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Abstract

1.1 Background and objective of the North Sea Programme 2022-2027

Partial Revision

The North Sea Programme (NSP) 2022-2027 has been included as an independent appendix to the National Water Programme 2022-2027. The government sets out its policy for the North Sea in this programme. The NSP covers aspects including the spatial planning framework created by the various draft policies. The NSP designates wind farm zones that offer space for around 21 Gigawatts (GW) in combination with previously identified zones and existing wind farms. These zones are included in the 21 GW Roadmap. The cabinet's ambition is to generate 50 GW of offshore wind energy by 2024 in order to achieve the climate goals[1]. However, no further wind farm zones have been designated for the period following the implementation of the 21 GW Roadmap, which will be later than 2031. To safeguard continuity of the roll-out of offshore wind energy after 2031, it is important to identify new wind farm zones in good time. A decision like this cannot be deferred until the new North Sea Programme 2028-2033 due to the extensive planning time for the required energy infrastructure. Hence the need for an interim review of the NSP, the 'Partial Revision' (PR).
As per its programme, the government first assesses how much space is available for fisheries, also taking into account aspects such as shipping safety, nature legislation and mining. In addition, it has been decided to reserve extra space for sand extraction in this PR. This is to do with the increasing need for sand to protect the coastline, on the one hand, and, on the other, an increase in spatial claims within the existing reservation zone for sand extraction.

Why an Strategic Environmental Assessment?

As the NSP creates a framework for decisions/activities that require an strategic environmental assessment, it is also mandatory to go through the process of an SEA for the PR. This relates to the identification of wind farm zones and sand extraction, but not to the other aspects of the PR. The Strategic Environmental Assessment (SEA) describes the alternatives, the consequences for the environment (including cumulative consequences), any mitigating measures, plus focus areas and pre-conditions for decision making, making clear the environmental information that the government considers in coming to the decisions set out in the PR.

The SEA procedure

The Strategic Environmental Assessment has been drawn up as per the method described in the Memorandum on Scope and Detailing (*Notitie Reikweijdte en Detailniveau*)[2]. The draft version of the PR will be confirmed, together with the Strategic Environmental Assessment, by the Minister of Infrastructure and Water Management (in agreement with the Minister of Agriculture, Fisheries, Food Security and Nature, the Minister of Internal Affairs and Kingdom Relations and the Minister for Climate and Green Growth) in mid-2025, pending consultation. After processing any views submitted, recommendations from various bodies (including the National Heritage Board), recommendations from the Strategic Environmental Assessment Committee and discussion in the Council of Ministers, the final partial revision of the North Sea Programme and Memorandum of Reply can be adopted by the Minister for Infrastructure and Water Management, in consultation with other ministers at the end of 2025.

[1] Government programme; Interpretation of the coalition agreement of the Schoof Cabinet, 13 September 2024
[2] Draft Memorandum on Scope and Detailing for the Partial Revision of the North Sea Programme 2022-2027

1.2 Areas examined and baseline situation

The SEA has been drafted in two parts: one relating to wind energy and the other relating to sand extraction. The energy infrastructure from the wind farm zones to the land forms the area in which both activities overlap. This is examined in the SEA within the Exploration of Cable Landing Points for Offshore Wind Energy programme (pVAWOZ). For the most part, the plan to designate wind farms has no significant overlap due to the extensive distance between the zones for wind energy and sand extraction, and the differing nature of the activities. The sole possibility of an overlap of this kind is if the Lagelander area is designated and, at the same time as the turbines are being installed, sand extraction is under way in the reservation zone. This is described in the section on cumulative effects, which states that this effect is negligible in relation to the existing baseline situation. Otherwise, potential environmental effects do not combine in any way and no cumulative effects are expected, so it is logical to view these intentions in this Strategic Environmental Assessment separately.

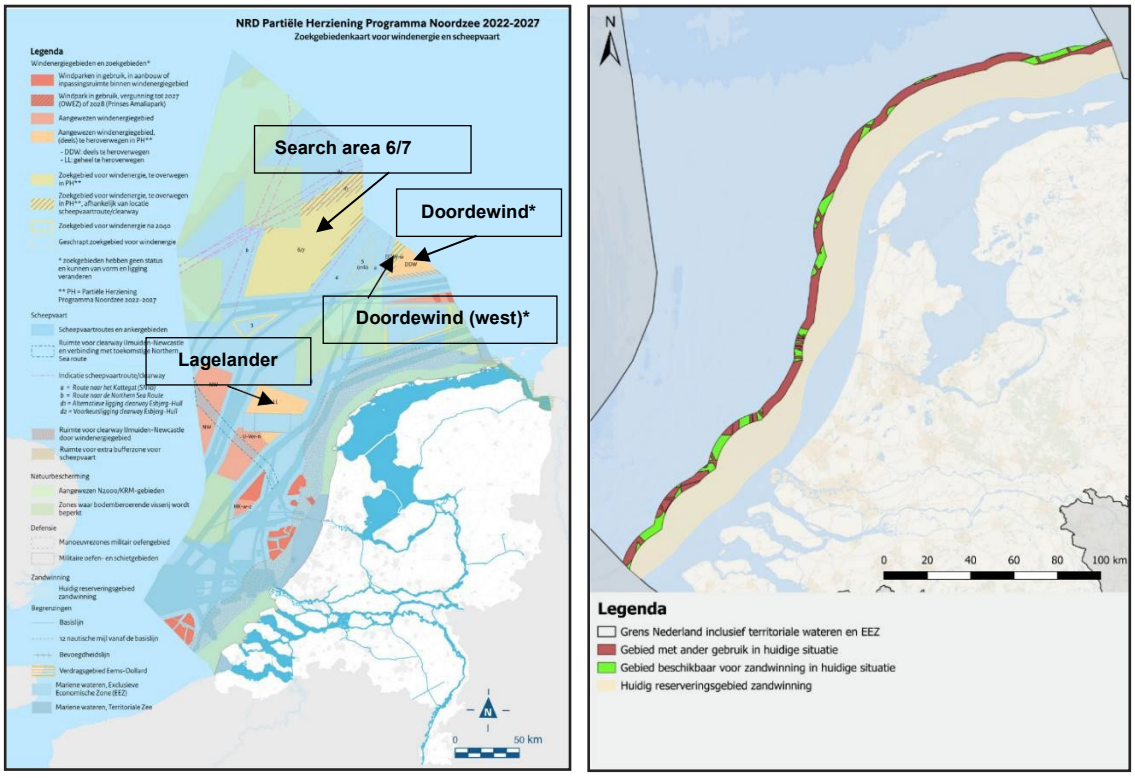
Potential wind farm zones

The task facing the PR is to designate wind farm zones to generate at least 23-26 GW. To that end, the SEA investigates both search areas and parts of previously designated wind farm zones that remain unutilised under the terms of the Offshore Wind Energy 21 GW Roadmap. The following areas are investigated in this SEA:

- **Search area 6/7**;
- **Doordewind**: unutilised part of designated area, expanded to include Doordewind (west)
- **Lagelander**: designated, but still entirely unutilised.

Figure S1.1 includes the areas on the map under consideration.

Figure S1.1 Strategic Environmental Assessment zones investigated: wind energy (left) and sand extraction (right)



* Doordewind (west) is part of the Doordewind wind farm zone

Search area 6/7 is very large and is made up of previously identified search areas 6 and 7, plus the zone in between. The reason to consider the area as a single entity in considerations for the PR is that this would make it possible to make informed choices about how the total area is subdivided, so that both the efficiency of wind farms, including the infrastructure this entails, and the implications for other use and nature are taken into account. In comparison with the NSP 2022-2027, the delimitation of search area 6/7 has been amended on the basis of new insights on the situation of certain adjacent shipping routes.

Sand extraction

The Strategic Environmental Assessment investigates a spatial expansion of the reservation zone for sand extraction. This is a seaward expansion of the reservation zone for sand extraction. This reservation zone is currently between the continuous -20 m and 12 nautical mile (NM)-lines from the coast. The seaward adjustment represents an expansion of 2 NM up to the continuous line 14 NM from the coast. So, the area under investigation lies between 12 NM and 14 NM from the coast.

A range of solutions are needed to satisfy the increasing demand for sand for coast protection as a result of rising sea levels (Deltares, 2023). The quantity of extra sand that is required depends on the extent to which the sea level rises. This SEA is currently investigating only the 'seaward expansion of the reservation zone for sand extraction' in the context of the PR. This is because this measure, in relation to other measures, now requires a change in spatial policy. This measure is now also necessary, as extra cables and pipelines are taking up space in the current reservation zone for sand extraction due to the designation of extra wind farm zones. The North Sea Programme 2028-2033 envisages a recalibration of the current sand-extraction strategy, at which point a wider-ranging package of measures will be considered.

1.3 Research method and configuration

1.3.1 Wind farm zones

Search area 6/7 has a very wide surface area (4636 km^2) To meet the terms of the task, it is not necessary to utilise the whole area for wind energy. Moreover, the area is large enough for the zoning to contribute to the effects. In view of this, a spatial analysis of search area 6/7 has led to various options for how to complete the task. The effects, too, have been assessed and evaluated step by step.

There has been no spatial analysis comparable to that for search area 6/7 for the other wind farm zones, Lagelander and Doordewind. These are less extensive zones and the spatial planning has less impact on the effects. Where relevant, this SEA specifies whether effects differ in different parts of these two zones. In Doordewind (572 km^2 in total, inc. Doordewind West), there is availability for a maximum of 4 GW in addition to the planned site of 2 GW (21 GW Roadmap). For this zone, there is a difference between an additional 2 or 4 GW. In Lagelander (757 km^2), there is a potential future site of at most 2 GW (around 200 km^2), the precise location of which is as yet unclear. If this zone is designated in the allocation of sites, an intensive customisation process will be needed in relation to the existing drilling platforms.

The steps for search area 6/7 are outlined below, with images showing the different spatial configurations that present themselves. The map images in question are also shown in appendix S1.

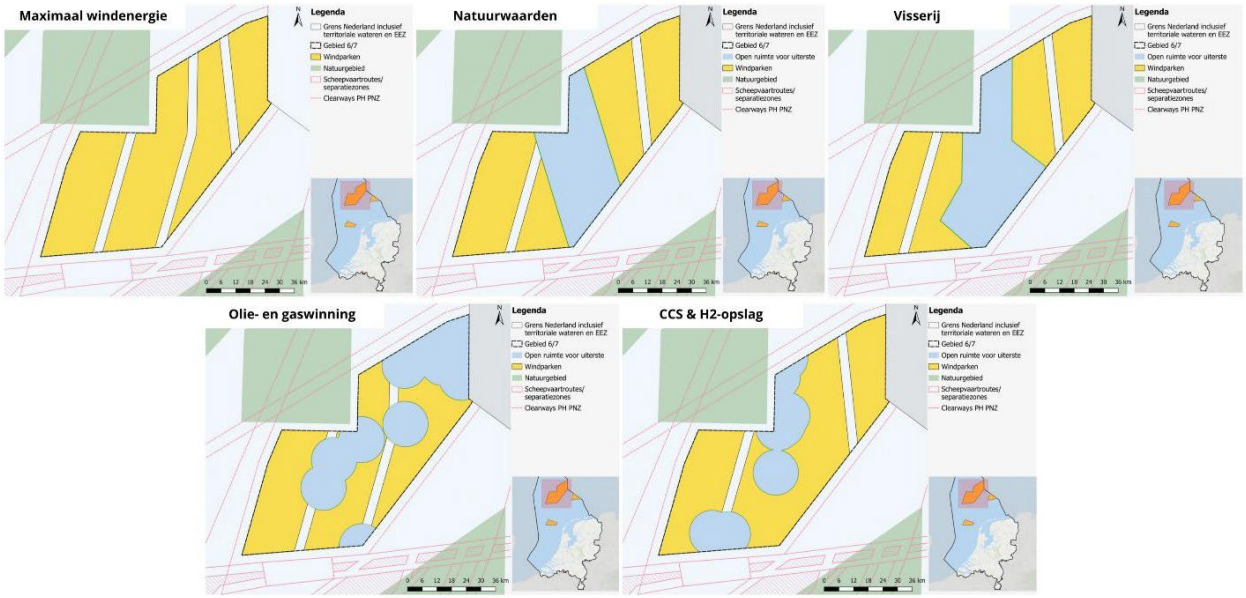
This is a separate appendix that can only be consulted when following the parts of this SEA that address search area 6/7.

Step 1: extremes for future area classifications

In the first step, the spatial requirements for use for nature and other sectors than wind energy (commercial fishing and drilling) are identified by means of desk research, starting points from the NSP and/or discussions with sectors (see Figure S1.2). The purpose of this is to see what can be done to accomplish the wind energy task and, at the same time, to protect space for other use where possible. The extremes show for nature, fisheries and drilling respectively, the amount of space in search area 6/7 that must be kept free from that specific perspective. No extreme has been drawn up for shipping, although the space required for shipping has been incorporated in the spatial analysis.

The extremes are specifically not alternatives between which a choice can be made; rather they are extremes with the potential for wind energy if spatial requirements for each sector in search area 6/7 are respected. An assessment has been made of the expected least and greatest effects for each aspect/sub-aspect. This offers information on the range of effects and shows, for each aspect, what the limit of the assessment of effects is. This range of effects is described in the various sections in part B of this SEA.

Figure S1.2 Overview map of extremes, search area 6/7



Maximaal windenergie	Maximum wind energy
Natuurwaarden	Natural assets
Visserij	Fisheries
Olie- en gaswinning	Oil and gas production
CCS & H2-opslag	CCS & H_2 storage

Table S1.1 range of extremes in GW

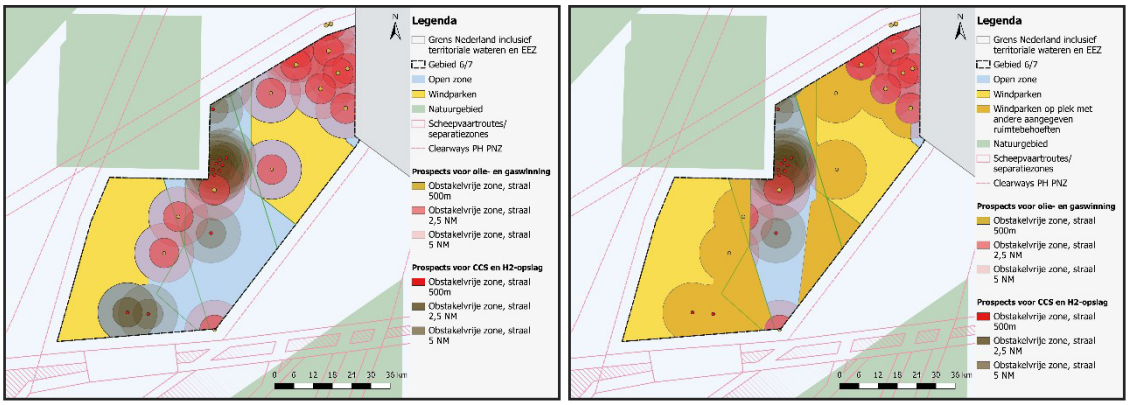
Extreme	Wind energy	Nature	Fisheries	Drilling (oil and gas)	Drilling (CCS and H_2 storage)
Number of GW	37.4	26.9	25.6	22.6	30.6

Step 2: from extremes for each sector to extreme combination variants

If the spatial requirements of all sectors (uses other than wind energy and nature) are taken into account,

there is not enough space left over in search area 6/7 for wind energy to accomplish the task. So choices will have to be made. For that reason, steps 2 and 3 show a spatial analysis, starting by identifying two extreme combination variants (Figure S1.3). This is a single extreme combination variant with the least installed capacity of wind energy (10.6 GW), where all stated spatial requirements of sectors other than wind energy are respected. One extreme combination variant (with the most wind energy (26.7 GW)) is also included. Both extreme combination variants allow for an open zone of the largest size in the case of the least wind energy and the smallest size in the case of the most wind energy. This is important for nature, fisheries and the helicopter accessibility of potential future drilling platforms.

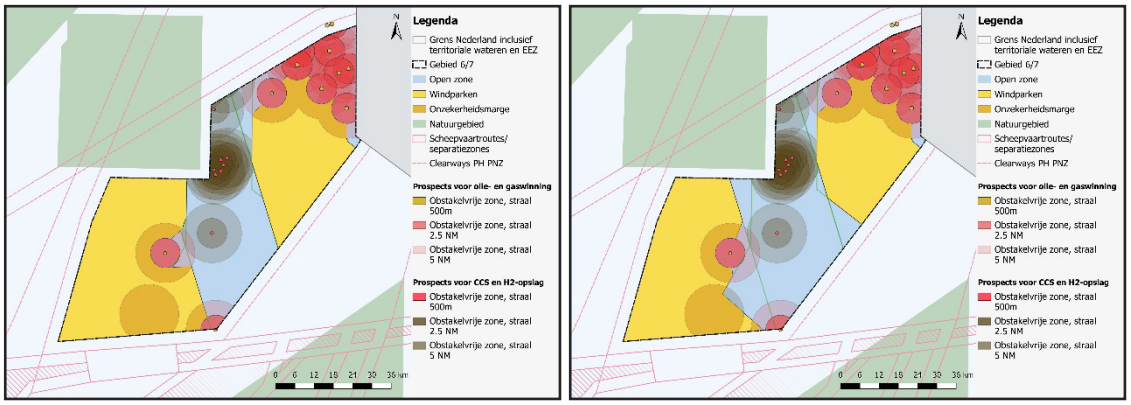
Figure S1.3 Left: extreme combination variant with least wind energy (10.8 GW), right: extreme combination variant with most wind energy (26.7 GW)



Step 3: spatial analysis leading to funnelled variants

There are many conceivable variations between the two extreme combination variants offering the least and greatest amounts of wind energy. To obtain an overview for the SEA and the decision-making process, we worked towards a limited number of assessed funnelled variants. Firstly, we assessed what the implications for shipping of an open zone were. This revealed aspects such as the necessity of having sufficient space for a safe clearway, which was incorporated as a condition in the subsequent development of variants. Then, we looked at how much space had to be kept free for drilling, using information on how promising prospects were and how much space was needed for helicopter access. The analyses relating to shipping and drilling led to two extreme funnelled variants, with space for around 18.5-21.5 GW of wind energy (Figure S1.4).

Figure S1.4 Extreme funnelled variants (left = lowest extreme funnelled variant ~21 GW, right – highest extreme funnelled variation ~19 GW)



Six other funnelled variants between the two extreme funnelled variants were modelled, leading to a total of **eight funnelled variants** (Figure S1.5 - S1.7 inc.). The funnelled variants differ in scope and location of an open zone through search area 6/7, and thus also in the available space for wind energy. To keep the Strategic Environmental Assessment decision-making process clear, the eight variants were sorted into three groups: 'basic open zone', with space for around 19 GW, 'wider open zone', with space for around 20 GW and 'widest open zone', with space for around 21 GW. These three groups were considered to estimate and assess the ecological effects. The effects of the two extreme funnelled variants, which were part of variants with the basic open zone and the widest zone respectively, were estimated in relation to other uses (other than wind energy), and the energy returns and prevented emissions.

Figure S1.5 Possible 'Basic open zone' area classifications, funnelled variant 1320 – 1420 km^2, ~ 21 GW (from left to right: no. 1, 2 and 3)

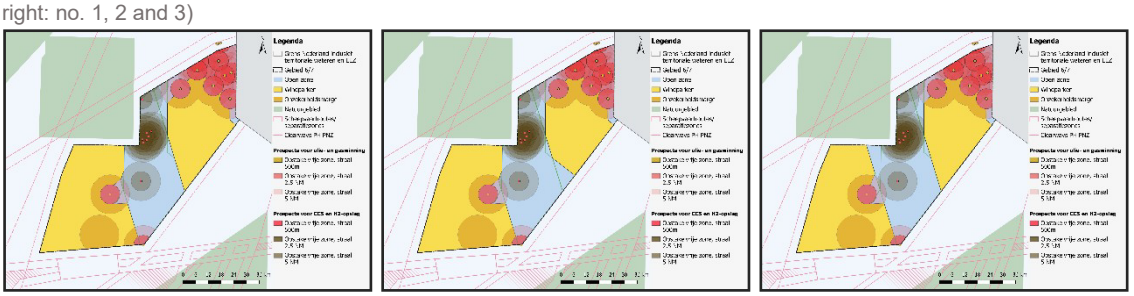


Figure S1.6 Possible 'Wider open zone' area classifications, funnelled variant1420 – 1520 km^2, ~ 20 GW (no. 4 and 5)

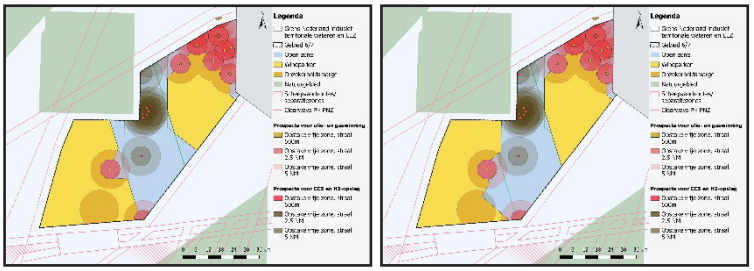
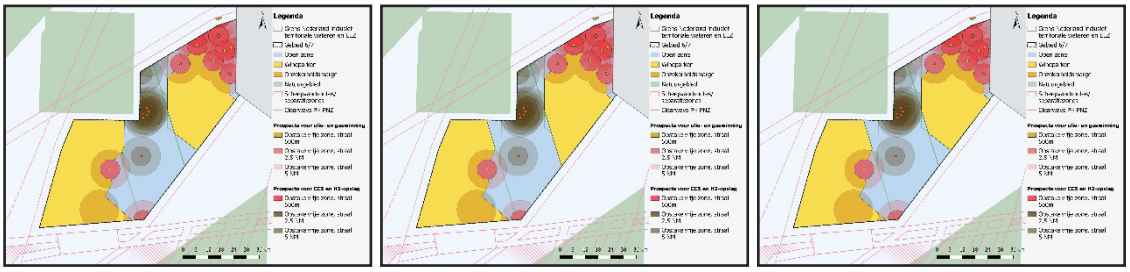


Figure S1.7 Possible 'Widest open zone' area classifications, funnelled variant 1520 – 1620 km^2, ~19 GW (no. 6, 7 and 8)



Assessment methodology

A range of environmental aspects are assessed in the SEA. These aspects are summarised by topic in the table below. An **Appropriate Assessment** was also drafted. This addresses the effects on Natura 2000 areas and the designated species for these areas.

Table S1.2 Aspects of wind farm zones for assessment

Topic	Aspect	Sub-aspects, or factors that may determine whether specific effects occur
Ecology: ecological function and biodiversity throughout the North Sea	Birds	Collisions Habitat loss Barrier effect Underwater noise
	Bats	Collisions
	Turbidity and algal bloom (ecosystem effects)	Change in water flow, destratification
	Benthic fauna	Disruption and destruction of benthic fauna Permanent habitat change
	Fish	Disruption and destruction of fish and habitat, EMF, Permanent habitat change
	Marine mammals	Disturbance during installation and operation phase, EMF
Shipping: safe and smooth shipping traffic	Shipping safety	Safety hazards, determined by risk of incidents and consequences of incidents (consequences at this stage cannot be determined, risks determined both by quantifiable modelling and expert judgement)
	Accessibility for shipping	For route-specific and non-route-specific traffic: availability of routes, options and potential need for detours.
Drilling: exploration and commercial opportunities for drilling	Accessibility by helicopter (possible future) platforms for oil and gas production, and CO_2 and hydrogen storage	Presence of open space (for possible future platforms), approach paths available
	Options for monitoring injected CO_2	Presence of open space around possible future CCS sites
Fisheries: possibilities for commercial fishing	Contribution to food production from the sea, whether supply or any other part of the supply chain, and local communities.	Changes in available space for various fishery types as a result of wind farms
Cultural heritage and archaeology	Known assets Expected assets	Presence of wrecks and prehistoric landscapes
Electric energy infrastructure	Disturbance and destruction during installation, habitat change and other ecological aspects	Location of cables and platforms, electromagnetic fields, attractive force Platform lighting

Topic	Aspect	Sub-aspects, or factors that may determine whether specific effects occur
Hydrogen production and transmission lines	Disturbance and destruction during installation, habitat change and other ecological aspects	Water absorption, heat output, brine, chemicals, noise and vibrations, centralised, semi-centralised or decentralised hydrogen production, technological choices relating to amount of hydrogen production (GW)
	Potential installed capacity (GW)	Available space, capacity per wind turbine, feasible density
	Energy return (GWh)	Wind behaviour, expected wake losses
Energy return	Prevented emissions	Prevented emissions of CO_2, SO_2 and NO_x as a result of not generating electricity with fossil fuels
	Options for viable operation (LCoE = Levelised Cost of Energy)	Average updated costs per unit of energy generated during the full life cycle of a wind farm

The impact assessment is performed on the basis of a +/- score in relation to the baseline situation. The scale used for assessment has more subtle differences on the negative side than on the positive. The reason for this is that a more or less negative effect is expected for most environmental aspects. In this respect, it must be possible to specify particular nuances. The assessment is relative; although it provides an indication of the scope of the affect, at the same time it cannot be taken as absolute at this stage of planning. The assessment does not, after all, show one-to-one whether the effect on one aspect (e.g. consequences for commercial fishing) is more serious than on another aspect (e.g. shipping safety), nor whether the effect on one species group (e.g. porpoises) is more serious than on another (e.g. birds).

Table S1.3 Assessment scale

Assessment	Finding in relation to the baseline situation
Very negative (---)	The plan leads to an extremely negative change
Negative (--)	The plan leads to a negative change
Minor negative (-)	The plan leads to a minor negative change
Somewhat negative (0/-)	The plan leads to a somewhat negative change
Neutral (0)	The plan is not distinct from the baseline situation
Minor positive (+)	The plan leads to a minor positive change
Very positive (+++)	The plan leads to an extremely positive change

Baseline situation

The **baseline situation** is not the situation in which the plan is put into effect, although autonomous developments are taken into account. These are developments about which decisions have already been made. In this SEA, we assume that the 21 GW Roadmap has been created and forms part of the baseline situation. In addition, it is reasonable to assume that additional objectives for certain Natura 2000 and MSFD areas have been allocated. The NSP 2022 - 2027 use map is also used as the starting point for other activities on the North Sea.

1.3.2 Sand extraction

Alternatives

A single variant for sand extraction is studied in this SEA. There are several reasons for this:

- Policy is being changed in relation to the prioritisation of spatial interests. Expansion of the area in which sand extraction has priority over other activities/use functions is under consideration. Even without this amendment in prioritisation, sand extraction is already permitted in this area under the prevailing regulations;
- This seaward expansion of the reservation zone from 12 NM to 14 NM is, at present, the only spatial policy amendment that, where sand extraction is concerned, contributes to increasing the exploitable sand reserves, for sand extraction as a national interest, for which additional policy is required;
- Reserving areas for sand extraction elsewhere on the North Sea is more expensive (not economically feasible) and would lead to increased CO_2 emissions from more shipping traffic making longer journeys. Exploration for reserves elsewhere on the North Sea is thus not a realistic alternative from the operational perspective;
- The expansion of the reservation zone from 12 NM to 14 NM is one of the long-term solutions for expanding the exploitable reserve of sand, but would not result in sufficient additional exploitable sand reserves to meet the predicted rising demand for sand. When the sand extraction strategy is recalibrated as part of the North Sea Programme 2028-2032, additional solutions will be considered;
- A seaward shift of the reservation zone further than 14 NM is not currently under consideration because: 1) sailing distance is the largest factor in terms of costs of sand extraction and is thus unwelcome from an operational perspective, 2) there is less known about the composition and availability of extractable sand further into the reservation zone, hence it is not clear to what extent that contributes to the objective of increasing exploitable sand reserves.

Assessment methodology

The SEA assesses a range of environmental aspects. These aspects are grouped by topic and summarised in the table below. The impact assessment is made on the basis of a + / - score in relation to the baseline situation. In that respect, the same assessment scale is used as with the SEA section for the wind farm zones.

Table S1.4 Sand-extraction aspects to be assessed

Category of aspects	Aspects	Qualitative or quantitative	Explanation
(Hydro) Morphology	- Sediment transport (sand) - Current - Morphology of the sea floor after extraction - - Sludge and turbidity	Qualitative	Effects on the water flow and consequences for transportation of sand and sludge

Category of aspects	Aspects	Qualitative or quantitative	Explanation
Ecological effects	Habitat characteristics	Qualitative	Disturbed sea-floor surface Primary production Direct additional effects on abiotic factors Underwater disturbance
	Benthic fauna	Qualitative	Direct disturbance
	Birds	Qualitative	Disturbance
	Marine mammals	Qualitative	Disturbance Underwater noise Electromagnetic fields
Emissions	Area protection	Qualitative	N2000 areas: MSFD areas
	CO_2, NO_x	Qualitative	Additional emissions, pollution
Fisheries	- Effects on fish - Effect on spawning beds and foraging areas	Qualitative	Expected impact of ecosystem effects and additional spatial overlap
Shipping	- Spatial overlap	Qualitative	Additional spatial overlap and expected impact on shipping security
	- Spatial overlap - Shipping security		
Cultural heritage	- degradation of man-made areas of interest - degradation of archaeological areas of interest	Qualitative	Possible degradation of known and expected archaeological assets and objects, such as shipwrecks or submerged settlements. New archaeological assets may be discovered. Large detected objects must be avoided; they lead to losses in extractable sand. Palaeolithic landscapes are disturbed and ancient strata of earth are brought to the surface when sand is excavated. Fossils may be unwittingly excavated along with the sand.

Baseline situation

The baseline situation for sand extraction assumes the current sand-extraction strategy and prevailing policy. In the current policy, sand is extracted in the reservation zone that extends along the entire coastline, between the continuous -20 m NAP line and to 12 NM from the coast. In the baseline situation, a trailing suction hopper dredger operates between the extraction and replenishment sites sucking up sand from the sea floor to a maximum depth of 6 m.

1.4 Environmental assessment of wind energy

1.4.1 Summary table

There are various possibilities for the designation of space for wind energy for each zone, expressed in the number of GW per zone. The various numbers of GW count towards the total number of GW for which space can be designated. This is subject to an integrated (political) deliberation, in which the space required for other interested parties in the zones under consideration is taken into account, plus potential environmental effects that are estimated and assessed for each environmental aspect below. Table S1.5 includes a summary of the environmental assessment for each aspect and each zone.

Below the table is a summary for each zone and each aspect of the impact assessment, including the key partial findings. For several aspects, such as off-shore hydrogen production, this SEA discusses potential effects without making an assessment, as too little is known at this stage in terms of technology, situation and/or potential effect. In the case of drilling, potential effects on helicopter accessibility can be estimated but, in the same way, no assessment can be made. It is not possible to assess the scope of the effect of reduced helicopter accessibility for platforms that have not yet been built.

There are separate tables (S1.5 and S1.6) for search area 6/7 and for Lagelander, Doordewind. There are two variants under consideration for Doordewind: +2 GW and +4 GW. In the second option, the whole zone will be required.

Table S1.5 Impact assessment of environmental aspects in search area 6/7

	Phase	Extremes		Funnelled variants		
Aspect	**When is the effect visible?**	**Extreme with least effect**	**Extreme with greatest effect**	**Widest open zone (~19 GW)***	**Wider open zone (~20 GW)***	**Basic open zone (~ 21 GW)***
Ecology (marine birds - collisions)	Use phase	Fisheries -	Wind energy ---	0/-	-	--
Ecology (marine birds - habitat loss)	Use phase	Fisheries -	Wind energy ---	-	-	--
Ecology (marine birds - barrier effect)	Use phase	Ecology -	Wind energy ---	-	-	--
Ecology (migrating birds - collisions)	Use phase	Fisheries 0/-	Wind energy --	0/-	0/-	-
Ecology (bats)	Use phase	Fisheries 0/-	Wind energy -	0/-	0/-	0/-
Ecology (turbidity and algal bloom)	Use phase	Fisheries 0/-	Wind energy -	0/-	0/-	0/-
Ecology (benthic fauna)	Installation phase	Fisheries 0/-	Wind energy -	0/-	-	-
	Use phase	Fisheries 0	Wind energy n/a	0	0	0
Ecology (fish)	Installation phase	Fisheries 0/-	Wind energy 0/-	0/-	0/-	0/-
Ecology (porpoises)	Installation phase	Fisheries -	Wind energy --	-	-	-
Ecology (seals)	Installation phase	Fisheries 0	Wind energy 0	0	0	0
Shipping (safety)	Use phase	Extreme combination variant minimal wind energy 0/-	Wind energy --	0/-	n/a	-
Shipping (accessibility) route specific	Use phase	Maximum open zone 0/-	Wind energy --	0/-	n/a	0/-
Shipping (accessibility) - non-route specific	Use phase	Maximum open zone 0/-	Wind energy --	0/-	n/a	-
Drilling, helicopter accessibility**	Use phase	extreme combination variant minimal wind energy***	Extreme combination variant maximum wind energy***	***	n/a	***
Fisheries (beam trawling for sole and plaice)	Use phase	Fisheries -	Wind energy -	-	n/a	-
Commercial fishing (otter trawling for langoustine)	Use phase	Fisheries 0/-	Wind energy --	0/-	n/a	0/-

	Phase	Extremes		Funnelled variants		
Aspect	**When is the effect visible?**	**Extreme with least effect**	**Extreme with greatest effect**	**Widest open zone (~19 GW)***	**Wider open zone (~20 GW)***	**Basic open zone (~ 21 GW)***
Energy return	Use phase	Extreme combination variant minimal wind energy +	Wind energy +++	+++	n/a	+++
Prevented emissions	Use phase	Extreme combination variant minimal wind energy +	Wind energy +++	+++	n/a	+++
Cultural heritage – known archaeological asset	Installation phase	Fisheries 0/-	Wind energy 0/-	0/-	0/-	0/-
Cultural heritage – expected archaeological asset	Installation phase	Fisheries 0/-	Wind energy 0/-	0/-	0/-	0/-

* In total, 8 funnelled variants for search area 6/7 have been considered, in three groups. The differences between these 8 funnelled variants have only been assessed in terms of natural aspects. For the other aspects, only the range was identified; only the funnelled variants with the lowest and highest readings for GW were considered. Where nature is concerned, the differences between the funnelled variants do offer an insight into the sections of the area in which a greater/lesser impact is expected. For the other aspects, the differences between the various variations are too small for the abstraction level of this SEA.

** Where drilling is concerned, helicopter accessibility has yet to be assessed, as most platforms are still to be built and the necessity of accessibility for individual platforms has not been established.

*** The extreme combination variant with the least wind energy has the least effect; the extreme combination variant with the most wind energy has the greatest effect. The analysis carried out shows no difference between the accessibility in funnelled variants. In these variants, uncertainty about the space around the (possible future) platforms that must be kept free of obstacles is taken into account. How this space is used has an impact on accessibility. If there is a 5 NM exclusion zone (free of obstacles) around platforms, the effects tend towards the extreme combination variant with the least wind energy. If there is a 2.5 NM exclusion zone, more accessibility-related implications can be expected. The extent to which accessibility diminishes as a result depends on whether space-saving flying procedures (which are still being studied) apply.

Table S1.6 Impact assessment of environmental aspects, Lagelander and Doordewind

Aspect	When is the effect visible?	Lagelander	Doordewind	
	Phase	(2 GW)	(+2GW)	(+4GW)
Ecology (marine birds - collisions)	Use phase	0/-	0/-	-
Ecology (marine birds - habitat loss)	Use phase	0/-	0/-	-
Ecology (marine birds - barrier effect)	Use phase	0	0	0
Ecology (migrating birds - collisions)	Use phase	0/-	0/-	0/-
Ecology (bats)	Use phase	0/-	0/-	0/-
Ecology (turbidity and algal bloom)	Use phase	0	-	-
Ecology (benthic fauna)	Installation phase	-	0/-	0/-
Ecology (fish)	Installation phase	0/-	0/-	0/-
	Use phase	0	0/-	0/-
Ecology (harbour porpoises)	Installation phase	0/-	0/-	0/-
Ecology (seals)	Installation phase	0/-	0	0
Shipping (safety)	Use phase	-	0/-	0/-
Shipping (accessibility) - route specific	Use phase	0	0	0
Shipping (accessibility) - non-route specific	Use phase	0/-	0/-	0/-
Drilling	Use phase	n/a	n/a	n/a
Fisheries (beam trawling for sole and plaice)	Use phase	0/-	-	-
Fisheries (otter trawling for langoustine)	Use phase	0	0	0
Energy return	Use phase	+	+	+
Prevented emissions	Use phase	+	+	+
Cultural heritage – known archaeological asset	Installation phase	0/-	0/-	0/-
Cultural heritage – expected archaeological asset	Installation phase	0/-	0/-	0/-

1.4.2 Ecology

The ecological effects have been estimated and assessed on six aspects: birds, bats, algal bloom and turbidity, benthic fauna, fish and marine mammals. Below is a summary of the key effects for each area.

Search area 6/7

- For protected **sea bird species** (including northern gannet, great skua, guillemot), the effects expected are the result of collision, habitat loss and barrier effect. Search area 6/7 is relatively important for these species of sea bird, which spread out from their breeding colonies in the north of the UK over the whole of the North Sea outside the breeding season.
- The close Frisian Front Natura 2000 area has been designated for protection under the Birds Directive (BD) for the **guillemot**. The Central Oyster Grounds MSFD area may also be designated for the guillemot. Search area 6/7 lies between these areas, so the potential barrier effects for species including the guillemot are specifically important.
- Retaining an **open zone** in search area 6/7 could mitigate the negative **effects on birds** (although not completely) as the extent of the barrier effect would be reduced, and as the presence of fewer wind turbines would mean less risk of habitat loss and collision. Further research is required into the scope of an open zone that would mitigate these effects sufficiently. See also the conclusions and recommendations.
- For **marine mammals** (**harbour porpoises**), we expect effects associated with disruption during construction. There are on average slightly more harbour porpoises per km^2 in search area 6/7 than in the other two areas. The limit for porpoise disturbance days for the Dutch Continental Shelf (DCS) is exceeded for all funnelled variants of search area 6/7, as a result of which the population may shrink (calculations based on current understanding). For seals, the area is less important due to its northerly situation and the sizeable distance from the coast.
- For **bats**, it is likely that search area 6/7 is less important due to its northerly situation and the sizeable distance from the coast.
- As search area 6/7 lies in a part of the North Sea where the water never fully mixes (stratifies) in summer, the area is sensitive to the **effects of destratification**. This may lead to changes in the timing and spread of **algal bloom**. These effects can be reduced by keeping a contiguous part of the area free from wind turbines. Although, the larger the open zone, the smaller the effect. The extent to which the effects of destratification have an impact on the food web is unknown.
- As far as is known at present, the area does not have special importance for protected **fish species** or species that are important due to their place in the food web. For most species, the effects are not expected to have a noticeable impact on populations. Any effects from electro-magnetic fields generated by cables are (as yet) unknown, but may pose a threat to species including sharks and rays due to the size of the area.
- In the relatively silt-rich middle section of search area 6/7, there is a valuable, species-rich **community of benthic organisms** (with a number of species rare to the Dutch continental shelf, such as the ocean quahog), which is adapted to summertime stratified circumstances. The potential for flat oyster (banks), not currently present, to colonise the area is good.

Lagelander

- Compared with search area 6/7 and Doordewind, this area is less specifically important to **sea birds**. Not least due to the limited size of the area, effects from collisions, avoidance (habitat loss) and barrier effect on bird populations will probably be limited.
- Some negative effect in the form of disruption to **harbour porpoises** (during construction) is to be expected. For seals, the expected effects will be very limited.
- Due to the situation of Lagelander, between the Dutch mainland and the United Kingdom, the area could be of some, albeit limited, interest for **migrating bats** (in particular Nathusius' pipistrelle).
- Expected effects on **algal bloom and turbidity** (ecosystem effects) are very limited, given the size of the area and the dynamics already present in the baseline situation.
- The area is not distinct from other sandy areas in the North Sea and is not particularly important for benthic fauna. Effects on **benthic fauna** will thus probably be limited, both as a result of disruption/destruction during construction and due to possible habitat change.
- The area is not of particular importance for protected **fish species** or species that are important due to their place in the food web, hence there is not expected to be a noticeable impact on populations.

Doordewind

- The expected ecological effects on protected/vulnerable **sea bird species** are effects of collision and habitat loss. In this area, the guillemot and lesser black-backed gull are most relevant.
- An increased concentration of **guillemots** can be expected for the Doordewind area. So determining the effects on the guillemot population (due to habitat loss) deserves special attention. This will have to be investigated in the follow-up phase. The barrier effect is not significant due to the size and situation of this area. Given the proximity of the Frisian Front N2000 area, avoidance effects on guillemots there cannot be ruled out in the event of greater disturbance distances than assumed to date (knowledge gap).
- For **marine mammals** (**harbour porpoises**), effects of disturbance are expected during construction;
- It is likely that the Doordewind area, due to its northerly situation and the large distance from the coast, is of less interest to **seals**. The effects are therefore minimal.
- For **bats**, it is assumed that the area is of less interest, due to its northerly situation, although this is an assumption based on expert judgement.
- The sea floor in Doordewind is slightly more silt-rich than that in Lagelander (but less silt-rich than the middle section of search area 6/7). The model results reveal that the ecosystem effects, such as **turbidity**, and a reduction in **algal bloom** are to be expected. This effect may well, in part, be caused by wind farms in the adjacent German North Sea.
- The area does not have special importance for protected **fish species** or species that are important due to their place in the food web, hence there is not expected to be an impact on populations. The area is suitable as a habitat for flat oyster (banks), but these are not currently present.

Mitigating measures and phased approach

There are still various knowledge gaps, hence the recommendation for a roll out of offshore wind energy that is phased and adaptable. That makes it possible to use the results of in-depth research to develop

plans and measures. Phasing is primarily important in the case of guillemots and harbour porpoises, and also offers the opportunity of filling other knowledge gaps. See also conclusions and recommendations.

In addition, efforts will target mitigating measures (and their development). This includes:

- **Reducing bird victims of collisions**: temporary stopping of turbines during passage of specific critical species or migration. This can be done in various ways, both reactively (with detection) and proactively (based on predictions). These techniques are already prescribed in specific existing permits and are already in use on land. Another method is to increase the height of the tip lowest level to prevent collisions. This is where the distance between the surface of the water and the lowest point of a turbine rotor blade is increased.
- **Reducing bird habitat loss**: mitigating measures to reduce habitat loss must still be developed. There are indications that distance between wind turbines, sight lines and configuration all play a role in the extent of habitat loss. Research into possible mitigation of these effects is under way and is scheduled for the coming years.
- **Reducing barrier effect**: mitigating measures must still be developed to reduce barrier effect. These measures may include creating corridors and adjusting the configuration of wind farms. Research into possible mitigation of these effects is running and is scheduled for the coming years.
- **Reducing 'attractiveness' of wind farms**: the lighting of wind farms may attract birds (not least migratory birds) and bats, increasing the risk of them becoming victims of collisions. Adjusting the lighting, or merely activating lighting when needed, may mitigate attractiveness.
- **Reducing bat collision victims**: a mitigating measure would be to stop the turbines, or to reduce the rotation speed of the rotor blades during the migration period, under specific weather conditions.
- **Reducing the effects of impulsive sound in water**: there are various possibilities for limiting the adverse effects of underwater sound on marine mammals when constructing wind farms. A noise standard has been imposed allowing mitigating measures, such as bubble screens, to be used in existing construction projects. Furthermore, the use of species-specific Acoustic Deterrent Devices, which encourage animals to swim away from the sound, may prevent adverse effects on hearing. Other types of deep foundation, methods that do not involve pile driving and produce no or very little underwater sound are relevant mitigating measures. There is a lot of research currently being done into such noise-reducing foundation methods.
- **Reducing possible effects during maintenance in the wind farms**: maintenance vessels have an effect due to underwater sound or visual disruption. Measures to mitigate against this include the use of quieter (electric) vessels, an optimised logistics programme, anchor buoys and working with ROVs (remotely-operated underwater vehicles) and/or drones.
- **Reducing ecosystem effects**: wind farms may change the water flow, causing effects such as turbidity and algal bloom (ecosystem effects), for instance as a result of effects on the timing and duration of summer stratification. Modelled studies suggest that the right configuration of wind turbines and the deployment of relevant corridors may help mitigate any ecosystem effects. This requires further development.

1.4.3 Fisheries

There are fisheries throughout the North Sea. Commercial fishing focuses on demersal (groundfish) and pelagic (non-groundfish) fish. Demersal fish include sole, plaice, mullet, squid and langoustine. Pelagic fish include herring, mackerel and Atlantic horse mackerel. In the areas investigated in the SEA, commercial fishing focuses on sole, plaice and, in particular, langoustine (search area 6/7). The Strategic Environmental Assessment looks at the (relative) **contribution to total food production** per type of fishery (quantitative effects) and at the **significance of the various areas to the sector**, supply chain and fishing communities. The key effects per area are described below.

Search area 6/7

With an average annual catch value of € 330 per km^2, search area 6/7 represents a relatively lower value than the Doordewind and Lagelander areas. However, the area is large and, taken as a whole, corresponds to an average annual catch value of around €1.5 million. There are considerable variations in the use of the area by different types of fishing. For Urk, the fishing region for which the area is most important, search area 6/7 represents around 1.3% of the local catch from the Urk pelagic trawler cutter fleet (from the whole North Sea, including the waters of neighbouring countries). Search area 6/7 is of limited importance in terms of **beam trawling for sole and plaice**) Search area 6/7, as a whole, represents 0.5% of the total annual catch of sole (whole of the North Sea, including waters of neighbouring countries). However, search area 6/7 is particularly important for **otter trawling for langoustine**. The annual langoustine catch (from the whole of search area 6/7) is around € 0.8 million, which represents 7.9% of the total langoustine catch (in the whole of the North Sea). This percentage is so high because langoustine are found only in high concentrations in specific habitats, which is why langoustine fisheries are highly site-specific. The middle of search area 6/7 is one of those specific areas for langoustine fishing: the water is deeper and more silt-rich. If the middle of this area is kept (partially) open, it can still be used as a langoustine fishery. The scale of the effect of wind farms on langoustine fisheries depends on the shape, location and size of an open zone of this kind.

The effect on beam trawling in search area 6/7 is comparable with a potential catch loss of between € 485,000 and € 593,000 for the extremes and for all funnelled variants. The differences are small, because beam trawling is generally confined to the eastern section, in which wind farms in all variants are anticipated. The effect on otter trawling for langoustine shows a greater difference (between € 100,000 and € 792,000) between the most favourable funnelled variant and the wind energy extreme. By retaining an open zone in search area 6/7, the effect on langoustine fisheries will be very restricted. In the variant with a basic open zone, around 70% of commercial langoustine fishing in search area 6/7 will be preserved; in the variant with the widest open zone, this is around 85%.

Lagelander

With an average annual catch value of € 887 per km^2, Lagelander lies between Doordewind and search area 6/7. In this area there is no otter trawling for langoustine. The most significant form of commercial fishing is **beam trawling for sole and plaice**. The space that is necessary to generate 2 GW (200 km^2) represents around € 178,000, or 0.20% of the total annual catch from beam trawling (whole of the North Sea, including waters of neighbouring countries). For the *Kop van Noord-Holland* region the area is the most important, in relative terms, with a larger proportion of the catch value of the local beam trawling fleet. At the same time, it should be noted that catches landed from this area have declined in comparison with previous years. This may (in part) be to do with restructuring of vessels in the *Kop van Noord-Holland*, which were primarily involved in this area.

Doordewind

With an average annual catch value of € 2,293 per km^2, Doordewind is more valuable, in relative terms, than Lagelander or search area 6/7. The most important of the fisheries is **beam trawling for sole and plaice**. The annual catch value from beam trawling corresponding to 200 or 400 km^2 (to generate either 2 or 4 GW respectively) is around € 446,000 - € 891,000, or 0.39 - 0.78% of the total catch value for beam trawling in the whole of the North Sea (including from waters of neighbouring countries).
Otter trawling for langoustine is very limited. Urk is the most dependent on this area with the highest proportion (in relative terms) of catches landed locally by the beam trawling fleet.

The previously designated part of Doordewind is more valuable in relative terms than the additional Doordewind (west) section. A decision on generating +2 GW would have fewer implications for the fisheries than opting for +4 GW and would potentially have even less effect if a 2 GW site were created further to the west.

Permitting active commercial fishing within wind farms as a joint use function (partially) could potentially **mitigate** the loss of space, subject to a feasibility study.

1.4.4 Shipping

To assess the effects on shipping, we have looked into two aspects: the **accessibility** to shipping, for both route-specific and non-route-specific traffic, and the effects on **shipping safety**. Modelled calculations on the risk of shipping incidents have been made so that we can make quantitative statements on shipping safety. These are supplemented with qualitative expert judgement. Accessibility has only been viewed qualitatively. The risk of shipping incidents is calculated for each wind farm zone (Lagelander, Doordewind, search area 6/7 and the areas in the baseline situation) and cumulatively for the areas considered in this SEA. As the areas in question differ greatly in size, a relative comparison on the risk of accidents caused by collision or drifting has been made for each wind turbine. This shows how the effects per area relate to each other and how to compare the risk of collision in the light of other offshore wind farms that are already part of the baseline situation. The effects for each area are summarised below.

Context: total effects on the North Sea
Cumulative calculations reveal that the total number of incidents calculated in our models is rising by 0.114 - 0.257 each year, depending on how capacity in search area 6/7 is used. The number of wind turbines is very significant in that respect. Search area 6/7 has the lowest risk of accidents caused by collision or drifting per individual wind turbine of all wind farm zones on the North Sea. Where shipping safety is concerned, search area 6/7 has relatively little effect (per wind turbine) in comparison with other areas.
As the area is relatively large, there is no 'fragmentation' of wind farms; shipping intensity in the northern section of the North Sea is relatively low compared with the southern section of the North Sea.

Search area 6/7

Safety hazards in the area are generally caused by the fact that the southern edge of the area is marked by relatively long contour lines along busy shipping routes. The size of the area means that there is a certain amount of pressure from route-specific traffic heading to adjacent shipping routes, particularly if there is no open zone. Traffic destined for the wind farm covers relatively long to long distances within the wind farm, passing wind turbines, which increases the risk of a collision. The size of the area may complicate SAR operations. Compared with Lagelander and Doordewind, the installation of wind farms in search area 6/7 has fewer implications for shipping per GW. That also applies if search area 6/7 is compared with other wind farms on the North Sea in the baseline situation. If search area 6/7 is designated with an open zone, about 100% more wind turbine capacity will be available, while the number of incidents with vessel/turbine collisions/drifting incidents will increase by less than 20%.

The calculated number of incidents if search area 6/7 has no open zone (wind turbines throughout the area) is 0.1658 per year. If the area configuration includes an open zone, this number varies from 0.0522 (extreme combination variant with least wind energy) to 0.1009 (variant comparable with basic open zone). If capacity in search area 6/7 is used to its fullest extent there will be considerably more wind turbines and, with this use of capacity, more wind turbines will be sited adjacent to busy shipping lanes. The effects on shipping safety will therefore be assessed less negatively in variants with an open zone than those without, except where this zone offers sufficient space for creation of a safe clearway. In that case, the availability of an open zone would also be important for the accessibility of both route-specific and non-route-specific traffic.

Lagelander

Shipping intensity is said to be high around this area. Using the capacity of Lagelander exclusively for wind farms would form a barrier to east-west shipping traffic and loss of space for other shipping functions that currently take place in the area (such as drifting). Furthermore, local traffic would be squeezed onto shipping lanes in the busiest part of the North Sea, which presents a heightened risk. This means that wind farms in the Lagelander zone are relatively (per wind turbine) more effective than in the other investigated zones.

Doordewind

Where the Doordewind wind farm zone is concerned, the risk of collisions and drifting incidents is relatively low. The number of vessel/turbine collisions/drifting incidents in this wind farm zone (assuming a decision to generate an extra 4 GW) will increase by around 8%, while the wind turbine capacity will increase by nearly 20%. The recommendation is to add Doordewind (west) to the zone to create a fluid transition to the German wind farms. This would prevent shipping from 'hitting a wall' of wind turbines when moving into German waters, which would increase the risk of accidents. There would be relatively little squeezing of non-route-specific traffic, in particular, onto adjacent shipping lanes.

Mitigating measures that reduce risks

There are a number of spatial measures that promote shipping safety. These include:

- **Greater distance** to crossings: in some places, it may be locally necessary to incorporate more space than the usual 2 NM distance between wind farms and shipping lanes. This is particularly the case when crossing busy traffic separation schemes (TSSs), where it is important to avoid endangering shipping using the traffic lanes, in the furthest south-west corner of search area 6/7 and at the corners of a potential open zone. The point here is that the corners of wind farms must be 'blunted'.

- **Routing measures**: the purpose of routing measures is to improve shipping safety. Experts have specifically recommended an adjustment to the nautical configuration at the Botney Grounds TSS.
- **Emergency Response Towing Vessel (ERTV):** A drifting incident due to a malfunction in the propulsion of a vessel may be prevented. Options available are to drop anchor, or to repair the malfunction. A third option for preventing a drifting incident following a malfunction is for a towing vessel to intercept a drifting vessel. In this event, a towing vessel (ERTV) of the Dutch authorities is sent to a 'drifter' as soon as the Coast Guard receives an alert.
- **Search and Rescue (SAR)**: Extra SAR capacity will, in particular, have an impact on the consequences of accidents for the crew of vessels and workers in the wind farms. Wind farms further out to sea may demand extra SAR capacity and facilities, in response to which a number of options are conceivable. Among these is the deployment of extra craft and/or repurposing existing craft for SAR operations (e.g. Emergency Response Towing Vessels (ERTVs) or Coast Guard multi-purpose craft).

1.4.5 Drilling

In and around the areas to be investigated for wind energy are existing drilling platforms and there are prospective (identified) resources for future drilling activities that may lead to new platforms being built for oil and gas production, and for CO_2 and H_2 storage. Depending on the type of platform, operators use helicopters for transportation to and from the platform. Whether or not a platform can be accessed safely by helicopter is influenced by the space available on the platform. If wind turbines are built in the vicinity of platforms, this may affect helicopter accessibility of such platforms. Where accessibility is compromised, this may have implications for the extent to which operations on the platform are viable.

The required level of accessibility tends to differ, depending on the sort of platform and the development life-cycle phase. It is difficult to make specific statements on this in advance, and it is difficult to estimate what the effect of reduced accessibility is without specific analysis of each individual platform. In addition, it is also uncertain whether prospective resources are actually recoverable. Hence, this appraisal of effects is solely an estimation of the effects on helicopter accessibility, although without a rating scale.

To70 conducted an accessibility analysis to make a quantitative estimate of the effect on helicopter accessibility for search area 6/7. This was done only qualitatively for Lagelander and Doordewind. In the case of Lagelander, this is because without a precise position for the 2 GW-site within the zone, it is impossible to estimate the effects on helicopter accessibility. For Doordewind, quantitative accessibility analyses have already been conducted as part of the refinement of the 21 GW Road map (the baseline).

In addition to space for helicopter accessibility, space around CCS platforms may be needed for seismic monitoring of injected CO_2. This required space is referred to in the SEA, although it is not quantified and the effects of this have not been determined. The required space does depend on the technology used and the shape of the expended gas field in which captured carbon can be stored.

Search area 6/7

When estimating the effect on offshore helicopter accessibility for search area 6/7, we assessed the feasibility of four different flight paths per platform. The procedure that can be deployed depends on visibility and the available space around the platforms, and may also depend on the type of helicopter.

19 platforms, generally prospective resources, were considered to estimate the effects within search area 6/7. This included the difference in accessibility before and after construction of wind turbines. The results show that it is important to have an open zone in search area 6/7 for proper accessibility of platforms. In funnelled variants, the difference in the size of the open space has little effect on helicopter accessibility, although the space reserved around the platforms is important. Where an exclusion zone has a diameter of 2.5 NM, there is less space for helicopter accessibility and more space for wind energy than where the radius measures 5.0 NM.

A number of assumptions that are not yet certain were used to make these estimations. It is assumed that the 'Point in Space' (PinS) procedure can be used on the North Sea, but this is yet to be demonstrated. Another such assumption is that where there is an exclusion zone of 5 NM around the platform, supplemented by an open zone, accessibility is 95%, although that could be lower given the assumed wind turbine height. So there is a chance that the effect on accessibility has been underestimated. In-depth investigation is needed for individual platforms to achieve more precise estimations.

Lagelander

Lagelander has high drilling activity; there are currently 11 platforms in the zone. There are also opportunities for CCS in and around the zone. If wind turbines are built in the zone, this will also create considerable accessibility losses due to the large number of platforms. Future generation of 2 GW-worth of wind farms is possible only with an intensive unique process involving the relevant drilling operators, covering both helicopter accessibility (of existing and new platforms) and seismic monitoring where there is CCS. If this is successful, there will be no impact. However, it is currently in no way certain that this will succeed.

Doordewind

Unique solutions are being investigated in relation to helicopter accessibility for Doordewind. The designation of DDW (west) will increase the available space in the zone as a whole. That increases the available space for helicopter accessibility. The assumption is that 'tailor-made' unique solutions are feasible and acceptable to the relevant drilling operator. For that reason, the impact on helicopter accessibility is assessed as neutral where there is a configuration of +2 GW, if Doordewind (west) is also utilised for this. This unique solution will not be possible if a configuration of +4 GW is realised, which is why the impact of this is considered negative.

1.4.6 Cultural heritage

Archaeological assets can be found on the sea floor or in the seabed, throughout the North Sea. These possible archaeological assets may, for instance, take the form of shipwrecks or aircraft wreckage, or prehistoric remains. Some of these have been charted, whereas others are still to be detected. In the context of the SEA, we have assessed the (known) presence of various archaeological assets within the zones. No activity that disturbs the sea floor may be carried out in a 100-metre zone around (potential) archaeological assets.

Search area 6/7

Differences between the extremes and the funnelled variants are very limited, where known archaeological assets are concerned. The section to the east of the open zone has a higher density than the section to the west of the open zone. These average densities are relatively low. Within the design of the wind farm, it is possible to take into account the known archaeological assets when determining the sites of wind turbines. According to the *Indicatieve Kaart Archeologische Waarde* (Indicative map of archaeological assets, IKAW) the chance of such finds is low. As an effect cannot be completely ruled out in advance, this has a slightly negative assessment in the SEA.

Lagelander and Doordewind

Known assets are present in Lagelander that may be of archaeological relevance. This is also the case for Doordewind, but to a lesser extent. In both zones, the density is so low that no negative effects are expected. Within the design of the wind farm, it is possible to take into account the known archaeological assets when determining the sites of wind turbines. According to the IKAW, the chance of finds is low in both zones. Based on what is currently known, both zones have been assessed as 'slightly negative'.

In relation to archaeological assets, degradation can be prevented by 'micro-siting' or by digging up the archaeological assets. Micro-siting means that when the site for construction of a wind farm is chosen, the wind turbines or cables can be positioned in such a way that they are not in conflict with the archaeological assets, which can be preserved. Extra research at a later stage can ascertain the location and relevance of archaeological assets precisely, after which the wind turbines and/or cables can be adjusted so that they are sufficiently far from the archaeological assets. The conclusion is that, when compared with each other, the zones are not distinctive in terms of cultural heritage.

1.4.7 Energy return

This aspect assesses the installed capacity (number of GW) per zone, the expected energy return (GWh per year) and prevented emissions (tonnes of CO_2, NO_x and SO_2 per year). In addition, the Levelised Cost of Energy (LCoE)[3] was also considered, as this is an indicator of the profitability of a wind farm in relation to a benchmark wind farm (IJmuiden Ver Alpha).

Search area 6/7

For search area 6/7, the effects of the extremes and the basic open and widest open zone funnelled variants have been estimated. The extreme in which all space is allocated to wind energy (37.4 GW) is more than enough to meet the task for this PR. This would allow 137,000 GWh to be generated per year, preventing 58,200 tonnes of CO_2 emissions.

Of the funnelled variants, in the widest open zone 19 GW could be positioned and in the basic open zone, 21 GW. The energy returns vary from max. 70,700 GWh per year (widest open zone) to 79,400 GWh per year (basic open zone). This energy return corresponds to 29,100 - 33,700 tonnes of prevented CO_2 emissions. The difference in installed capacity between the funnelled variants is a maximum and not rounded off, around 2.7 GW, while the difference in net energy return is 11%. The funnelled variants - with space for around 19 - 23 GW – approach the task of generating at least 23-26 GW, which would

[3] The focus of the LCoE calculations is on the impact of technical parameters, not including market developments.

require extra space, while there are also uncertainties in relation to required space for drilling and nature.

If search area 6/7 is completely filled with wind turbines, this will lead to a less favourable LCoE. This is primarily because the wake effect increases in parallel as the number of wind turbines in the zone increases, although also because the foundation expense increases slightly as the installed capacity rises. The latter is because the water depth in the central section of search area 6/7 is greater. The remaining LCoE parameters (cable expenses, capital expenses and operational expenses relating to wind turbines and inter-array cable losses) are not distinctive for the various variants. The variant with the widest open zone (~19 GW) has, on average, almost the same LCoE as the baseline wind farm (-0.1%) and the variant with the Basic open zone (~21 GW) has, on average, a slightly higher, i.e. less favourable LCoE (+1.3%). This is an average LCoE; lower LCoEs are expected on the edges of the wind farm zone than in the middle. So, it is advisable to examine the possibilities for optimisation of site layout.

Lagelander and Doordewind

In the Lagelander wind farm zone, there is space for 2 GW of installed capacity; this corresponds to generation of 8,000 GWh of energy per year, leading to 3,390 tonnes of prevented CO_2 emissions. The LCoE compared with the baseline, with -11.2%, is the most favourable of all variants. This is the result of the low wake effects, in particular. In Doordewind, there is space for 2 or 4 GW of (extra) installed capacity, potentially generating 7,700 and 14,500 GWh respectively. This leads to 3,390 and 6,610 tonnes of prevented CO_2 emissions respectively. Both variants in the Doordewind zone have a more favourable LCoE (compared with the baseline wind farm). In the case of + 2GW (-6.2%), this is better than in the case of the +4 GW variant (-2.2%). The difference between them is caused primarily by the increasing wake effects of higher wind farm density in the zone.

1.4.8 Electrical infrastructure and hydrogen production

Electrical infrastructure

The Offshore Grid connections outside the wind farm (inc. hydrogen pipes) are considered in the pVAWOZ Economic Impact Assessment. The decision-making process involves close consultation between the pVAWOZ and the PR process. In this SEA, assessment has been confined to the effects of the platforms required and the section of the 'offshore grid' cable/export cable within the boundaries of the zones investigated. Effects are expected on ecology (benthic fauna, fish, marine mammals, bats and birds) and shipping. These effects generally have less of an impact than the effects of building and operating the wind farms, but are not quantifiable in detail in this phase as actual configuration of the zones is fundamental to the scope of the effects. The infield cables in the wind farms are part of the initiative that is under investigation in this SEA plan and are dealt with in the other sections, relating to the effects of the wind farms, where relevant.

Hydrogen production

Offshore wind energy landing will, in future, potentially be made after conversion of electricity to hydrogen (offshore hydrogen production). Offshore hydrogen production is largely still under development. Initially, a decision must be made as to whether offshore hydrogen production is viable in the zones to be designated. Then, important system choices, such as on the amount of hydrogen production and its configuration (e.g. centralised or decentralised hydrogen production) will still have to be made. That is why the SEA only considers the potential effects that are expected for offshore hydrogen production qualitatively. The investigated bandwidth in that respect is an amount of hydrogen production that

corresponds to 0 - 10 GW of wind energy. Various system choices are also under consideration. We also looked into the options of a closed or open cooling system and centralised, decentralised or semi-centralised layout.

When considering this, it was important to distinguish between known environmental effects and hydrogen-specific environmental effects. The known effects are comparable with those of building an offshore platform and laying out cables and pipes. Hydrogen-specific environmental effects are those as a result of water abstraction, heat output (including cooling water), brine, discharge of chemicals, and noise and vibrations.

The actual configuration of the zones (centralised or decentralised hydrogen production) and the technology used (open or closed) have a significant impact on the effects. Air cooling, compression on land and a closed cooling system emerge as the most significant system choices with which ecological effects can be avoided. Air cooling and a closed cooling system mean that water does not need to be abstracted in such large quantities, while compression on land reduces the effects of vibrations, which spread further through water than through the air.

As stated, a lot is still unknown about the system choices to be made and the potential effects they will exert on offshore hydrogen production Hence, an assessment has not yet been made although knowledge gaps, in particular, have been identified.

1.4.9 Cumulative effects

In this SEA, we look into the cumulative effects between the different potential wind farm zones (search area 6/7, Lagelander and Doordewind) and into cumulative effects with (future) developments on the North Sea that offer relative certainty and specificity. However, the required clarity can only be sufficiently given in respect of wind-farm developments. There are still too many uncertainties and knowledge gaps on the future development of other activities that it is not possible to make any statements on potential cumulative effects. The section on cumulative effects addresses the relevant uncertainties and knowledge gaps in greater depth. Below is a summary of what the cumulative effects for wind energy and possible wind-farm development in neighbouring countries investigated in this SEA plan are.

Cumulation among potential wind farm zones (search area 6/7, Lagelander, Doordewind) themselves

In determining what the cumulative effects of various wind farm zones are, we looked at different options for distributing the total number of GW among different areas (distribution options, see Table S1.7). If the available space for wind farms in Lagelander, Doordewind and the funnelled variants for search area 6/7 is added up, the various areas together offer space for a total installed capacity between around 19 and 25 GW. This sum takes into account an open zone in search area 6/7 and 2 GW in Doordewind, as it has been decided that 4 GW in this area is only feasible if a sufficient exclusion zone around a drilling platform is disregarded.

Table S1.7 Cumulative configuration of the wind farm zone task: distribution options for installed capacity**

Area	**Installed capacity and its distribution over the areas (GW)**					
Search area 6/7 Basic = basic open zone Widest = widest open zone	Basic ± 21	Basic ± 21	Basic ± 21	Widest ± 19	Widest ± 19	Extreme wind energy ± 37
Doordewind	2	2	0	2	0	4
Lagelander	2	0	2	2	0	2
Total	± 25	± 23	± 23	± 23	± 19	± 43*

* this is the 'worst case' option
** there are more possible combinations, however the angles of the playing field in terms of cumulative effects are covered with these configurations.

At the same time it may be the case that more energy than 25 GW is indeed possible, due to the lack of drilling platforms (for prospective resources). For that reason, the distribution option has been incorporated in a configuration of search area 6/7, in which no open zone is kept free (wind energy extreme), in combination with 4 GW in Doordewind and 2 GW in Lagelander. Viewed from the perspective of most interests other than wind energy, this a 'worst case' distribution option that offers space for around 43 GW in installed capacity. Potential (extra) effects of this worst case distribution option compared with the other distribution options will be discussed below, separately in each case, on the various sub-aspects.

This involves cumulative effects for the following topics (ecology, shipping, fisheries and energy return). The cumulative effects on shipping safety and accessibility have already been integrally incorporated in the studies and assessment and, as a result, are not included here individually.

Ecology - birds and bats

The number of wind turbines in the array is generally decisive for the effects of **collisions involving sea birds, migrating birds and bats**. Most of the effects, then, are to be expected from the combination of the basic open zone variant for search area 6/7 with 2 GW in Lagelander and Doordewind (assuming that the installed capacity per wind turbine is the same). The effects are least if, in search area 6/7, in the widest open zone variant there are no wind turbines and, as a result, merely 19 GW is installed. In addition, precisely in this section of 6/7, increased densities of a number of bird species are to be expected. Not positioning wind turbines here would prevent excess collisions.

Cumulative effects of **habitat loss** for sea birds are more difficult to assess, specifically where this concerns the effects on guillemots. Based on the available information, it is expected that the configuration of search area 6/7 will generally be decisive (the wider the open zone, the better); however, to achieve the minimum target for wind energy of 23 GW, the funnelled variant with the basic open zone must be combined with both Doordewind and Lagelander. On the basis of the information currently available, Doordewind does, however, appear to be an important area for guillemots. It is not possible to use current knowledge to predict what will have the least impact: a wider open zone (i.e. fewer wind turbines) in search area 6/7 or no extra wind turbines in Doordewind.

Potential effects of a **barrier** will primarily play a role in search area 6/7, as this area is situated between the protected Dogger Bank and MSFD Central Oyster Grounds areas on the one hand, and between the Frisian Front and the rest of the southern North Sea on the other. Birds that arrive from the breeding colonies to the north-west of search area 6/7 after the breeding season and are forced to fly or swim

a longer route due to the presence of a large, unbroken wind farm may well lose lots of energy. Where distribution options in which an open zone in search area 6/7 is kept free of wind farms, as is the case in the funnelled variants, such barrier effects can be prevented. There are still knowledge gaps on the extent to which a barrier effect can be prevented. The larger the open zone and the greater the number of sight lines, the smaller the barrier effect will be. There are still uncertainties on the extent to which this effect can be prevented. For that reason, further research is necessary. This will be dealt with in greater detail under conclusions and recommendations.

The cumulative effects of the **worst case** distribution option (43 GW) are worse than the distribution options discussed above, not least because search area 6/7 is completely filled with wind farms. This is particularly due to the large number of wind turbines. In addition, the effects of habitat loss and barrier effect (guillemots) will be greater if there is no open zone.

Ecology - marine mammals

The cumulative effects on porpoises will largely be determined by the number of wind turbines (= number of disruption days) and as a result, of the options with an open zone through search area 6/7, the greatest effects are to be expected in the 25 GW distribution option, in which the basic open zone for search area 6/7 is combined with 2 GW in Doordewind and 2 GW in Lagelander. According to the calculations, this distribution option results in around 2.0 - 2.1 million porpoise disturbance days which, when aggregated with the effects of the 21 GW Roadmap (baseline situation), may lead to an indicative fall in the porpoise population on the Dutch section of the North Sea of around 8.0 - 8.2%.

The cumulative effects of the **worst case distribution option** are greatest, particularly due to the large number of turbines in search area 6/7. This is because the number of wind turbines is decisive for the effect on marine mammals, as this has a direct relationship with the number of disruption days. This is considerably higher (around 1.2 million more porpoise disruption days than in the option with around 25 GW). The estimated reduction of the porpoise population, in this case, is around 11%.

Fisheries

The various distribution options have also been assessed in terms of the fisheries. In the event that both search area 6/7 and Lagelander and Doordewind are used for the maximum possible deployment of wind farms (43 GW), this would lead to missed annual catch value of around € 2.6 million for the beam trawling and otter trawling fisheries together.

Energy return and prevented emissions

For energy return and prevented emissions, the effects are positive. If the combination with the highest energy option (43 GW) is created, a potential energy return of 167,100 GWh could be generated. However, this option has a relatively high LCoE in relation to other configurations (+3.5%), as a result of the large wake effects in search area 6/7. In the event of an open zone in search area 6/7 and full wind-turbine capacity for Lagelander and/or Doordewind, the aggregate energy return will fall (between 87,100 and 101,600 GWh per year), but achieve a better LCoE.

Aggregation with offshore wind farms outside the Dutch territorial waters

Offshore wind farms are also being developed in neighbouring countries: Germany, Denmark, Belgium, the UK and Norway. It is expected that there will be cumulative effects for aspects classified under the topics ecology, shipping, energy return and drilling.

Ecology - birds

There will probably be cumulative effects for **non-breeding bird species** due to collisions, disruption and barriers. For a number of species, it will be impossible to exclude significant negative effects for the partial revision in cumulation with the international development of offshore wind energy In the international context, consultation is required on measures that can be taken on a country-by-country basis to prevent these, while in-depth research and a phased approach are recommended (see section 1.7.2).

Ecology – bats

A section of the future British wind farms are sited on the line followed by **bats** migrating between the Netherlands and the UK. This means that international cumulative effects on migrating bats cannot be ruled out.

Ecology - marine mammals

In combination with the wind farm ambitions in neighbouring countries significant effects on the porpoise population cannot be ruled out, as this is also the case when combining the areas studied in this SEA. However, in that respect there are also other knowledge gaps and possible mitigating measures that needs to be further explored (see also 1.7.2).

Shipping, energy return, helicopter accessibility of drilling platforms

Where shipping is concerned, vessels on international shipping lanes will have to pass wind farms in new zones in neighbouring countries, which may bring about a change in shipping intensities.
Such changes have already been incorporated in the context of the appraisal of effects on shipping, as the calculation models used for shipping intensities are based on Dutch, German and Danish planning.
Potential closure of shipping lane SN17 in Germany will have an impact on accessibility. Experts advise certainly configuring search area 6/7 with an open zone in that case. Given that plans in the Netherlands are focused on the German border, there is less interaction with future British wind farms. As yet, there have been no indications of potential bottlenecks due to aggregation of wind farms within the UK EEZ.

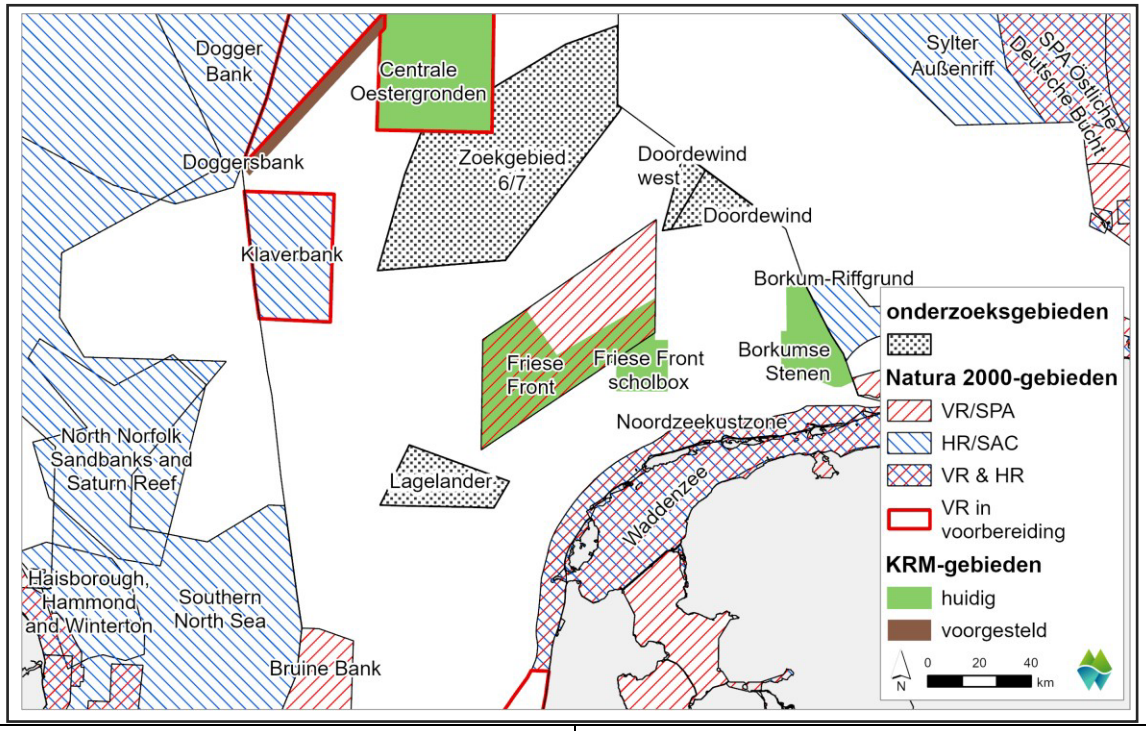
When estimating the effects on helicopter accessibility, it was assumed that there are wind farms on the German side of the border, making any future drilling platforms in the north-eastern section of search area 6/7 inaccessible from the west. That is why cumulative effects of German wind farms have already been factored into calculations.

As far as energy return is concerned, the effects of wake losses between the wind farms play a role, certainly where the density/number of wind farms on the North Sea increases. An integrated study is currently being carried out by the Netherlands Enterprise Agency (RVO), the results of which will not be published until mid-2025. These effects have, thus, not been further quantified.

1.4.10 Cross-border environmental effects

The environmental effects in the Dutch section of the North Sea have been individually assessed in the various previous sections but, for certain topics, the associated effects do not stop at the border. We assess the effects that could arise outside the Netherlands below. Only Doordewind and Search Area (*Zoekgebied*) 6/7 are relevant in this respect. Lagelander is situated more than 40 km from the border, so cross-border effects are not deemed likely, with the exception of migrating bats to and from the British Isles (see below).

Figure S1.8 Map: Detailed overview of the site of research areas in relation to close, relevant Natura 2000 areas and MSDF areas on the coast and along the coastline of the southern North Sea.



Onderzoeksgebieden	Research areas
Natura 200-gebieden	Natura 2000 areas
VR	BD
HR	HD
VR in voorbereiding	BD in preparation
Huidig	Current
Voorgesteld	Proposed

Ecology - birds

Ecological studies have shown that **breeding birds** from all colonies in the protected areas in Germany and the United Kingdom do not traverse the three planned zones (Lagelander, Doordewind and search area 6/7). So, effects via direct external impact on breeding bird species in these foreign Natura 2000 areas can be excluded. For **non-breeding**, non-native **bird species**, there may be effects caused by collisions, habitat loss (due to disturbance) and barrier effect. The extent to which barrier effects arise depends, in part, on the scope and orientation of an open zone in search area 6/7. At this point, these effects cannot be further quantified and investigation in combination with a phased approach is recommended. See conclusions and recommendations.

Ecology – bats

Cross-border effects for **bats** are expected particularly as a result of the presence of wind turbines in

Lagelander. If migrating bats from populations in the United Kingdom cross the North Sea (or bats from European mainland populations cross the other way) there could be incidences of collisions.

The precise situation relating to bat migration in the vicinity of the wind farm zones will have to be investigated in greater detail. Whether there is any chance of an effect on a population from the United Kingdom is unknown. The precise situation relating to bat migration in the vicinity of the wind farm zones will have to be investigated in greater detail.

Ecology – marine mammals

Protected areas outside the Dutch territorial sea that are designated for marine mammals are Borkum Riffgrund (for harbour porpoise, harbour seal and grey seal) and Southern North Sea (for harbour porpoise).
Cross-border effects on protected species of marine mammal in neighbouring countries may arise if the quality of areas with conservation targets is compromised or if the plan compromises the conservation status of the species in the neighbouring country. Disturbance contours caused by underwater noise from the three search areas do not overlap with the Borkumer Riffgrund. Assuming a noise standard of 160 dB (Sound Exposure Level at 750 m), the noise contours do not overlap with the British protected Southern North Sea area either, where there is a conservation target for harbour porpoise.

Shipping

Cross-border effects on shipping in the British section of the North Sea do not apply if shipping traffic on the Esbjerg-Hull route is safeguarded due to the creation of a clearway. Cross-border effects on shipping in Belgium do not apply, given the location of the zones in relation to Belgian waters. Cross-border effects on shipping in Germany and Denmark have been investigated in the context of an international FSA, in which the German, Danish and Dutch planning is assessed jointly and, where the Dutch situation is concerned, the worst case distribution option (search area 6/7 with no open zone) is assumed. An open zone through search area 6/7 may, in comparison, lead to fewer cross-border effects.

1.5 Environmental assessment of sand extraction

The SEA assesses the effects of sand extraction in the 12-14 NM zone. The impact assessments of the various environmental aspects are summarised in a table below. The key conclusions are incorporated under the table.

Table S1.8 Impact assessment of sand extraction

Environmental topic	Sub-aspect	Assessment
Hydro-morphology	Effect on sediment transport (sand), current and morphology of the sea floor after extraction	0/-
	Effects on sludge and turbidity	0/-
Ecology	Habitat degradation	-
	Turbidity	0/-
	Sedimentation	0/-
	Surface water disturbance	0/-
	Underwater disturbance	0/-
	Effects on benthic fauna	-
	Effects on birds	0/-

Emissions	Effects on marine mammals	0/-
	Effects on N2000	0/-
	Effects on MSFD and OSPAR	0/-
	Effect on emissions	-
Fisheries	Effect on area covered and space overlap	0/-
Shipping	Effect on spawning beds, juvenile habitats and foraging areas	0
	Effect on shipping security	0/-
Cultural heritage	Effect on shipwrecks	-
	Effect on evidence of civilisation and palaeolithic landscapes	-

Based on the assessment, it seems that the expected environmental effects are comparable with those of current sand extraction, performed immediately adjacent to the expansion zone. The most important of these are:

- Effects on **hydro-morphology** are limited. The most significant effect is caused by a portion of the fine sand and the silt in the sediment that flows back into the sea (overflow), causing turbidity. This effect may be visible over great distances and over an extended period of time as a result of storms. The contribution in relation to normal concentrations of silt is very limited;
- Where the sand is extracted, **habitats are degraded**. This is the result of the presence of vessels (temporary disruption by noise and movement), the suction exerted on the sea floor and the resident benthic fauna and the discharge of transport water. Sand extraction activities primarily **affect** local **benthic fauna**. Complete removal of the sea bed to create sand-extraction pits does lead to full-scale mortality of benthic flora and fauna. This has long-term local effects on the benthos. Further on in the food chain, this also has temporary effects on the animals that live from benthic fauna, such as fish and, as a consequence, birds;
- None of the designated **Natura 2000 areas** overlap with the expansion zone for sand extraction. So, at most, the effect will be indirect. These effects depend on the technology used, duration and intensity of the sand extraction, and the sea current when the sand is extracted, but are expected to be limited;
- Extraction, transportation and replenishment of sand are associated with **emissions** of substances including CO_2, NO_x and SO_2. The difference in emissions is the same as the differences in fuel consumption. As the expansion zone is further away, the transportation distance and, as a result, the emissions will increase. Calculations indicate that a 50% rise in transportation distance means fuel consumption increases by 20-30%; It may be possible to mitigate this effect with technical measures on vessels;
- When sand is extracted, there is a temporary local ban on fishing. The effects on the **fisheries** within the 12 NM zone and in the zone between 12-14 NM are comparable. Forms of fishing that disturb the sea floor, particularly those that are active outside the 12 NM zone may be subject to greater disruption due to the expansion of the reservation zone. The expansion of this area is relatively limited in relation to the total available area, so effects will be restricted;
- Sand extraction may well have an effect on **shipping safety** where trailing suction hopper dredgers cross shipping lanes. Whether, and to what extent, this is a factor depends on the location of the extraction area. There will be a (very limited) increased risk of collisions in comparison with the situation without or with less sand extraction.

- Sand extraction may have effects on **archaeological assets** (including shipwrecks) and **assets of cultural/historical importance** (palaeolithic landscapes) on or under the sea floor. Wrecks of which the location is unknown may be discovered during sand extraction and be damaged. To prevent this, prior to designation of an extraction area sites must be investigated to avoid disturbing shipwrecks and palaeolithic landscapes.

Cumulative effects of sand extraction

There can only be cumulation associated with the development of wind farms at the point at which this occurs relatively close together in terms of time and location. The distance between search area 6/7 and Doordewind, and the expansion areas for sand extraction exceeds 55 km, so it is possible to exclude cumulative effects. There is less distance between Lagelander and the expansion area for sand extraction, yet this is still around 5.6 km. Furthermore, sand extraction is a short-term activity, so any effects will only be temporary in nature. There are two aspects for which (in theory) there could be cumulative effects, namely shipping and ecology.

Where shipping safety is concerned, there could be a (minimal) heightened risk of collisions because both trailing suction hopper dredgers crossing shipping lanes and the presence of wind turbines represent an increased risk of collision compared with the baseline situation. This effect cannot be further quantified, as it requires an understanding of the exact sand-extraction strategy and the layout of the wind farms. The presence of wind farms could also change non-route-specific shipping with the result of more (or less) shipping passing sand-extraction sites. It is expected that this effect will be negligibly small in relation to the total amount of shipping movements.

Ecological cumulative effects may arise as an indirect effect due to turbidity, where sand is extracted near Lagelander at the same time as a wind farm is built here. In this case, effects could play a role in the food chain as a result of silt and sedimentation. The sand will, in part, sink in and around the sand-extraction pit within the sand-extraction areas, but the silt will be spread over a larger area, potentially even as far as Lagelander. How great this effect is and what the precise consequences for the relevant species are cannot be accurately quantified at present (see also areas of uncertainty and gaps in knowledge), although it is expected that this effect will be negligible in relation to the dynamics naturally present in Lagelander and the fact that sand will only be extracted for a short period. Disruption resulting from the presence of vessels (noise/light) is unlikely, given the sizeable distances between the sand-extraction locations and the wind farm zones.

The cumulative effects between sand extraction and wind energy are negligible in scope and form no impediment to expansion of the reservation zone.

1.6 Areas of uncertainty, gaps in knowledge and monitoring

The effect descriptions and assessments in this SEA are made on the basis of state of the art knowledge. However, projects for which the PR is used to reserve space will not be implemented until well after 2030. This means that there are still many uncertainties about future developments and the exact configuration, not least within the wind farm zones. In addition, there are subjects that have not yet been addressed, or about which there is insufficient knowledge. The most significant uncertainties and the key gaps in knowledge are listed below, broken down into wind energy and sand extraction.

A knowledge gap that applies to both plans relates to the cumulative effects due to all activities on the North Sea and the significance of this for mutual relationships within the ecosystem. For instance, it is still uncertain whether there is a relationship between turbidity, algal bloom and food production.

Once the knowledge gaps have been discussed, the issue of monitoring arising from these gaps will be briefly addressed.

1.6.1 Areas of uncertainty on wind energy and focus areas on formulation of report

The following uncertainties could have an impact on the environmental assessment for wind energy in this SEA:

- **Ecology:** At this stage, ecological effects are generally judged in qualitative terms. It is impossible to predict the effects on populations prior to the period in which wind farms are built and are operational. What is more, the effects can be determined more accurately if more is known about the configuration of areas. In addition, there are also a number of knowledge gaps on which new insights will be obtained over the next few years, prior to the wind farm site decision. 1.6 addresses the gaps in knowledge, while 1.7 covers aspects including the way in which knowledge still to be acquired can be deployed in the follow-up process.
- This SEA and the accompanying OJ assume that the Central Oyster Grounds MSFD area will be designated a **BD area**. New knowledge on the use of the Dutch section of the North Sea by guillemots may have implications for the future delimitation of this area. The delimitation will depend on local guillemot densities over a period of several years. At this point, it is not possible to confirm this; investigations are in progress. There is a chance that parts of search area 6/7 may be designated as a BD area. This makes the issue of available space for wind farms in search area 6/7 uncertain.
- Plans relating to the cumulative effects in relation to **future wind farms in neighbouring countries** are still in development. This will become clearer and it will be easier to make statements about these cumulative effects in the follow-up process.
- **Shipping:** SN17 is a shipping lane within the German Exclusive Economic Zone (EEZ). Germany is considering closing this shipping lane as it aims to build a wind farm on this site. If SN17 is, indeed, closed this will lead to a slight increase in shipping traffic, particularly through a potentially open zone, and a slight fall in shipping traffic to the west of Doordewind. The potential closure of SN17 primarily has implications for the desirability of an open zone to offer sufficient choice of routes.
- **Shipping:** In the follow-up process, there will be increased attention to shipping safety in relation to non-route-specific traffic, as it was not possible to incorporate this in the model calculations due to uncertainties. There is also a level of uncertainty on how work traffic patterns will evolve when offshore wind energy further out to sea is rolled out. Other areas of uncertainty are the effects of a collision or drifting incident caused by a wind turbine, the effects of wind farms on crew behaviour (human factors) and the effectiveness of mitigating measures. The Offshore Wind Energy Shipping Safety Monitoring and Research Programme (MOSWOZ), among others, is investigating this.
- Where drilling is concerned, the effects on helicopter accessibility for existing platforms and possible **future drilling** for prospective resources has been assessed. This involves various types of uncertainty. Firstly, it is still not clear whether and, if so, when these prospective resources will actually lead to the establishment of a drilling platform. If the answer is no, then there will be more space for wind energy than calculated for the funnelled variants. Other drilling locations may also be added which, depending on the choices made, could lead to

less space for wind energy. Secondly, it is still uncertain how much space is needed for helicopter accessibility around platforms; this may lead to changes in estimations of helicopter accessibility or changes in the available space for wind energy and, as a result, the expected energy return. In the follow-up process, therefore, research is required into solutions for individual platforms and into 'space-saving' flight paths.

- In future, there may be a need for **CO_2 storage (CCS)** in or in the vicinity of the investigated areas. Choices to be made at a later date on the technology to be used to monitor the injected CO_2 could lead to an extra demand for space for CCS and, as a result, less space for wind energy, or to reduced feasibility of CCS.
- The economic catch values for **the fisheries** as presented tell part of the story, as the effect of an area being closed could exceed the presented figures, for example due to practical problems associated with fishing close to the edges of wind farms and possible restrictions in through shipping (passage) opportunities. In addition, a portion of the fish caught by vessels from outside the Netherlands on the Dutch Continental Shelf (DCS) is landed in the Netherlands. In terms of commercial langoustine fishing in particular, the landing of catches from search area 6/7 is probably underestimated. Many of those foreign-flagged vessels are under Dutch ownership and they land their fish at Urk or in other Dutch ports. Multiplication by two would probably yield a better estimate of realistic catch values.
- During the horizon of the developments for which this SEA has been drawn up, the effects of **climate change** are expected to continue. How this will manifest itself is unknown, but it may have implications for the environmental status of the North Sea.
- The SEA assumes an installed capacity of 20 MW per wind turbine, a maximum tip height of 303 metres and a density of 10.5 MW per km^2. As a result of technological developments, however, this may change and become greater (e.g. 25 MW), but there is also a chance that developments fail to live up to expectations and, for instance yield only 15 MW per wind turbine. **Capacity per wind turbine** has implications for the number of wind turbines within an area, the distance between them, the (tip) highest level, swept area and the foundations required. At larger capacities, the distance between turbines is greater and the wake effects are expected to be less. The consequence for the effects on **birds and bats** is difficult to predict, as the various changes in the properties of turbines influence the effect in different ways. In terms of the effect on collisions, the number of wind turbines is the decisive factor. As far as marine mammals are concerned, a larger capacity per wind turbine means that fewer turbines are needed (if the standard for percussive pile driving undertaken for offshore installation of foundations is applied) and there is less of an effect on **marine mammals** due to underwater noise. If there are fewer wind turbines, it is also expected that there will be fewer **destratification effects**. If wind turbines have dimensions in which the tip height exceeds 1000 ft (~305 metres), this may **interfere with aviation**. 1000 ft is the altitude at which air space for (commercial) aviation begins.
- Whether, and to what extent there will be any **hydrogen production** in wind farms is still uncertain; if this is the case, then there are still a number of system choices to be made that could determine whether there are any ecological effects on external safety.

1.6.2 Areas of uncertainty on sand extraction

The following areas of uncertainty may have an impact on the environmental assessment for sand extraction in this SEA:

- There are **areas of technical uncertainty**: The technologies and methods for sand extraction may change in future. Innovations in dredging technology and extraction strategies may reduce or increase the intensity of the effects on the environment. The level of emissions depends on the vessels used and the state of their technology. New shipping technologies may lead to lower emissions of CO_2, NO_x and SO_2. The transition to cleaner fuels such as biofuels, electricity or hydrogen may reduce the impact on the environment considerably.
- There are also **areas of ecological uncertainty**: The precise sites where sand extraction will take place within the expansion zone are not yet known. The environmental effects depend on the specific circumstances at the extraction sites. Sites closer to sensitive nature areas may have a greater ecological impact than sites further away. Climate change may also have a sizeable impact on the ecological status of the North Sea. Rising sea water temperatures, changes in salinity and acidification of the water may drastically alter living conditions for marine species. The species composition and the health of the ecosystem may be influenced as a result, which may have a knock-on effect on sand extraction.
- Lastly, there are **areas of spatial uncertainty**. Things like changing fishing practices, shipping intensity and the creation of new offshore infrastructure, such as wind farms and undersea cables. These developments may restrict the space for sand extraction or, indeed, broaden them and, as a consequence, influence the impact on the environment and other use functions.

1.6.3 Gaps in knowledge on wind energy

Further to areas of uncertainty on autonomous and technological developments, and on assessing the effects that will be determined in greater detail in the follow-up process, there are knowledge gaps that demand specific follow-up investigation. The key knowledge gaps are summed up below.

- There are **knowledge gaps on collision risks, barrier effect** and **disruption/habitat loss** for both migrating birds and sea birds as a result of wind farms. The missing knowledge relates in particular to species-specific knowledge, not least to disturbance distances for and (variations in) guillemot density. See also the recommendations in 1.7.2.
- The extent to which the results of the **population models** match the actual values and whether assumptions for the specific conditions in each area when calculating the effect on **marine mammals and birds** are correct.
- Research into the **presence of bats on the North Sea** is currently limited to the area to the west of the Netherlands. Very little is known about the presence or absence of bats in other parts of the North Sea, such as close to search area 6/7. Scheduled research is due to reveal whether the presence of a wind farm in this area could have an impact on populations of bats.
- The presence of wind turbines has **effects on stratification and, as a result, on algal bloom and turbidity**. Modelling of these effects is still in the initial phase of development. Physical changes such as these may, however, have an impact on the food web and may thus result in a

change in the species composition of fauna. It is unknown whether such changes could lead to effects on protected species.

- There is still a lack of knowledge on the **effect of electro-magnetic fields (EMFs) on fish and marine mammals**. Sharks and rays are sensitive to EMFs. Migratory fish and other fish species may be sensitive to EMFs. For porpoises, the extent to which their foraging behaviour and/or other forms of behaviour on sites in the immediate vicinity of electricity cables is affected is unclear. It is also unclear how (and whether) these effects have an impact at population level and for which specific species this is relevant.
- Activities in the **fisheries** may have to move as a result of the closure of areas for the development of wind farms. Movements of this kind may cause local increases in fishing intensity elsewhere, which may indirectly cause an increase in the impact of fishing on fish and benthic fauna, but the impact may reach further into the ecosystem and along the food chain to birds. The precise impact of this is unclear at present and requires further research.
- The impact on the **fishing chain and local fishing communities** are estimated in proportion to the amount of catches landed. The way in which the effects leave their mark on chain and the fishing communities could be better highlighted with in-depth quantitative research.
- The model calculations relating to **shipping safety** assess the risk of incidents, but not the impact they have. More must be learnt about the actual risks to be able to make any claims about them.
- The effects of potential **hydrogen production** on ecological aspects and external safety can, at present, only be stated in a general sense; this needs focused research.
- Where the effects of space-saving flight paths for **helicopter accessibility** for drilling platforms are concerned, it is important to make more detailed predictions using simulations and specifically-tailored studies.s

1.6.4 Gaps in knowledge on sand extraction

Two knowledge gaps have been identified for sand extraction:

- The way in which sustainability in shipping is going to evolve between now and 2100 is, at present, still unclear; hence the **average emissions** produced when extracting sand in 2100 is unknown.
- Knowledge about **palaeolithic landscapes** is progressing. Information from geophysical and geotechnical studies are needed to accelerate this process. The presence of **shipwrecks** and **archaeological remains** within the sand extraction areas is also, to a certain extent, unknown.

1.6.5 Monitoring

The gaps in knowledge identified in this SEA require research, for which monitoring can make an important contribution in a number of cases. For example, this applies to increased knowledge on the use of the North Sea by bird species and disturbance distances for birds, the extent to which habituation may occur, the impact of innovative mitigating measures such as limiting underwater noise, the impact of destratification on algal bloom and turbidity, and interactions within the food web. Monitoring can also provide greater understanding of the effects on shipping safety and the effectiveness of mitigating measures. Such monitoring issues may be incorporated, or have already been scheduled, as part of current programmes.

- The **MONS** (Monitoring - Research - Nature Enhancement - Species protection) programme aims to answer the central question of whether and how the changing use of the North Sea fits within the ecological capacity of the North Sea.
- The Wind energy ecological programme (Wozep) focuses on important ecological issues around the construction and operation of offshore wind farms, which tend to have a generic character rather than being wind-farm or site specific.
- The effect on shipping safety of offshore wind energy is being studied in depth in the Offshore Wind Energy Shipping Safety Monitoring and Research Programme (**MOSWOZ**). The objective of the programme is to gain better understanding of the effect of offshore wind farms on shipping safety and the effectiveness of mitigating measures, and to be able to respond to innovations in this field in good time.

Demonstration projects offer the opportunity to monitor these, where the impact of hydrogen production is concerned, potentially in combination with simulations. The same applies to helicopter accessibility for drilling platforms in space-saving flight paths.

1.7 Conclusions and recommendations

1.7.1 Wind farm zones

Important environmental information has been gathered for each topic and each area on the basis of the descriptions and assessments of effects in the SEA with the ultimate aim of being able to reach a decision in the PR. This involves the designation or otherwise of the three areas (search area 6/7, Lagelander and Doordewind) and the quantity of GW of wind energy within these zones; the key conclusions for each area are presented below.

Search area 6/7

If search area 6/7 is fully utilised for wind energy, there is space for around 37 GW. This is more than required and, more to the point, very detrimental to various aspects, such as nature, commercial fishing, shipping and helicopter accessibility. The most significant ecological effects are for **sea birds** (including guillemot, gannet, great skua) as a result of habitat loss, barrier effect and collision, and for **porpoises** (disruption due to underwater noise). In terms of commercial fishing, the central area of 6/7 is important to the **langoustine fishery**. This cannot easily move to other fishing grounds, as the fishery is highly site-specific and, indeed, reliant on this area. Wind farms in search area 6/7 have relatively limited effects on **shipping safety**, as the area is large and not fragmented, while shipping intensity is relatively low in comparison with the southern North Sea. The area has the lowest collision/drifting incident risk per individual wind turbine of all the wind farm zones on the North Sea. However, shipping accessibility is a point for attention due to the area's size.

If an **open zone** is created that splits the area into two halves, the effects referred to above will subside. An open zone, in combination with space around potential future drilling platforms, is also favourable for **helicopter accessibility**. This open zone varies in the funnelled variants from 1,320 - 1,620 km^2. Based on the spatial analysis, the required space for a safe clearway, which is important to **shipping safety and accessibility**, has been accounted for in the funnelled variants. Depending on the choices to be made about the ultimate size and layout of the open zone, there is **space for around 19 - 21 GW** in search area 6/7.

For commercial fishing, an open zone means retention of the most important fishing grounds for the **langoustine fishery**. Depending on the variant selected, 70% (basic open zone) to 85% (widest open zone) of this fishery can be retained in the area. For **porpoises**, the number of wind turbines is particularly decisive, which means that the largest open zone and the fewest turbines have the least effect. In terms of the **barrier effect** to sea birds (guillemot), apart from the size of the open zone, the location and the width of the opening for birds to enter are relevant. The extent to which the barrier effect and (in the same way) **habitat loss** can be prevented is uncertain: there are knowledge gaps on disruption distances (for the guillemot in particular) and effects on population level. So, research and incorporation of flexibility in the follow-up process is recommended. As far as the effects on birds due to **collisions** are concerned, the widest open zone should have the least such effects. For **helicopter accessibility** of drilling platforms, accessibility analyses revealed no striking differences between each of the funnelled variants. That effect is generally determined by the space around platforms and the applicable flight paths. Research is needed to work out specific space-saving flight paths, and also tailored research into the accessibility of individual platforms.

Doordewind

Both a +2 and a +4 GW option have been studied for Doordewind. Adverse effects for nature, commercial fishing and helicopter accessibility (for existing and potential future drilling platforms) are expected for both options. The key ecological effects are seen for sea birds (the guillemot in particular) as a result of habitat loss and collisions, and for porpoises (disruption due to underwater noise). Given the size and location of this area, barrier effect is not as significant as for search area 6/7. Doordewind has a relatively high catch value per km^2 for the **sole fishery** in particular, although the total annual catch value is limited and this fishery can (potentially) move to other fishing grounds. The risks to **shipping safety** are relatively limited. The expansion of Doordewind with Doordewind (west) ensures there will be a smooth transition to the German wind farms, which is beneficial from the perspective of shipping safety. In Doordewind, the +2GW option is not expected to have an impact on **drilling**, because it is assumed that tailored solutions for helicopter accessibility for an existing platform will be sufficient. If the +4 GW option were to be selected, there would not be enough space and there would be an adverse effect on helicopter accessibility.

Lagelander

If 2 GW were to be built in Lagelander, there would be adverse effects for nature, the fisheries, shipping and helicopter accessibility for (existing and potential future) drilling platforms. Lagelander is of less specific interest to **sea birds**, but potentially lies on a **bat** migration route. Disruption to **porpoises** due to underwater noise is also to be expected. The area is important for the sole fishery, although the total annual catch value is limited and this fishery can (potentially) move to other fishing grounds. Shipping intensity is relatively high around the Lagelander wind farm zone. The configuration would block east-west shipping traffic and take up space for other shipping functions that now take place in the area, such as drifting.

For that reason, the area is relatively unfavourable in relation to **shipping safety risks**. There is a lot of drilling activity in the area, both for **oil and gas production** and, presumably in the future, CCS. Future creation of 2 GW of wind farms will only be possible using an intensive tailored process with the relevant

drilling operators, incorporating both helicopter accessibility (for existing and new platforms) and seismic monitoring for CCS.

1.7.2 Recommendations for ecological study, measures and phased approach to wind energy

At this stage, significant effects on N2000 areas and protected species cannot be ruled out. This is because there are knowledge gaps on the impact on sea birds and porpoises. For that reason, the recommendation is to commit to research and use mitigating measures on the one hand, while on the other committing to flexibility in the follow-up process.

Firstly, the recommendation is to initiate the research and to commit to further development of mitigating measures. In relation to sea birds this means, among other things, research into the disruption distances of guillemots and the implications of this for designated BD areas. Another issue is the potential impact of habitat loss (related to disruption distances) and the consequences of that for the populations of sea birds (the guillemot in particular), and research into mitigating measures to limit this impact. In relation to the effects of underwater noise on marine mammals, this is about being able to predict effects precisely and conducting research into the effectiveness of new mitigating measures currently in development. This research may reveal that significant effects can be ruled out. Mitigating measures may also be effective.

Secondly, it is recommended to incorporate flexibility into the follow-up process, the aim being to be able to adapt the plan depending on the results of the research. This may include:

I. adjustments in the space available for use as wind farms or;
II. adjustments in the number of GW to be generated.

Both types of adjustment would lead to fewer or no wind farms in areas in which they would have a significant impact. It may be the case that this leads to the ambitions for wind energy set out for the areas studied in this SEA and the PR not being realised.

1.7.3 Sand extraction

For sand extraction in the 12 - 14 NM zone, the **expected environmental effects are of limited scope** and not different to the known effects of current sand extraction in the designated zone. These effects will not form an impediment to the expansion of the sand-extraction area. Prior to the granting of the permit for specific sand-extraction areas, an EIA project would have to look into the potential effects in the area in question. The purpose of this would be to check for the presence of shipwrecks and archaeological remains.