will only be compounded further by impacts from climate change.

Marine renewable energy

Straddling both these areas of concern, marine renewable energy is a rapidly expanding industry. There is a need to balance the promotion of the sustainable development of renewable energy to benefit climate change reduction, whilst simultaneously protecting and minimising impacts to biodiversity.

Ensuring the right development is in the right place is one principle that may help reduce impacts to biodiversity, whilst enabling the building of marine renewable energy sites. Mitigation is another mechanism that helps to prevent potential impacts, such as increasing wind turbine height to reduce bird collisions. If there is a strong case for a development to still go ahead, even with significant residual impacts to biodiversity, then formal compensation may be considered. This involves measures that offset the impact, for example, the creation of artificial habitat.

The Netherlands is at the forefront of biodiversity benefits, with commitments to nature-inclusive design[2] embedded within offshore wind farms (The Ministry of Agriculture, Nature and Food Quality, 2020) and the development of innovative mitigation offshore, such as implementing the curtailment[3] of turbines to help migrating birds pass safely (Recharge News, 2023).

To further highlight the significance of offshore wind, maps are included of offshore wind in Scotland (Annex – Figure 18) and the Netherlands (Annex – Figure 19), with both including potential future developments that are currently in the pre-application or planning stage.

Objectives of the study visit

The overall aim of my Netherlands visit was to develop my skills and knowledge relating to marine and coastal sustainable development within or near to protected areas, focusing on wind farms. Specific topics I wanted to better understand include:

- different approaches to impact assessments, particularly for offshore wind;
- innovative approaches to mitigation, along with their effectiveness and limitations;
- potential compensation measures and examples of nature-inclusive design; and
- how other industries implement sustainable development within protected areas.

Overview of the study visit

In May 2023, I travelled via ferry from the UK to visit various places in the Netherlands over ten days. Most sites were nearshore wind farms, with each development located within or nearby a protected area. In addition, I also visited a water treatment plant and the dune reserve managed by the water company. An overview of the study visit is mapped in Figure 2. Sites visited include:

[2] Nature-inclusive design: measures that are integrated in or added to the design of infrastructure to benefit biodiversity. For example, suitable scour protection or fish hotels can be placed around turbines that serve as nursery areas or offer shelter.

[3] Where a wind farm is temporarily shut down and stops exporting to the grid.

- Eemshaven wind farm – trialling painting one turbine blade black to reduce bird collisions;
- Fryslân wind farm – use of radar to monitor bird collisions, examples of nature-inclusive design and creation of an artificial island for compensation;
- Andijk III water treatment plant, Puur Water & Natuur (PWN) – using floating solar panels to generate electricity for water purification;
- North Holland Dune Reserve, Puur Water & Natuur (PWN) – management of the reserve and use of the dunes to naturally purify drinking water; and
- Maasvlakte II wind farm – use of radar to track gulls and curtail turbines.

To supplement the various sites visited, I also attended the University of Amsterdam and the Offshore Expertise Centrum, to learn more about the technologies and processes involved with offshore wind energy in the Netherlands.

In addition, I visited the artificial island of Marker Wadden for touristic purposes and gained some further insights into ecosystem restoration.

Figure 2. Overview of the sites visited in the Netherlands, along with the corresponding Natura 2000 designations.

Protected Areas

To better understand sustainable development in protected areas and impacts arising from nearshore wind farms, I chose sites that had connectivity to Natura 2000 areas. These included those designated under the Birds Directive (SPA) and/or Habitats Directive (SCI, SAC) and are presented in Figure 2.

IJsselmeer – Birds Directive (mainly) and Habitats Directive

The IJsselmeer was created through the construction of a series of dykes, with the Afsluitdijk blocking access to the sea since 1932. Freshwater communities replaced the former brackish fauna. This site is designated for many breeding and non-breeding birds and the lake is home to large numbers of waterfowl in particular. However, the Afsluitdijk acts as a barrier to various species of diadromous fish[4], that once had access to the sea, with certain species disappearing from the area entirely.

Markermeer & IJmeer – Birds Directive (mainly) and Habitats Directive

The Markermeer was created through the construction of a dyke (Houtribdijk) in 1976, separating it from the IJsselmeer. The lake is an important habitat for numerous waterfowl. However, water clarity is usually limited due to high levels of silt combined with wind and wave action. As a result, fish and bird populations have declined dramatically. Thus, a large-scale restoration effort is taking place, with a series of islands, marshes and mud flats being constructed in the Markermeer. One of the islands, Marker Wadden, was opened to visitors in 2018, with the remaining islands to be kept as biodiversity havens (KIMA, 2022).

Figure 3. Yellow wagtail on Marker Wadden.

Waddenzee (Wadden Sea) – Birds Directive and Habitats Directive

The Wadden Sea is the largest tidal flats system in the world, extending along the coast of Denmark, Germany and the Netherlands. There are various habitat types associated with this site, including estuaries, mud and sandflats, salt marshes and various dune systems. Home to a range of species, including commercially important fish, diadromous fish, marine mammals and migratory and breeding birds, the Wadden Sea is richly diverse. For coastal birds in particular, this site is one of the most important areas globally, with almost one million ground-breeding birds reliant on the Wadden Sea (Common Wadden Sea Secretariat, n.d.). Furthermore, the site is recognised under the Ramsar Convention as a wetland of international importance, with more than 20,000 wintering migratory birds (RSIS, 2022).

[4] Fish species that migrate between salt water and fresh water.

Voordelta – Birds Directive and Habitats Directive

The Voordelta is a dynamic area, which includes outer deltas, with channels and banks. The coastal zone is relatively nutrient-rich, leading to high productivity and food supply for migratory birds. The expansion of the Port of Rotterdam in 2008 has resulted in the loss of 2,455 hectares of sandbanks and shallow sea area. The European Commission gave permission for the expansion on the condition that this loss be compensated. However, it has recently come to light that the compensation put in place has not been effective (van der Heide, 2022). Thus, the Ministry of Agriculture, Nature and Fisheries and the Port of Rotterdam must quickly decide on further effective nature compensation.

Noordhollands Duinreservaat (North Hollands Dune Reserve) – Habitats Directive

Figure 4. Taking photos at the PWN water purification site at the North Holland Dune Reserve.

The North Hollands Dune Reserve is mainly formed of calcareous dunes, with coniferous or deciduous forest spanning large areas. Since 1920, the site is managed by Puur Water & Natuur (PWN), which is the provicincial water supply company for the region. Large areas of wet dune slacks have been lost historically, partly as a result of water extraction. This has been reduced considerably over the past two decades, with further nature development, including redesigning dune slacks and introducing grazing, aiding in the recovery of species richness and wet dune slacks.

Offshore wind: the journey to net zero

Both Scotland and the Netherlands have high ambitions for the expansion of offshore wind energy. In 2020, the Scottish Government set a new ambition to increase offshore wind capacity to 11 gigawatts (GW) by 2030, which is enough to power more than eight million homes (Scottish Government, 2020). The Netherlands took this one step further and in 2022, the Government raised the target for offshore wind generating capacity from 11 to 21 GW by 2030/2031 (Netherlands Enterprise Agency, n.d.). This would equate to 75% of the current electricity consumption in the Netherlands, although this is expected to increase, requiring even more energy.

Scotland are aiming for net zero by 2045 and the Netherlands by 2050, which only adds more pressure to increase offshore wind generating capacity. In fact, the Netherlands have set an ambitious target of 70 GW of offshore wind by 2050. For Scotland, over 45 GW of offshore wind is potentially already in the pipeline, when considering sites that are at the pre-application (prior to consent) stage.

However, currently only ~1.89 GW of offshore wind is operational in Scotland, though other wind farms are under construction or in development (Annex – Figure 18). Likewise, only ~2.5 GW are operational in the Netherlands (Annex – Figure 19). To meet the ambitious targets by 2030 and beyond, offshore wind capacity must increase rapidly in the coming years.

In this section, comparisons are made between the offshore wind consenting process and approach to impact assessments across Scotland and the Netherlands, to better understand the expansion of the offshore wind sector over the coming decades.

Offshore wind expansion in Scotland

Offshore wind leasing

In Scotland, the seabed in inshore waters (within 12 NM) is owned by the Crown and managed by the Crown Estate Scotland (CES)[5]. Likewise, in offshore waters (from 12 NM to 200 NM – Exclusive Economic Zone limit), CES has rights over certain commercial activity, including offshore wind. Thus, CES are responsible for leasing the rights to build new wind farms in Scottish waters.

During a leasing round, zones or option areas are proposed, within which several individual wind farms could be situated. Wind farm developers are then able to bid based on these areas.

The first Sectoral Marine Plan for Offshore Wind Energy (2011) in Scotland led to six option sites identified, with three offshore wind farms progressed to consenting. Additionally, a third UK Offshore Wind Farm Leasing Round led to a further two sites being progressed in Scottish waters.

More recently, the Sectoral Marine Plan for Offshore Wind Energy (2020)[6] was developed, which aims to identify sustainable plan options for the future development of commercial-scale

[5] Prior to April 2017, the seabed in Scotland was managed by The Crown Estate (TCE), in line with England, Wales and Northern Ireland. The duties were then transferred from TCE to CES.

[6] https://www.gov.scot/publications/sectoral-marine-plan-offshore-wind-energy/pages/3/

offshore wind energy in Scotland across deeper waters. It spans both Scottish inshore and offshore waters and aligns with the National Marine Plan (2015)[7], which provides a framework for managing all developments, activities and interests in or affecting Scotland's marine area. Through this plan, 15 option areas were identified through a series of opportunity and constraint analyses, consultations and assessments. The consultation process also included screening and scoping for the Habitats Regulations Appraisal (HRA), Strategic Environmental Assessment (SEA), and the Socio and Economic Impact Assessment (SEIA). The CES undertook a leasing round (ScotWind) with these 15 option areas.

Additionally, there was another leasing round – Innovation and Targeted Oil & Gas (INTOG) – for offshore wind projects that will directly reduce emissions from oil and gas production and boost further innovation. This will tie into the INTOG Sectoral Marine Plan[8].

Timelines – from lease to operation

The process of planning, building and operating offshore wind farms is carried out by developers. Planning permission or consent is needed before construction can take place and usually this requires a formal Environmental Impact Assessment (EIA) to be submitted alongside the consent application. Relevant stakeholder consultation is required and the EIA Report must consider the impacts from the project alone, as well as in combination with other projects – known as the Cumulative Effects Assessment (CEA). This work is carried out by the developers, before being submitted to the regulator (Marine Directorate) to undertake separate consultation with stakeholders and to inform the decision on whether the wind farm can be consented. Marine Directorate aim for a determination period of 9 months, but this is dependent on whether additional information is required, amongst other factors.

Prior to submission of an EIA Report, developers may also submit a Scoping Report to the regulator outlining: key project parameters, baseline data, intended topics and impacts to be considered in the assessment and intended approaches to analysis. The regulator then forms a Scoping Opinion on the topics and analysis required for the EIA, again through consultation with stakeholders. This provides guidance to influence the direction of the EIA Report and assurance before formal submission.

Figure 5. Offshore Substation Platform (OSP) at Seagreen Offshore Wind Farm, which is currently under construction in Scottish waters.

As part of the EIA, NatureScot require site-specific data for baseline characterisation. If new data is required, it is the responsibility of the developer to collect this through surveys. For ornithology, we advise that baseline characterisation should comprise two years of monthly surveys. This enables a robust assessment to be made, reducing uncertainty in predictions.

[7] https://www.gov.scot/publications/scotlands-national-marine-plan/

[8] https://www.gov.scot/publications/initial-plan-framework-sectoral-marine-plan-offshore-wind-innovation-targeted-oil-gas-decarbonisation-intog/

Given construction of offshore wind farms can take several years to complete, coupled with baseline survey requirements and the various consultation / determination periods, the timeline from awarding a lease to the operational wind farm can be considerably lengthy.

Offshore wind expansion in the Netherlands

Offshore wind leasing

Similar to Scotland's National Marine Plan, the Netherlands has the North Sea Programme for 2022-2027[9], which balances spatial development of the North Sea, whilst aiming to achieve good environmental status. Through this plan, search areas for offshore wind farms are identified, again following an exploration of constraint analysis and the SEA process.

Figure 6. Offshore wind farm in the North Sea.

Where the Netherlands and Scotland differ is that following this initial search process, the Government of the Netherlands undertakes individual EIAs for each search area identified. As mentioned previously, this is the responsibility of the developer in Scotland. The EIAs consider the same aspects, from distribution of species to impacts, including collision risk and habitat loss. This process also runs through the Ecology and Accumulation Framework (KEC) and any Appropriate Assessments (under HRA).

Approach to impact assessment

Many of the approaches to impact assessment are the same between the Netherlands and Scotland, including the use of the Interim Population Consequences of Disturbance (iPCoD) model[10] to consider marine mammal population consequences from offshore wind developments and the use of the stochastic Collision Risk Modelling (sCRM) tool[11] to assess population level effects from offshore wind farms on birds.

However, one difference is that density maps are used rather than conducting site-specific baseline surveys. Furthermore, a number of assumptions are made relating to potential wind farm design parameters, including: installation method, blade tip height, maximum wind turbine capacity, pile driving energy, etc. Worst-case parameters are used, for example, assuming installation is via monopiles and would occur all year-round, as this would generate the highest underwater noise risk. Similar scenarios are assumed for international projects for the CEA, where parameters are not yet refined. Given the various assumptions through out the EIA process, this leads to a higher level of uncertainty in impact predictions, even if the assessment is precautionary overall.

Following the completion of the EIA, site decisions are made by the Government of the Netherlands to determine the maximum allowable parameters of any potential offshore wind

[9] https://www.noordzeeloket.nl/en/policy/north-sea-programme-2022-2027
[10] https://marine.gov.scot/information/interim-population-consequences-disturbance-model-ipcod
[11] https://www.gov.scot/publications/stochastic-collision-risk-model-for-seabirds-in-flight/

farm for each area. Mitigation measures to prevent impacts and nature-inclusive design to restore the ecosystem are also developed.

Timelines – from tender to operation

Another key difference in offshore wind consenting in the Netherlands is that overall consenting is a much faster process. Following the completion of the EIA, site decisions are made by the Government of the Netherlands and then these are released to tender. Developers may then bid for a site and whichever developer is awarded the site is then given the exclusive right to build a wind farm. Following this site lease award, the developer must complete any pre-construction works and construction of the wind farm within five years, which is roughly half the time it takes for offshore wind farms to be fully operational in the UK from being awarded a lease.

Mitigation: reducing impacts to biodiversity

Wind energy is a crucial player in combatting the climate crisis. However, wind farms can have negative impacts on biodiversity, for example: bird and bat collisions with turbines, habitat loss, and underwater noise during construction (for offshore sites). The mitigation hierarchy provides a logical framework to address the negative impacts of developments on biodiversity (Figure. 7). This is based on four sequential steps: avoid, minimise, restore and offset.

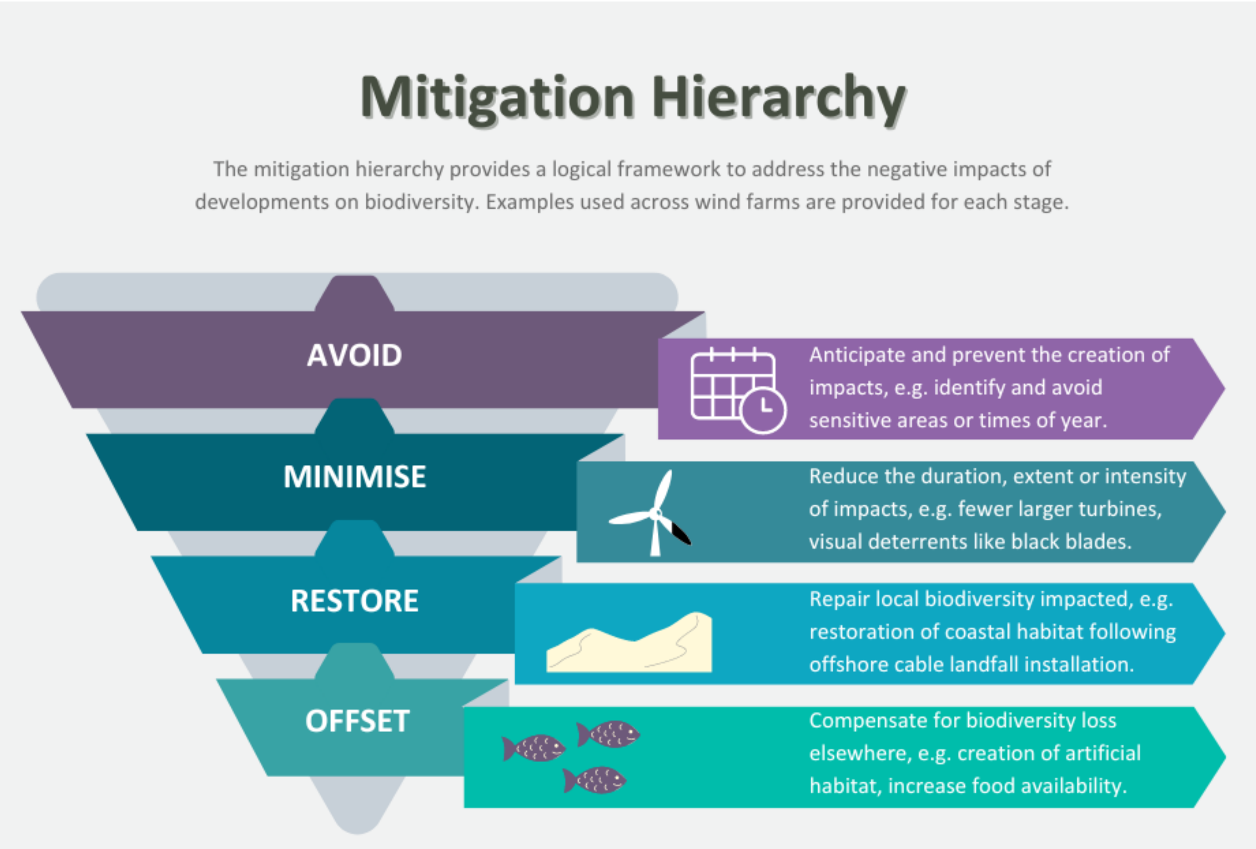

Figure 7. Graphic depicting the mitigation hierarchy, with relevant examples given at each stage of the process.

Avoidance is the first action that should be considered and is based on anticipating and preventing the creation of impacts. Examples include avoiding key areas with sensitive species during the site selection phase (i.e. important migratory corridor for birds) or scheduling the impact so that it bypasses sensitive periods (i.e. migration). Complete avoidance is not always possible, especially with other constraints on the planning process, such as engineering restrictions and interactions with other sectors.

Thus, minimisation is the next step, which seeks to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided, as far as is practically feasible. Often this stage is referred to as 'mitigation'. Potential measures include curtailment of turbines during bird migration or using Noise Abatement Systems (NAS) in the marine environment to reduce the noise produced during construction. Even with these measures, residual impacts may still exist.

The following two actions – restoration and offsetting – are the last steps in the hierarchy. Restoration aims to repair the local and specific biodiversity features or ecosystem services damaged by project impacts that could not be completely avoided or minimised. This could include restoration of habitat once an offshore cable has come ashore and been installed at the coast. Whilst offsetting is similar, this is a last resort used to compensate for significant adverse impacts and involves restoring biodiversity at a different location when all other steps have been exhausted. For example, creating artificial nesting sites for impacted bird species away from the development to benefit the overall population. This stage is often referred to as 'compensation'.

In this section, mitigation measures used for nearshore and offshore wind developments in the Netherlands are discussed, particularly those applied for birds. Developments were chosen based on their close proximity to protected areas, and thus the focus is on minimisation of impacts. Restoration and offsetting are discussed separately further in the report.

Eemshaven black blades

Flyway to the danger zone

Eemshaven wind farm is one of the largest wind farms in the Netherlands, located on the north-east coast, adjacent to the Wadden Sea Natura 2000 site. This is a particularly important site for birds, given it is located on a major migration route and close to high-tide roost sites[12] in the Wadden Sea.

So it is no surprise that this nearshore wind farm also has incredibly high bird collision rates. A study conducted in 2018/19 estimated total mortality from collisions as approximately 1,000-1,200 victims in the autumn and 500-600 in the spring, when extrapolated across the entire wind farm and considering corrections for carcass predation, probability of finding victims and areas searched (Klop & Brenninkmeijer, Aanvaringsslachtoffers Windpark Eemshaven najaar 2018 & voorjaar 2019, 2020). Songbirds had the highest mortality across both seasons, representing 58% and 49% of victims in the autumn and spring respectively, once correction factors were accounted for. Gulls and terns combined also represented 20% of victims in the autumn. To further highlight the impact at Eemshaven, a study was conducted comparing collision risk at another wind farm in the Netherlands, Delfzijl, which is further inland and not a key area for birds. The corrected collision mortalities per turbine per year at Eemshaven were roughly six to ten times the number at Delfzijl (Brenninkmeijer & Klop, 2017).

[12] Many shorebirds feed on intertidal flats during low tide and are then forced to 'high-tide roosts' to rest during high tide, which are small coastal areas just above the tide line.

Black blade pilot project

Thus, a pilot project is being trialled at Eemshaven wind farm, which involves painting one of the blades of a wind turbine black to assess the effectiveness in reducing the number of collision victims among birds. This follows on from a similar study conducted in Norway, which found a reduction of 70% in the annual collision rate, with the biggest benefits for raptor species (May, et al., 2020). However, this study was at an inland location (different species composition compared to nearshore sites), had a limited sample size (four control turbines and four black) and exhibited high interannual variation.

Figure 8. Turbine with one blade painted black at Eemshaven wind farm. Credit: Allix Brenninkmeijer.

Between August and October 2022, seven blades of seven turbines were painted black at Eemshaven. Prior to this, collisions were monitored at these seven turbines and a further seven control turbines from August 2021 to August 2022. The victims found at the control turbines (88) were comparable to those found at the impact turbines to be painted black (89), with gulls and songbirds the most prevalent, although geese, ducks and waders were also reported. Monitoring is ongoing and the first year of results will be reported later in 2023, with the full project running until September 2024.

If results show a significant reduction in bird collisions at the black blade turbines compared to the controls, this could be a relatively easy mitigation measure to implement at the wind farm design stage. However, the first year of results may also be inconclusive, especially as there are limitations. For instance, the searchable area beneath each turbine varies considerably, from 25% to 80%, due to land ownership and access (Klop, Jeninga, Kappers, & Kleyheeg-Hartman, 2022). Whilst correction factors can be applied, this still represents a level of uncertainty when comparing turbines. Furthermore, the outbreak of Highly Pathogenic Avian Influenza (HPAI) posed a significant threat to many birds in 2022, including wildfowl and seabirds. Some of the carcasses found could be victims of HPAI, rather than turbine collisions, which could also influence the results.

Research into the effects on landscape and visual impacts of the black blades is also being undertaken. This involves a qualitative study of people within cities, rural areas and in the vicinity of Eemshaven to better understand their perception of the black blades. If this measure was adopted for offshore wind farms, it would likely be less of a concern giving the lower visibility from shore.

That tracks: different radar applications

Figure 9. Robin Radar MAX used at Maasvlakte II wind farm to curtail the turbines.

Radars are a useful tool that can be used at different stages of a wind farm, to collect data on local bird movements (including bird size and flight behaviour) and migration activity. Similar applications of radar can also be used for bats. If used during the pre-construction stage, radars can provide information on bird use within an area, to better inform the EIA Report and de-risk the consenting process by reducing uncertainties in modelling. Similarly, they can also be implemented during the operational phase of a wind farm to monitor bird use and compare this with what was assessed during the EIA phase, to ensure conclusions remain valid. A novel use of radars during the operational phase also includes automatic curtailment of turbines if birds are detected nearby or mass migration is expected.

Current use in Scottish waters

There are a few collision risk modelling projects using radar at Scottish offshore wind farms, including: Aberdeen (reported in 2023), Kincardine (ongoing) and Neart na Gaoithe (planned deployment late 2023). All three research projects are focused on better understanding offshore bird behaviour and interactions with offshore wind farms, to help decrease uncertainty in the EIA process.

At Aberdeen offshore wind farm, birds were tracked inside the array using an integrated radar-camera monitoring unit (Tjørnløv, et al., 2023). This generated three-dimensional (3D) flight tracks, with video footage for species identification and behavioural classification. The DHI MUSE system was employed, which allowed birds discovered by the radar to be automatically targeted by the camera. Results strongly indicate that avoidance responses mainly take place 100-120m from the rotors and overall, the flight characteristics translate into a low risk of collision. In fact, no collisions or even narrow escapes were recorded in over 10,000 bird videos.

However, a limitation of this study is that the Aberdeen offshore wind farm is close to shore (3-4.9km from the coast) and is a relatively small site (11 turbines). Thus, findings may not translate to larger sites or locations further offshore, especially in locations where mass nocturnal migration may occur. Furthermore, radar systems struggle to detect birds during severe weather (i.e. sea states above 5), as the larger waves will also be picked up by the radar as clutter and this can be difficult to disentangle. This means that the sample size will be smaller in severe weather.

Similar research is currently underway at Kincardine offshore wind farm, which is using DT Bird radar combined with HD and thermal cameras. Again, this is a relatively small site (five turbines) and the system will also struggle in severe weather. Finally, another research project is planned to be deployed at Neart na Gaoithe offshore wind farm later this year. This site is considerably larger (54 turbines), although radars and cameras will only be installed on nine of the turbines.

Montoring at Fryslân wind farm

Fryslân wind farm is located within the IJsselmeer Natura 2000 site, adjacent to the Wadden Sea Natura 2000 area and is therefore an important area for many breeding and non-breeding birds, especially waterfowl. The development comprises 89 turbines and is capable of powering 500,000 homes.

Similar to the projects in Scotland, radar is being used at this location along with regular visual observations by ornithologists, to monitor and validate collision estimates and modelling parameters at the EIA stage. The Robin Radar MAX is a 3D radar, which provides data on flight intensities, flight altitudes, number of collisions, behaviour and avoidance rates of birds. The radar is not able to identify birds to a species level, instead categorising as a small bird or flock of birds. In the future, it is hoped that the radar can be trained using the visual observation data to potentially identify more distinctive species. Located on the shore, the radar also has limitations picking up smaller birds flying further into the wind farm.

This development also includes a number of other monitoring measures, including: bat detectors, aquatic plant surveys, monitoring fish populations, benthic community sampling and measurements of abiotic conditions. Furthermore, an artificial island was built as a nature reserve, to further benefit biodiversity and help Fryslân wind farm be nature-positive, with the aim to leave lake IJssel in a better condition. This measure is discussed in more detail further in the report.

Figure 10. Birds flying through the Fryslân wind farm.

From a landscape perspective, Fryslân wind farm is an interesting site as the turbines are arranged in a hexagon shape. This layout was to ensure that the wind turbines restricted the view of the horizon as little as possible, to reduce landscape and visual impacts.

Maasvlakte II: gulls galore

Maasvlakte II wind farm is a coastal development, which consists of 22 turbines, with 12 located directly on the beach. It is located adjacent to the Voordelta Natura 2000 site, which is an important area for migratory birds.

Furthermore, a gull colony in the urbanised Port of Rotterdam (Europoort to Maasvlakte) area is home to approximately 20,000 breeding pairs of lesser black-backed gulls, with a smaller population of herring gulls (Arts & Janse, 2021). However, this area

Figure 11. Lesser black-backed gull at Maasvlakte.

is not designated as a protected site, despite likely being the largest colony in Europe.

Figure 12. Luc Hoogenstein (Eneco) showing me the Maasvlakte II wind farm on the beach.

Thus, there is a clear risk of bird collisions with the turbines at Maasvlakte II wind farm. To mitigate this risk, a Robin Radar MAX has been installed, which works alongside the IoT[13] tower. The radar continuously records flight movements of birds in the area and transmits this data to the IoT tower. If a certain number of birds are recorded at turbine rotor height, the IoT tower sends an automatic signal to curtail one of more of the turbines.

When initiating this shutdown protocol, real-time bird movements are considered alongside weather conditions. For instance, bird presence is lower when it rains, thus the risk of collision is decreased, and shutdowns will have a lesser benefit to birds. Furthermore, the current stability of the power grid in the Netherlands is also considered before initiating the curtailment. This procedure helps protect large flocks of migratory birds and local breeding birds, like the nearby gulls, whilst minimising the effect on energy production.

Curtailment at Dutch offshore wind farms

During my study visit in May 2023, turbines at two Dutch offshore wind farms, Borssele and Egmond aan Zee, were temporarily shutdown to help migrating birds pass safely (Recharge News, 2023). This is an international first and a positive measure for birds, especially given the global importance of the East-Atlantic flyway for migration, which crosses the North Sea.

Predicative modelling is used to forecast nights on which large-scale bird migration around offshore wind farms will take place (Bradarić, 2022). The model is informed by bird movement data collected from radars at offshore wind farms, coupled with information on environmental variables. The weather is a strong driver of migration dynamics, for example, birds prefer tailwinds to cross barriers like the sea and migration is negatively correlated with precipitation as rain decreases visibility (Bradarić, 2022). The model can apply these learnt patterns to real-time weather forecasts and predict mass nocturnal migration 48 hours in advance, to allow curtailment of turbines. To have more confidence in the modelling predictions, a group of bird migration experts also review the modelling results to assess the likelihood of a large-scale migration. The curtailment in May was proven to be a success, with the model correctly predicting mass migration and preventing collisions.

[13] IoT stands for 'Internet of Things' and describes a network of physical objects that are connected wirelessly to exchange data.

The forecast model provides predictions 48 hours in advance, with this notice needed to better plan energy production and ensure stability of the energy supply. If curtailment were to happen instantly at multiple wind farms when the radar detected bird movements, this could destabilise the power grid and leave the network with insufficient energy supply. Thus, whilst this mitigation measure has been proven to work for migratory species, where mass migration can be forecast in advance, it may not be as applicable to the protection of other birds, i.e. foraging seabirds.

There are also limitations associated with the radar system. The main challenge is from clutter in the environment, including reflections from waves or rotating turbines. There are different filters in place to help discard this clutter. However, similarities between birds and different clutter types means that sometimes clutter is still recorded as bird tracks on the radar. This is especially the case during rain events or harsh winds, and where the sea state is rough (Bradarić, 2022).

Another challenge that this project faced was the difficulty of implementing these systems at offshore locations. The radars, sensors and other technology used often require regular updates. To prevent travelling the distance offshore before being able to validate if these updates work correctly, a secondary radar onshore at the Offshore Expertise Centrum (OEC) was built. This replica radar system allows changes or fixes to be tested to ensure they work correctly, before pushing these through to the offshore locations.

Figure 13. Joris Diehl showing the radar system and sensors at the secondary radar located at the OEC to Kees Borst and me.

Compensation: positive measures for nature

If avoidance and minimisation are not possible, the next steps to be considered are restoration and offsetting. As described previously, restoration aims to repair the site-specific impacts from a development, whereas offsetting is focused on compensating for the impacts at a different location.

In Scotland, compensation is a hot topic for offshore wind. Offshore wind capacity needs to increase in the coming years, but there is only so much space in the marine environment, especially considering other marine industries like fisheries, aquaculture and ferry / shipping routes. Impacts to biodiversity and protected areas are likely to increase, especially when considered cumulatively. In the cases where there are no alternatives and there are imperative reasons of overriding public interest for the proposal to go ahead, consent may be granted under the condition that compensation is secured to offset any impacts to the protected site(s) in question. This follows the Derogations Provisions[14] under the Habitats Directive[15].

The first example of this in Scottish waters has already begun, with the proposed Berwick Bank offshore wind farm submitting their application last year, accompanied with a derogation proposal to offset their impacts. The consent decision is still under consideration.

In the Netherlands, formal compensation has not been required for offshore wind to date. However, there is a drive for projects to have a net-positive impact on biodiversity or incorporate nature-inclusive design. Since 2015, all new offshore wind farms should be designed and built with nature-inclusive elements in mind (Government of the Netherlands, 2022). These elements will be discussed further, drawing examples from the sites visited.

In addition, one example of formal compensation in the Netherlands will be considered in more detail. This relates to the expansion of the Port of Rotterdam, with lessons learnt relevant to other sectors.

Habitat creation through artificial islands

The Netherlands has a long history of changing its landscape, from the creation of dykes, restricting access to the sea (e.g. Afsluitdijk in the IJsselmeer), to reclaiming land and creating new areas for development (e.g. Port of Rotterdam expansion). This pattern continues when considering positive biodiversity actions, with the creation of artificial islands being a popular measure.

Fryslân wind farm built an artificial island in the IJsselmeer, with an area of two hectares and a submerged, shallow water area of 25 hectares. Whilst temporarily used during the construction of the wind farm, this island is now a nature reserve. Birds use the island as a foraging and resting area, with an artificial reef for fish. The artificial reef is made from biodegradable BESE

[14] This recognises the existence, in principle, of proposals (plans and project) which are of a sufficient importance that they justify the possibility (or certainty) of damage to a European site. To be granted consent, necessary compensatory measures which ensure that the 'overall coherence of Natura 2000 is protected' must be secured.

[15] https://www.nature.scot/professional-advice/protected-areas-and-species/protected-species/legal-framework/habitats-directive-and-habitats-regulations

elements[16], composed of potato starch-based polymers, forming 3D structures. It is already starting to be colonised and hopefully it will eventually develop into a larger bivalve reef. Monitoring of the birds, aquatic plant coverage, fish stocks, benthic communities and abiotic conditions are also taking place, to determine if the nature reserve is a success. Post-construction monitoring is planned form 2021-2026 and will compare results to a nearby reference area.

During my study visit, I also visited the artificial island of Marker Wadden in the Markermeer and IJmeer Natura 2000 area. Whilst this visit was more for recreational purposes, it was also another example of an artificial island created as a nature reserve for wildlife.

Figure 14. Pied wagtail on the island of Marker Wadden.

So far, five islands have been constructed (1300 hectares in total), with further islands planned / under construction. The islands were created using silt from the bottom of Lake Markermeer and as well as providing a bird haven, the hope is that sedimentation will occur on the lee side of the islands to improve water clarity (KIMA, 2022). The development of reed marsh is being observed on a few islands, creating more of this underrepresented habitat. Already a diverse breeding bird community has formed on the islands, with 47 species reported on Marker Wadden in 2021, including marsh species. Furthermore, over 60,000 migratory birds settled on the island between July 2020 and July 2021 (KIMA, 2022).

Nature-inclusive design

Whilst there is still a lot to be learnt about nature-inclusive design, offshore wind farms in the Netherlands are pioneering the way forward. Since 2015, the Netherlands have adopted a policy for all new offshore wind farms to be nature-inclusive (Government of the Netherlands, 2022). This could include a range of measures: conserving biodiversity hotspots; deployment of natural substrates (e.g. shells, gravel, etc); re-introduction of reef building species (e.g. flat oysters); and/or deployment of artificial substrates / incorporation in scour protection (e.g. reef balls, fish hotels, etc) (Bureau Waardenburg, 2020).

The European flat oyster (*Ostrea edulis*) is a key reef-forming species that has largely disappeared from the Dutch North Sea, due to overfishing, habitat destruction and diseases (Didderen, Bergsma, & Kamermans, 2019). Thus, this is a key species for marine conservation focus. Depending on the location of the wind farm, different measures can be applied. For more coastal locations the preferred focus is on co-use, for instance, the cultivation of flat oysters in the water column from aquaculture. For those sites further offshore, the focus is on nature enhancement, i.e. introducing flat oysters to the seabed (Government of the Netherlands, 2022).

[16] https://www.bese-products.com/biodegradable-products/bese-elements/

A pilot study was conducted in the Dutch North Sea at Luchterduinen offshore wind farm, to assess the effectiveness of oyster reef restoration (Didderen, Bergsma, & Kamermans, 2019). Increased growth and reproduction of introduced flat oysters was recorded and biodiversity around the installations also increased, with crabs, fish, mussels and squid eggs consistently observed. The introduced oysters were tested prior to deployment for *Bonamia* – a parasite that can cause lethal infections in shellfish – and remained *Bonamia* free. However, the racks used to deploy the oysters were found semi-submerged in the seabed, highlighting that the dynamic conditions of a potential restoration site need to be considered thoroughly for long-term success.

Fisheries-based measures at Voordelta

As previously discussed, the expansion of the Port of Rotterdam in 2008 has resulted in the loss of 2,455 hectares from the Voordelta Natura 2000 site. Given the impacts of the expansion could not be mitigated, compensation had to be secured instead.

It was agreed that 25,000 hectares of the Voordelta area would be improved by 10%, to offset the 2,455 hectares lost through the port expansion. More specifically, this compensation was to be achieved through banning heavy beam trawling in the area (van der Heide, 2022).

However, the beam trawl fishery was already starting to be phased out in that area since 2004 and thus the measure was not true additional compensation. This posed additional challenges with monitoring the effectiveness of the compensation measure. Initially, it was intended to be a comparative analysis between the new protection area (where the beam trawl fishery is banned) and a nearby unprotected area, to determine whether improvements in the development of benthic and fish communities could be evidenced. But this method was later deemed unsuitable because heavy beam trawling had almost completely disappeared from the Voordelta area prior to this compensation measure. Thus, true comparisons could not be made and without the differences in beam trawling activity, it is impossible to test the effect of the compensation (van der Heide, 2022).

Furthermore, fishing effort from the shrimp fisheries has increased since 2008. This involves dragging a lighter net over the seabed, but given the increase in fishing effort, this could still represent a significant hindrance to recovery. This fishery takes place across most of the Voordelta, with only 1-3% left unfished (van der Heide, 2022). The seabed is repeatedly disturbed, which may hinder the recovery of benthic communities that live on and in the top layer of the sediment. This is further exacerbated by the long recovery times of key species such as mussels, oysters and sand tube worms.

As a result, the compensation put in place could not be demonstrated to be effective (van der Heide, 2022). Thus, further compensation measures must be secured quickly by the Ministry of Agriculture, Nature and Fisheries and the Port of Rotterdam. It has been suggested that banning all bottom-contact fisheries in the Voordelta will lead to improved ecosystem functioning of the site (van der Heide, 2022).

Case study: sustainable development in the water industry

Examples of sustainable development in protected areas can be seen in other industries also. The role of the drinking water sector in protected area management is an interesting example of this.

Puur Water & Natuur (PWN) have a water production facility – Andijk III – where surface water from the IJsselmeer is purified for the North Holland region. Water purification goes through multiple stages before being suitable for human consumption, including: suspended iron exchange to remove dissolved organic carbon, nitrate and sulphate; ceramic membranes to remove large particles; UV and hydrogen peroxide to remove hazardous substances; and activated carbon to remove any remaining substances (PWN, n.d.).

At Andijk III, PWN have solar panels producing renewable energy to help reduce the environmental impact for the purification process. This includes the use of floating solar panels, which cover roughly 50% of the reservoir to prevent a complete barrier to light. Consideration is also given to which areas of the reservoir are key for birds, with these areas avoided. This is particularly important given it is adjacent to the IJsselmeer Natura 2000 site.

Figure 15. Floating solar panels at Andijk III.

Figure 16. Highland cattle in the North Holland Dune Reserve.

As part of the purification process, water is transported to the dunes on the coast to filter the water. PWN manage the North Holland Dune Reserve, with two water purification sites located here – one open to the public and one completely private. Rangers manage access at the private site and carry out a range of nature monitoring. To improve the condition of the reserve, infiltration ponds and dune slacks have been redesigned, to help promote the young successional stages of wet dune slacks. Species richness is also a key consideration, with grazing being introduced using highland cattle.

Research is also underway until 2024 to further understand the role of grazers in a dune landscape (PWN, n.d.). Grazers play an important role in keeping the landscape healthy. However, a balance is needed as overgrazing can lead to the degradation of an ecosystem, with certain vegetation species disappearing under high grazing pressure.

Furthermore, nitrogen deposition is monitored carefully at the dunes, as this can be harmful to people and also nature. This is a particular problem in the Netherlands, with agriculture, industry, transport and the construction sector all contributing to excessive nitrogen deposition (Government of the Netherlands, n.d.).

Coastal management of the dune system mainly involves nourishment – adding sand to the foreshore. This active intervention prevents some of the dune dynamics and mobility, effectively 'holding the line' of the coast. In Scotland, adaptive approaches are preferred (e.g. moving infrastructure landward) to allow the coastline to move naturally (Rennie, et al., 2021). However, the Netherlands rely on many ecosystem services provided by the dunes, including natural flood defences and drinking water reservoirs (Arens, et al., 2020). Coastal safety is particularly important, given much of the country is low-lying and thus the risk posed by flooding is greater (Verhagen, 1990). However, sea level rise also poses a risk to the drinking water supply through saltwater intrusion of the freshwater lens[17] (van Alphen, Haasnoot, & Diermanse, 2022).

In some areas of North Holland, PWN have implemented dynamic dune management to help restore mobile dunes and the associated biodiversity (PWN, 2014). However, the front chain of dunes must be maintained for coastal defence and thus were moved landward, to allow for the natural dynamics of the foreshore dune systems.

[17] A convex-shaped layer of fresh groundwater that floats above the denser saltwater.

Conclusions

There are many similarities to offshore wind consenting across the Netherlands and Scotland, including the approach to identifying potential lease areas and some of the methods used to assess impacts under the EIA process. However, there are also inherent differences. Firstly, the Government of the Netherlands carries out the EIA for each potential wind farm site, rather than the developer being responsible for this as in Scotland. This speeds up consenting timelines in the Netherlands, with offshore wind farms being operational within five years from being awarded a site. Whilst this process takes considerably longer in Scotland, part of this longer timeline stems from the requirement for developers to conduct site-specific baseline surveys, which helps to reduce uncertainty through the EIA process.

Mitigation measures also differ across the two countries, with the Netherlands pioneering novel techniques to reduce bird collisions, including curtailment of turbines using radar and trialling black blades on turbines. If painting one blade black is shown to be effective mitigation, this could be a reasonably easy measure to implement at future nearshore and potentially offshore wind farms. Whilst radar is being explored at Scottish offshore wind farms, this is from a monitoring perspective to help de-risk the consenting process, rather than as mitigation. The curtailment at Dutch offshore wind farms uses radar and a predictive model, to assess the likelihood of mass migration of birds 48 hours in advance.

Figure 17. Common tern.

Instantaneous curtailment is not used offshore currently, due to the concerns around grid destabilisation. One way around this may be through overplanting[18], which is usually applied so that full transmission capacity can be reached in lower wind speeds. When the additional capacity is not needed – i.e. high wind speeds – turbines could be curtailed. Whilst this additional capacity is usually sought to maximise economic benefit (Wolter, Klinge Jacobsen, Rogdakis, Zeni, & Cutululis, 2016), it could also be potentially used to benefit certain bird species. Similar to Maasvlakte II nearshore wind farm, a radar system could be applied at overplanted offshore sites to instantaneously curtail localised turbines if birds are detected in the vicinity, thereby lowering risk of collision. This would require further exploration to determine the feasibility of such a measure, including comparisons between flight behaviour of birds, wind speed and optimisation of the wind farm capacity setup.

[18] Overplanting of turbines increases the wind power capacity over the agreed transmission limit, either through additional turbines or higher generating capacity of each turbine, but the energy exported will not exceed the transmission limit.

Potential compensation measures may also need to be explored further as offshore wind demand grows. This is a pressing topic in Scotland, with the first formal derogation package for offshore wind submitted for consideration last year. Whilst there are no examples of formal compensation at Dutch offshore wind farms, lessons can be learnt from other developments, such as the expansion of the Port of Rotterdam. The fisheries-based compensation measure associated with this development was concluded ineffective, due to inadequate monitoring comparisons and an increase in other damaging activities. This highlights the importance of a thorough monitoring and implementation plan, as well as the need for adaptive management in instances where targets are not reached. Moreover, this demonstrates that further examples of relevant formal compensation may exist in other industries / European countries.

Furthermore, the Netherlands has many examples of embedding biodiversity positive measures into developments. This is an area that has received little consideration at Scottish offshore wind farms to date. However, both nature-inclusive designs (e.g. fish hotels in cable scour protection) and habitat enhancement (e.g. oyster reef restoration) are potentially suitable measures that could be applied at Scottish offshore wind farms. Given various parameters can influence the success of such measures, a feasibility study in Scottish waters similar to that produced for the Rich North Sea Programme (Bureau Waardenburg, 2020) could be a good place to start.

Finally, lessons can also be learnt from other sectors. In the Netherlands, drinking water companies manage some of the dune reserves. As sea level rise increases, dune systems and the associated water reservoirs may be at risk. Thus, the drinking water companies have a vested interest to conserve and enhance the protected sites to improve resilience to future threats and preserve the ecosystem services the dunes provide. When considering the bigger picture, our marine environment provides a wealth of ecosystem services including renewable energy, food security and flood defence. As with the dunes, it's important to protect and restore marine habitats and species, to improve resilience and secure the many ecosystem services we rely on for the future.

Recommendations

To summarise, recommendations for the offshore wind sector, particularly sites located in Scotland, include:

- Consider how the offshore wind consenting process can be streamlined, by looking at what works well in other countries.
- Exploring the use of novel mitigation techniques, including: painting turbine blades black (if found to be effective at nearshore sites), different uses of radar and feasibility of curtailment.
- As the need for formal compensation increases in Scottish waters, explore examples from other industries / European countries.
- Given we are in a biodiversity crisis, embedding biodiversity positive measures should be encouraged within the offshore wind sector, with a feasibility study guiding this.

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Annex

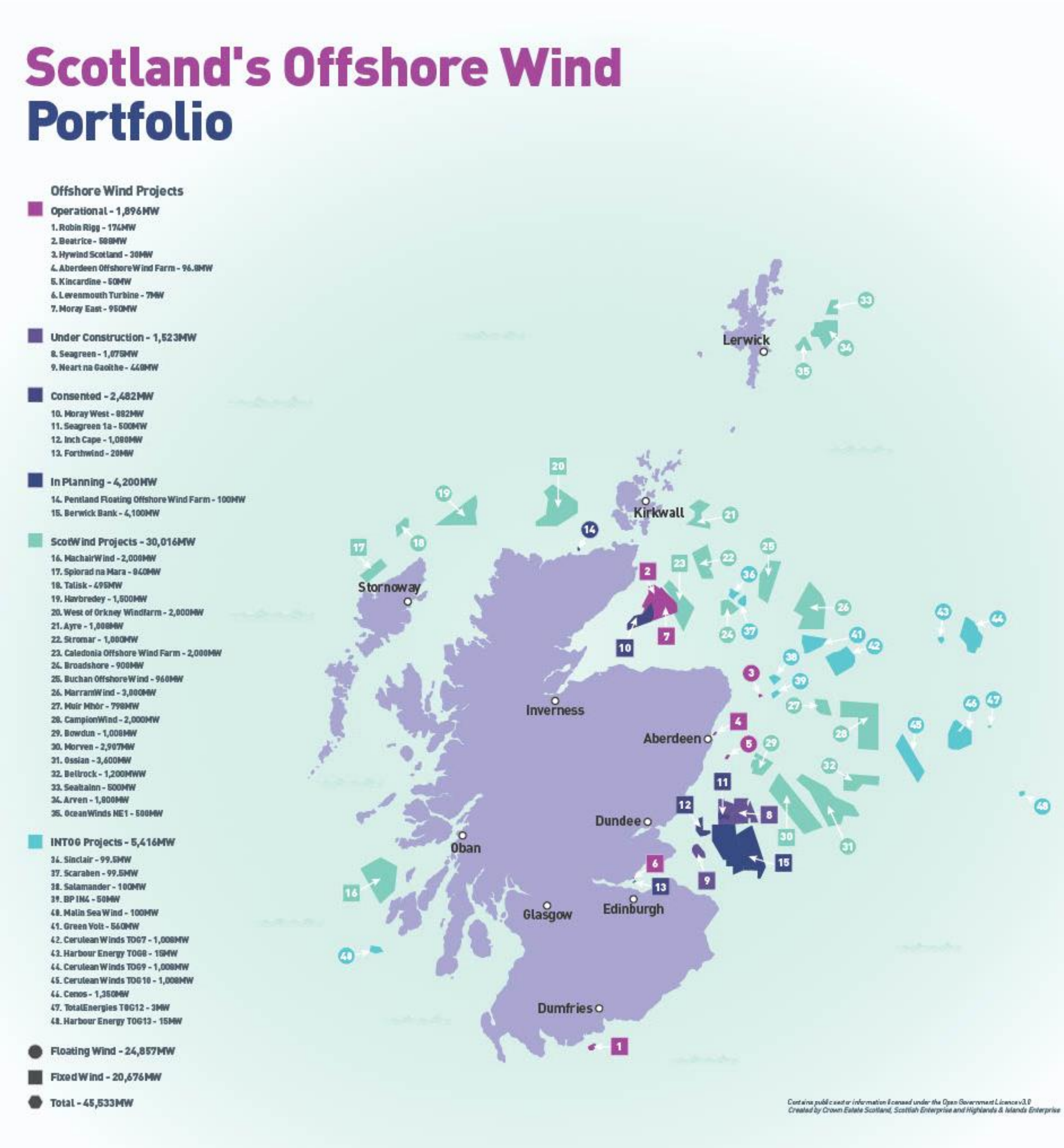

Figure 18. Scotland's Offshore Wind Portfolio. Source: Crown Estate Scotland, Scottish Enterprise, and Highlands & Islands Enterprise, https://energycentral.com/c/cp/scotlands-offshore-wind-portfolio

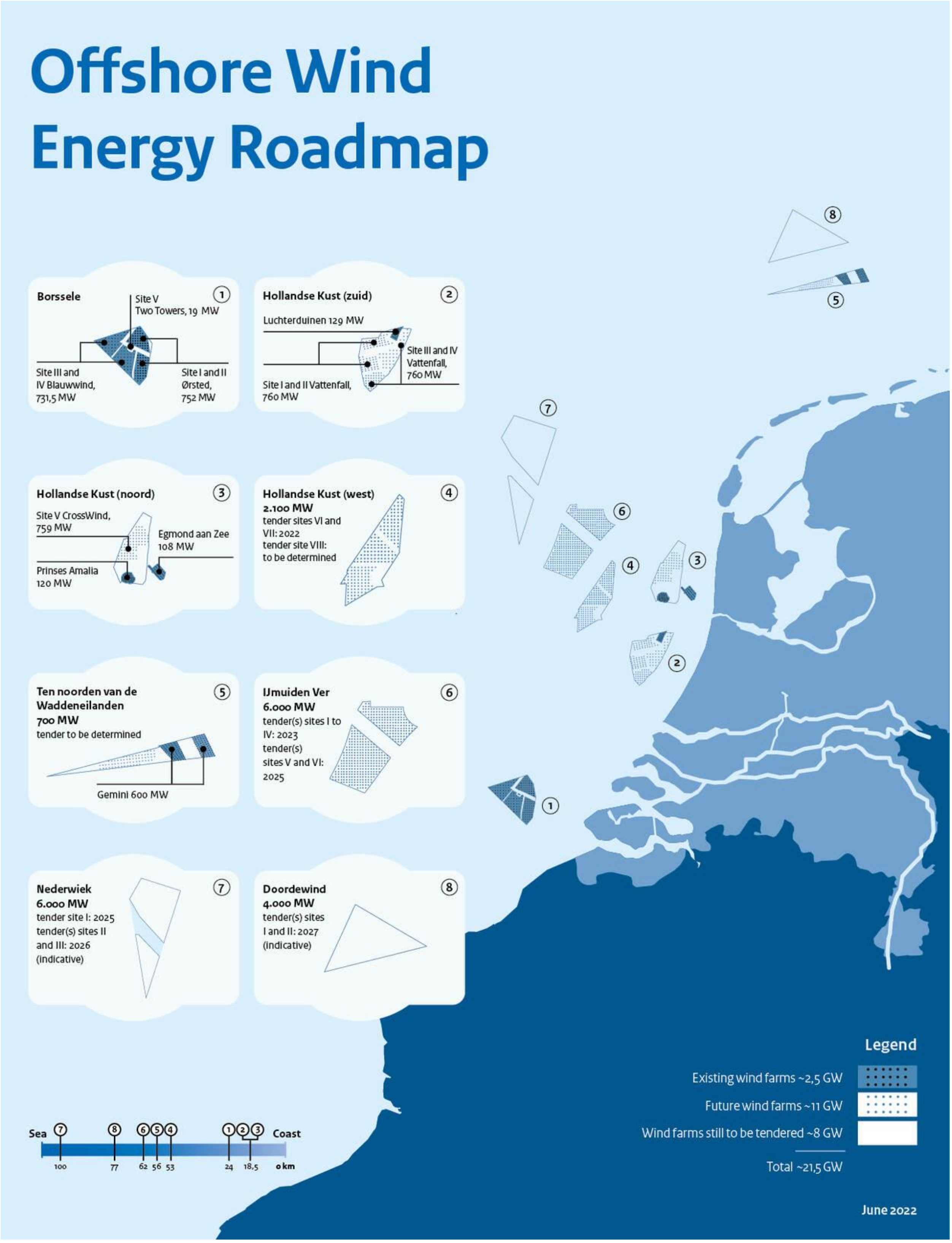

Figure 19. Offshore Wind Energy Roadmap for the Netherlands. Source: Government of the Netherlands, https://www.government.nl/topics/renewable-energy/offshore-wind-energy