Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

RWS INFORMATIE

Framework for Assessing Ecological and Cumulative Effects (KEC) 4.0 for the roll-out of offshore wind energy and wind farm zones (Extra Task 2030+)

Report A: Scope

Date	March 2022
Status	Final
Version	4.0

Credits

Published by	Rijkswaterstaat
Information	Rijkswaterstaat Sea & Delta
Telephone	
Fax	
Implemented by	Rijkswaterstaat Sea & Delta
Layout	
Date	
Status	
Version number	4.0, with English editorial improvements

In 2022 an English editorial improvement has been made.
No content-related changes have been made.

Contents

The Framework for Assessing Ecological and Cumulative effects 4.0 (2022) consists of:

Part A
Framework for Assessing Ecological and Cumulative Effects 4.0 for the roll out of offshore wind energy and wind farm zones (Extra Task 2030+), March 2022

Part A: Scope

Part B

Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea. Analysis of additional mortality using collision rate modelling and impact assessment based on population modelling for the KEC 4.0. Potiek A., Leemans J.J, Middelveld R.P, Gyimesi A. March 2022

Acceptable Levels of Impact from offshore wind farms on the Dutch Continental Shelf for 21 bird species. A novel approach for defining acceptable levels of additional mortality from turbine collisions and avoidance-induced habitat loss. Potiek A., IJntema G.T., van Kooten T., Leopold M.F., Collier M.P., March 2022

Advice on future assessment of ecosystem effects from offshore wind farms. Advice for KEC. van Duren L., November 2021

Cumulative population-level effects of habitat loss on seabirds 'Kader Ecologie en Cumulatie 4.0', F.H. Soudijn, F.H., Hin v., van der Wal J.T., van Donk S., March 2022

Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0) – marine mammals. Heinis F. (HWE), de Jong C.A.F., von Benda-Beckmann A.M., January 2022

Mitigation measures for bats in offshore wind farms. Evaluation and improvement of curtailment strategy, M. Boonman, Bureau Waardenburg, 2018

Northern gannet collision risk with wind turbines at the southern North Sea. Extension of the impact assessment for KEC 4.0, additional analyses of the assessment framework. Collier M.P, Potiek A., Hin V., Leemans J.J, Soudijn F.H., Middelveld R.P, Gyimesi. A, March 2022

Density maps of the herring gull for the Dutch continental shelf. Memo to supplement the seabird assessment reports within KEC (“Kader Ecologie en Cumulatie”) 4.0. Soudijn F.H., Chen C., Potiek A. van Donk, S. March 2022

1 Introduction

1.1 Background

Since the 1970s, there has been a need to describe and assess the effects of human activities on natural ecosystems. In the 1980s, it was realised that it was not enough to describe and assess the effects of specific proposals and activities. It is also necessary to examine whether the effects of various activities can accumulate to produce ecological or environmental negative impacts.
Despite the difficulties, addressing, describing and acknowledging the cumulative effect issue resulted in the incorporation into nature conservation legislation. These directives require that the ecological values, in terms of natural habitat types, species habitats and species, should not only be protected from the possible negative effects of each particular human activity but also from the cumulative effects of all human activities. In the Netherlands, the implementation of these directives in national law has created an explicit requirement under the 1998 Nature Conservation Act (Natuurbeschermingswet (Nbw)) and later on in the renewed Nature Conservation Act (Wet Natuurbescherming (Wnb)). The requirement states that in addition to the potentially significant negative effects on ecological values of individual initiatives, the cumulative effects in combination with other plans and projects in the area provisions of the Act should be assessed. The Nature Conservation Act also considers cumulative effects in the provisions relating to species. However, it does so more implicitly by assessing effects regarding favourable conservation status at various spatial scales.

Since 2005, the Dutch government has received development consent applications for offshore wind farms (OWFs) that require a decision about how to assess the effects on the marine ecosystem of the separate wind, the cumulative effects with other wind farms and wind farms in combination with other activities.
Given several issues, including knowledge gaps about the cause-effect relationships, the presence of marine species and the resulting mandatory application of the precautionary principle, the assessment led to the imposition of restrictions on the development of offshore wind power and several mitigation measures.

The identified knowledge gaps led to the establishment of research programmes (for example, in the Netherlands, the Offshore Wind Energy Ecological Programme (Wozep[1]). Other countries have also recognised the problem of identifying and assessing the effects (cumulative and otherwise) of OWFs and have completed extensive research in recent years.

1.2 Offshore wind energy in the Netherlands

The Dutch national Energy Agreement, signed in 2013, led to the development of wind farms in the wind energy areas Borssele, Hollandse Kust South and Hollandse Kust North before 2023. With the publication of the 2030 Offshore Wind Energy Roadmap on 27 March 2018, the government presented the plans for the continued realization of offshore wind energy from 2024 through 2030.
In April 2021, the European Union raised the CO_2 reduction target from 40% to 55% reduction of CO_2 emissions compared to the level of emissions in 1990. In achieving this target and fulfilling the related acceleration challenge before 2030, offshore wind energy plays an important role.

[1] https://zoek.officielebekendmakingen.nl/kst-33561-26.html (in Dutch) and https://www.noordzeeloket.nl/en/functions-and-use/offshore-wind-energy/

According to the minimum scenario elaborated in the North Sea Energy Outlook, at least 38 GW of offshore wind energy is needed in 2050. Based on this scenario, at least 27 GW of wind energy is required in addition to the already planned wind farms needed to meet the 49% CO_2 reduction goals. The Government decided to designate wind farm zones in two stages:

1. In stage one, the space necessary for achieving the stricter EU climate targets of 55% CO_2 reduction by 2030 is designated. This designation is elaborated on in the additional draft North Sea Programme (NSP) 2022-2027. The Stuurgroep Extra Opgave (Extra Task Steering Committee) advised that 10 GW of offshore wind energy will be needed to achieve the 55% CO_2-reduction goals. Additionally, it turned out that an extra 0,7 GW was still necessary to meet the 49 % CO_2-reduction goals. Therefore, by 2030 at the latest, wind farm areas should be designated to realize 10,7 GW of offshore wind energy to reach the 55% goal.

2. In stage two, the designation of the remaining space takes place to arrive at the 38 GW total. This will require a partial revision of the North Sea Programme to arrive at the 38 GW.

The NSP 2022-2027, an Annex of the National Water Programme (NWP), has mapped out eight search areas eligible for designation as wind farm zones in the North Sea by 2040. Additionally, a decision had to be made about the reconfirmation of the four already designated search areas.

A policy-based narrowing down process revealed that three search areas and two wind farm areas were suitable for realisation in areas 1, 2, 5 east and IJmuiden Ver North. There is space for a maximum of 16 GW wind energy, of which 4 GW appears less viable due to spatial or ecological restrictions. The 16 GW is more than the 10 GW needed for fulfilling the stricter EU climate target of 55% CO_2 reduction. With sufficient space for 10 GW, the obvious step was not to reconfirm Hollandse Kust Northwest and Hollandse Kust Southwest in the NSP as designated wind farms. The reason for this is the potential negative impact on nature, fisheries and shipping.

Accordingly, the national government has committed to draw up and apply a framework for ecology and cumulative effects.
The North Sea Agreement (NSA)[2] states that the Framework for Ecology and Cumulation will be used as guidance to map new wind farm areas (art. 4.12).

As mentioned above, recent EU agreements make it necessary to raise the target for the contribution of renewable energy to the total requirement by 2030 (to 55% instead of 49%). Therefore, the NSP 2022-2027 has designated wind farm zones with space for 10 GW + 0.7 GW of extra installed capacity for 2030.
The designated areas offer more space than needed (16,7 GW), but it is stated that no more than 10,7 GW will be realized in these areas by 2030. Therefore, policy choices must be made about the development of wind farm zones, providing that the ecological carrying capacity is not exceeded.

Wind areas have been selected where development is expected to be possible within that time frame. Table 1.1 shows the considered areas, the wind energy areas from the Energy Agreement and the original 2030 Roadmap.

[2] The North Sea Agreement (NSA) contributes to reaching the required spatial assessment for the various functions. Central to this is finding the right balance between the transitions relating to food, nature and energy.

Table 1 Wind energy areas on the DCS where construction activities have begun or may begin in the period 2016-2030

Wind energy site	**MW**	**(Estimated) Operational phase**
OWEZ	108	2006
PAWP	120	2006
Luchterduinen	129	2014
Gemini	600	2015
Borssele III/IV	2 x 366	2019
Borssele I/II	2 x 376	2020
Borssele V	2 x 9,5	2020
Hollandse Kust Zuid I/II	2 x 385	2021
Hollandse Kust Zuid III/IV	2 x 385	2022
Hollandse Kust Noord	700	2022
Hollandse Kust West VI/VII	1.400	2024
Ten noorden van de Waddeneilanden	700	2029
IJmuiden Ver	4.000	2027
Hollandse Kust West southern part	700	2028
IJmuiden Ver Noord*	2.000	to be decided
Wind-area 5 Oost*	4.000	to be decided
Wind-area 2 Noord*	4.000	to be decided
Wind-area 1 Zuid*	2.000	to be decided
Wind-area 1 Noord*	4.000	to be decided

*) In these areas, a maximum of 10,7 GW will be realized by 2030, providing that these developments will not exceed the ecological carrying capacity.

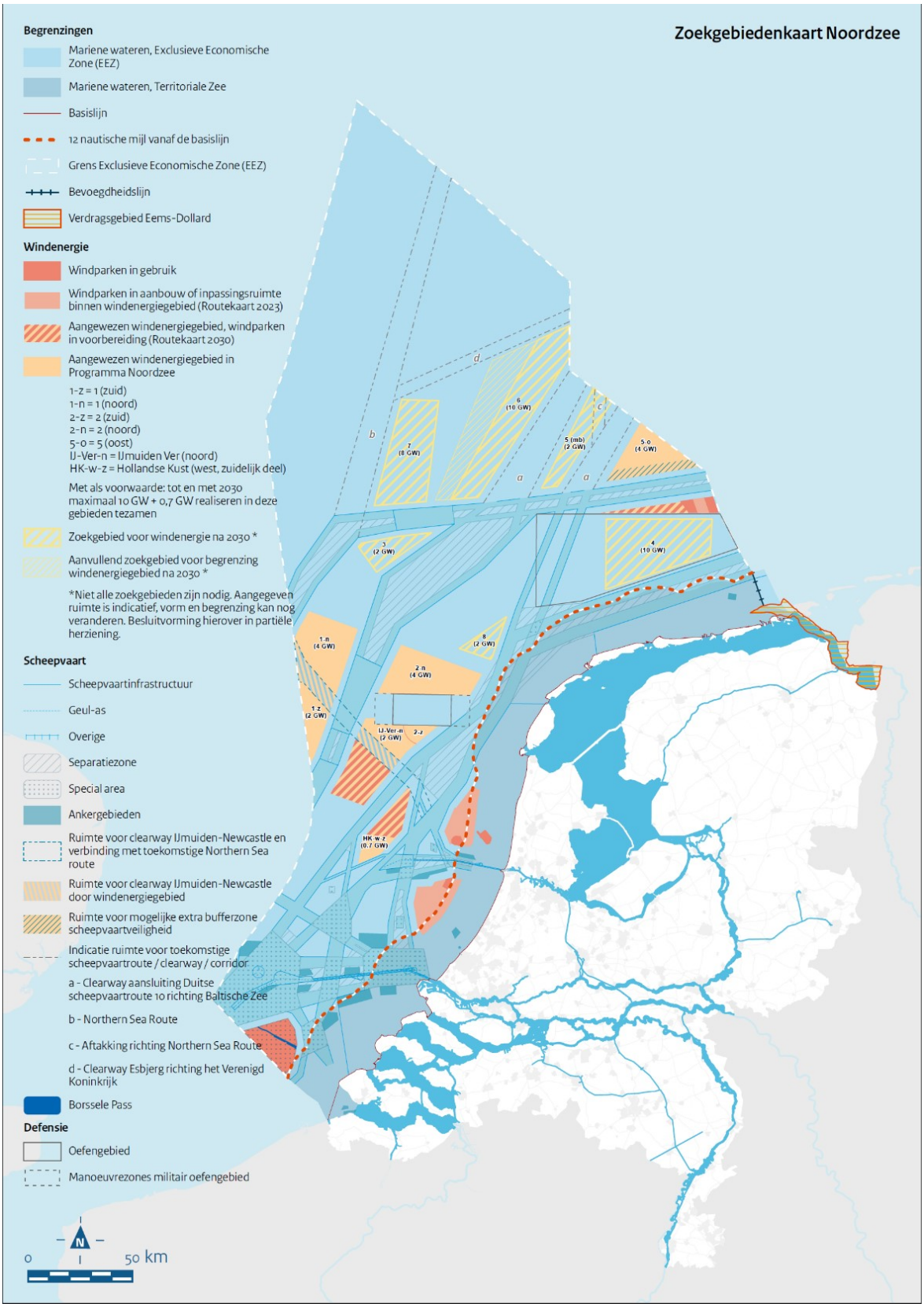

Figure 1: The location of wind energy areas as mapped in the North Sea Programme 2022-2027

1.3 Reasons for using the Framework

The mapping of cumulative effects is an intrinsically complex issue that may, in principle, include the consideration of large numbers of species and effects. In practice, decisions must be made about which effects, species and mitigation measures are relevant. Decisions must also be made about describing and evaluating these effects because specific field data are often lacking. Obtaining the best available scientific knowledge will always require modelling, expert evaluation or combinations of these two approaches since it is impossible to measure situations that are still only in the planning stages.

The Framework for Assessing Ecological and Cumulative Effects (KEC) describes how the decisions were made about which species, populations and activities to include in the assessment of cumulative effects, how these effects should be identified and described (including models when necessary) and which mitigation measures have to be taken. The KEC includes general information on the accumulation of effects and more specific information on how cumulative effects of offshore wind energy activities should be incorporated into (other) environmental assessments (and vice versa).

The framework and the calculations provide the possibility to check beforehand whether the future planned wind farms fit within the acceptable ecological level to prevent unpleasant surprises. It also gives insight into how the mitigation measures can be divided over multiple wind farms, which means that the financial and technical parts of the mitigation measures can be shared. Finally, the KEC provides insight into possible species that in the future may become critical and near the acceptable ecological level of impact. Based on these insights, interventions (research, measures) can be taken ahead of time.

1.4 The KEC as a living instrument

The KEC has been developed by Rijkswaterstaat (part of the Ministry of Infrastructure and Water Management) for the Ministry of Agriculture, Nature and Food Quality. An interdepartmental steering group of representatives from various departments of the Ministry of Economic Affairs and Climate, the Ministry of Agriculture, Nature and Food Quality and the Ministry of Infrastructure and Water Management assisted in the development.

The Framework Ecology and Cumulation originated in 2015. In preparing the first and second versions (version 1.1, 2015; version 2.0, 2016), two impact studies by Rijkswaterstaat were used (Platteeuw *et al.,* 2017[3]). In 2019 Rijkwaterstaat drafted the KEC 3.0 for 'Roadmap 2030'. This KEC 4.0 (2022) is conducted for the wind areas described in the North Sea Programme 2022-2027.

In addition to the new scenarios for wind farms on a national and international scale, new knowledge has been gained between the first KEC calculations and the KEC 4.0. For example, the latest insights from the 'Wind at Sea ecological programme (Wozep)' provided the need to update and amend the KEC. Including new mitigation measures in the calculations also required an update of the KEC. The KEC is designed to be a living instrument, which means that the KEC will be updated with the latest insights.

[3] Platteeuw M., J. Bakker, I. van den Bosch, A. Erkman, M. Graafland, S. Lubbe & M. Warnas 2017. A Framework for Assessing Ecological and Cumulative Effects (FAECE) of Offshore Wind Farms on Birds, Bats and Marine Mammals in the Southern North Sea. In: J. Köppel (ed.). Wind Energy and Wildlife Interactions. Presentations from the CWW2015 Conference. Pp. 219-237.

Annex 2 shows the differences between KEC 1.1 & KEC 2.0, KEC 3.0 and KEC 4.0.

1.5 Structure of KEC 4.0

The KEC 4.0 is divided into three building blocks and a separate threshold component, namely:

1) A part in which the conceptual framework is included on how to deal with ecology and accumulation, its interpretation for offshore wind energy and the scope (wind energy only or also other activities)
   This report, Part A, sets out the conceptual framework for addressing ecological and cumulative effects and how to interpret these effects for offshore wind energy. It replaces the previous Part A report versions.
2) The substantive knowledge base. It contains the most current knowledge, methodologies and models used.
3) A part in which a scenario is described. The scenario includes calculations stating under which conditions something is or is not possible (for example, underwater noise mitigation).

The threshold component is essential but not part of the actual KEC:

4) Thresholds. This is determined by the Ministry of Agriculture, Nature and Food Quality. The calculations in part 3 are tested against that threshold.

Building block 1 entails the 'Part A 'report, and building blocks 2 & 3 are combined in the substantive 'Part B' reports. These reports provide further details on the changes concerning the calculations in KEC 4.0.

The Part B reports include the following documents:
KEC 1.1 and 2.0:

- Cumulative effects of impulsive underwater sound on marine mammals; TNO 2014;
- A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea; Imares 2015.
- Framework for Assessing Ecological and Cumulative effects for the roll-out of Offshore Wind Energy, Part A - Methods - 2016 update Chapters 1.5 and 5.6;
- Framework for Assessing Ecological and Cumulative Effects and the roll-out of Offshore Wind Energy, Part B - Description and assessment of the cumulative effects assuming the implementation of the Offshore Wind Energy Roadmap - Version 2.0 26 May 2016.

KEC 3.0

- Framework for Assessing Ecological and Cumulative Effects – 2018.
  Cumulative effects of offshore wind farm construction on harbour porpoises. F. Heinis, HWE, C.A.F. de Jong, S. von Benda-Beckmann & B. Binnerts, TNO, 2018;
- Cumulative effects of offshore wind farms: loss of habitat for seabirds. Update for five seabird species until 2030. J.T. van der Wal, M.E.B. van Puijenbroek, M.F. Leopold, WMR 2018;
- Mitigation measures for bats in offshore wind farms. Evaluation and improvement of curtailment strategies. M. Boonman, Bureau Waardenburg, 2018;
- Update of KEC bird collision calculations in line with the 2030 Roadmap. Dr. A. Gyimesi, *ir.* J.W. de Jong, Dr. A. Potiek, E.L. Bravo Rebolledo MSc, Bureau Waardenburg 2018;
- Memorandum: Adding OWEZ and PAWP to the KEC 3.0 calculations. A. Gyimesi & J.L. Leemans, Bureau Waardenburg, 2018;

- Workshop Memorandum, 12 July 2018. E.L. Bravo Rebolledo & A. Gyimesi, Bureau Waardenburg, 2018.

KEC 4.0

- Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea. Analysis of additional mortality using collision rate modelling and impact assessment based on population modelling for the KEC 4.0. Potiek A., Leemans J.J, Middelveld R.P, Gyimesi A. March 2022
- Acceptable Levels of Impact from offshore wind farms on the Dutch Continental Shelf for 21 bird species. A novel approach for defining acceptable levels of additional mortality from turbine collisions and avoidance-induced habitat loss. Potiek A., IJntema G.T., van Kooten T., Leopold M.F., Collier M.P., March 2022
- Advice on future assessment of ecosystem effects from offshore wind farms. Advice for KEC. van Duren L., November 2021
- Cumulative population-level effects of habitat loss on seabirds 'Kader Ecologie en Cumulatie 4.0', F.H. Soudijn, F.H., Hin v., van der Wal J.T., van Donk S., March 2022
- Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0) – marine mammals. Heinis F. (HWE), de Jong C.A.F., von Benda-Beckmann A.M., January 2022
- Northern gannet collision risk with wind turbines at the southern North Sea. Extension of the impact assessment for KEC 4.0, additional analyses of the assessment framework. Collier M.P, Potiek A., Hin V., Leemans J.J, Soudijn F.H., Middelveld R.P, Gyimesi. A. March 2022
- Density maps of the herring gull for the Dutch continental shelf. Memo to supplement the seabird assessment reports within KEC ("Kader Ecologie en Cumulatie") 4.0. Soudijn F.H., Chen C., Potiek A. van Donk, S. March 2022. Evaluation and improvement of curtailment strategy, M. Boonman, Bureau Waardenburg, 2018

1.6 Structure of the report 'Part A'

The report 'Part A' sets out the approach used to describe and assess cumulative effects. The chapters are structured as follows:

- Chapter 2 provides insight into the future developments of the KEC instrument.
- Chapter 3 describes the scope and underlying principles. It explains how cumulative effects are dealt with in the Dutch nature conservation legislation, Wind Energy Law and the basic approach chosen in this assessment framework.
- Chapter 4 sets out the generic approach for identifying and describing cumulative effects and how this is done for offshore wind energy. This chapter explains how to address cumulative effects and which aspects should be included in the assessment and which should not. From an ecological and legal perspective, the factors to consider are identified in a step-by-step process.
- Chapter 5 examines the assumptions used for the scenarios and assessments.
- Chapter 6 gives an overview and a first exploration of the Marine Strategy Framework Directive (MSFD) descriptors concerning wind farms at sea.
- Chapter 7 discusses essential points to be considered in the subsequent stages.

2. The KEC roadmap

2.1 Need for a Roadmap KEC

The calculations for the North Sea Programme 2022-2027 were prepared under enormous time pressure. The KEC methodology and calculations work in a so-called "modelling chain", which implies that one step in the process must be completed before the next step can be carried out. For example, there had to be an update of the density maps of seabird distributions in space and time before the collision calculations could be continued. As new knowledge became available, various components of the "modelling chain" had to be updated for KEC 4.0. Therefore, knowledge building and decision-making ran parallel, making their interaction sub-optimal.

These factors advocate for a more structured KEC process, in which KEC calculations can be performed in a timely, structured manner and with an optimal interaction between knowledge building and policy choices. An important condition is always using an up-to-date knowledge base at any desired moment, particularly when policy decisions are bound to be considered, discussed and decided. This particular moment can also provide direction to timely knowledge building by research.

However, complying with this ambition will always remain a challenging task. Based on the precautionary principle, assumptions are maintained as long as there is uncertainty. Uncertainties can be reduced through research. It is necessary to consider, i.e. for planning the Roadmap KEC, that thorough investigations need their time to be carried out.

While developing KEC 4.0, it became clear that the current KEC method is less suitable for rapidly calculating multiple variants, which is needed to calculate the benefits of strategic plans (such as the North Sea Programme). In the strategic plans, the ecological effects of different variants are compared. From a policy perspective, there is a need to gain insight into a higher level of abstraction of ecological data and potential ecological cumulative bottlenecks concerning OWFs at sea. The KEC roadmap identified the need for a quick insight into whether, for example, a specific area takes up a disproportionate part of the ecological space or not. The aim is to be able to react more quickly and thus be able to respond to political and social wishes.

This consideration has led to the idea of another (additional) form of the KEC methodology, a "KEC for policy making". This spin-off of the KEC should be able to deliver in a relatively short period or even ad-hoc insight into Marine Spatial Planning of (new) offshore wind areas. It should be noted that the name KEC suggests a similar quality and legal status to the KEC. However, that quality is not achievable with the considered additional "KEC for policy making" method. Therefore, it has been suggested to call this TEC; Tool for Ecology and Cumulation (see paragraph 2.3).

Based on the urgency mentioned above, there is a need for KEC components that:

- Always have an up-to-date knowledge base;
- Always have up-to-date maps (numbers and distribution of species, road map for OWF development);
- Can provide timely input for the calculation of variants for the roadmap process;
- Work with a threshold based on the most recent state of conservation;

- Can be expanded with other effects of offshore wind energy or additional activities/effects concerning offshore wind energy (islands, shared use in wind farms, floating solar, tidal generators);
- May also be suitable for search area processes and provide insight into the effects of different variants.

2.2 Interdependency of the KEC Building Blocks

The entire KEC is divided into three building blocks and a separate threshold component (building block four), explained in chapter 1.5:

1) Conceptual Framework
2) Substantive knowledge base
3) Calculations
4) Thresholds

These four building blocks are interdependent and are kept up-to-date seperately. An update of the KEC is required when there is a significant change is one of the building blocks. Overarching data, information and knowledge management must be set up for continuity and traceability of the results of the KEC calculations. Therefore, a new KEC calculation can be quickly and efficiently tackled as a process.

There is a strong link between the four building blocks. Adding a different renewable energy source, such as floating solar, would require broadening the scope and conceptual framework (part 1), expanding the knowledge base regarding floating solar and demanding new and different calculations. The reason for requiring new calculations is if the new knowledge's insights are expected to affect the current calculations. For example, if a new threshold is established, a rerun of the calculations is necessary. A concrete example of this is the new methodology thresholds with the application of the Acceptable Levels of Impact (ALI-methodology, Potiek et al., 2021).

1) Conceptual Framework

The moment something changes from the perspective of politics, legislation and regulations, international cooperation or scope, it will have to be changed in the conceptual framework. B.E., if the Steering Committee Wozep/KEC decides that floating solar will be part of the KEC, it will be incorporated (as far as possible, considering the knowledge gaps).

2) Substantive knowledge base

New knowledge can be acquired from Wozep research or other ecological research (national or international). The substantive knowledge base can be set up separately so that an inventory can be made periodically on whether or not the knowledge base for KEC needs to be adjusted if there are significant new insights from research that might require new calculations. Periodic checks can then determine whether there is reason to adjust the substantive knowledge base based on substantial new knowledge.

The knowledge base includes:

- Latest scientific insights from either targeted Dutch research within Wozep and MONS or science in general.
- Used (numerical) models, which are a record of scientific knowledge. Version management is essential in the context of knowledge management.
- The user experience of involved employees. This experience is challenging to capture. In the context of continuity, an overlap in employee involvement is necessary. This knowledge can also be shared through workshops.

In addition to the knowledge base, there is also a data and information base. This information base is highly dependent on and is enriched by knowledge. Types of information are:

- Scatter maps of various kinds, density maps, etc.
- Dose-effect relationships (obtained from, e.g. expert elicitation or data analysis)
- Descriptions of scenarios
- Metadata about models (version management)
- Good process description of the total KEC process (with diagrams and data flows)
- Input data for calculations
- Scenario description
- Model parameters
- Oceanographic and meteorological data

New information about effects on species and population models can also lead to new knowledge. In addition, it can be checked whether the correct species are still being considered. A checklist could be a starting point for periodic new knowledge checks. A possible retrospect can also provide information about which new knowledge has been developed over the years (for example, from KEC 1.0 to KEC 4.0).

One of the recommendations for a more optimal functioning KEC is to automate the model runs to make processes run faster and to be able to respond adequately to the future roadmap of Wind Energy at Sea. Calculations can be carried out faster and more efficiently by automating the 'modelling chain'. Additionally, the cohesion between the different building blocks of the KEC becomes more robust and transparent.

The checklist for the substantive knowledge base should include scanning new:

- Maps (density (possible in combination with habitat modelling), distribution, numbers)
- Effects of knowledge
- Knowledge population models
- Dose-effect relationships information
- ALIs
- Species-specific parameters

3) Calculations.

The calculations can be considered a stand-alone module with one or more scenarios as input. A scenario can be an actual decision but also possible variants of a decision.

If there are new search areas, a new roadmap for OWF development, an extension or shift of the scope, significant new knowledge or new thresholds, then calculations will have to be made for this new situation.

4) Thresholds

The thresholds are not a part of the KEC but are essential for the assessment. The thresholds are based on the current conservation status and international status. Based on monitoring data the status can change, which means that the threshold will also have to be revised. So if there is new knowledge about population size, regeneration time or international status, the threshold will have to be revised. The

Ministry of Agriculture, Nature and Food Quality is primarily responsible for defining the thresholds and keeping these up-to-date.
Where changes occur based on new publications on status, the new thresholds will have to be compared with the results of the latest calculations, and new conclusions must be drawn. The threshold is established at least every six years. Therefore, it is likely that there will be some delay in terms of knowledge and thresholds. The delay does not have to be a problem, but we should be aware of it. Thresholds can also be adjusted in the meantime if there is good reason to do so.

In addition to an annual inventory to see whether the scope (process level) and knowledge base (content level) are still up to date, the wish is to make a new version of the KEC (update building blocks no. 1 to 3) once every three years. The envisioned document update fits the foreseen policy developments concerning offshore wind energy. By cutting up the KEC into the mentioned four parts, it is possible to ensure that it is up to date and warrants the ability to respond quickly to ad hoc questions.
The above is not an actual system change of the KEC instrument but more of a roadmap for working in a structured way with the KEC.

2.3 TEC-light: Tool for Ecology and Cumulation

From a policy perspective, there is a need to gain insight at a higher level of abstraction into the ecological data and potential ecological cumulative bottlenecks concerning OWFs.
There is a need for a quick insight into whether, for example, a specific area takes up a disproportionate part of the ecological use space or not. The aim is to be able to react more quickly and thus be able to respond to political and social wishes.

It is important to realize that the KEC has a certain legal and policy status, and a good and sound basis of the KEC is therefore important to comply with this legal and policy status. In a TEClight, which is more about quickly gaining some feeling for the differences between (sub)variants of options for OWF developments, the accuracy and objectivity inherent in the KEC will be considerably less. It will not be possible to base policy decisions on, but it can identify possible policy directions.

Ideas for implementing a TEClight are:

- Working with sensitivity maps. With a sensitivity map, you can mainly see which location is more or less suitable, thus providing an image of that location in itself, not whether that location fits within the ecological boundaries. Sensitivity maps cannot calculate cumulative effects.
- Calculating backwards from the ecological threshold limit so that it becomes clear which species should be taken into account when designating locations for wind farms.
- Ranking of search areas/potential search areas based on effects per species group/species.

3. Scope and legal basis

3.1 Purpose and scope

Purpose
This document is a generic framework for identifying, describing and assessing the cumulative ecological effects of decisions, particularly concerning the development of OWFs.
It describes a methodology for calculating cumulative effects. Given the reason for preparing this framework, it focuses exclusively on offshore wind energy[4]. The framework has been applied to the designated OWF search area, as described in the North Sea Programme 2022-2027. The reason is to check in advance whether and under which ecological conditions the entire OWF development roadmap can be implemented. The framework will also have to be used when drawing up environmental impact assessments (EIAs) and appropriate assessments (AAs) for the specific site decisions and when designating new areas for OWFs. The framework has been applied to the North Sea Programme. The calculated effects will be used as generic input for the EIAs/AAs for the site decisions.
A generic approach was adopted to make the framework more widely applicable in the long run and possibly useful for other offshore renewable energy sources. This approach is elaborated on specifically for assessing the effects of OWFs.
Additionally, this report identifies possibilities for mitigating the negative effects of OWF development.

The intended users of the KEC
The framework was drafted primarily for all government departments and agencies involved in decision-making related to offshore wind energy, such as strategic planning documents (‘*structuurvisies*’) and site decisions (‘*kavelbesluiten*’). It provides transparent information on how the cumulative effects of these developments should be identified and assessed. The KEC is also relevant for consultancies preparing EIAs/AAs and stakeholders and NGOs in offshore wind energy.

Scope
When adapting the KEC for offshore wind, it was decided to include only the (known) effects that could lead to significant negative consequences, on their own or in combination with other activities. The calculations are based on a scenario that virtually includes all national and international OWFs expected to be built in a defined period. It must also be made clear that the assessments of the effects on conservation status or the population level have been made at the national level. As the exact locations of the wind farm sites are not yet known, it cannot be excluded that more detailed calculations in project EIA/AA will identify specific effects, b.e. when a wind area is next to a Natura 2000 area. These location bound effects will have to be determined more precisely during location-specific EIAs/AAs for the relevant site decisions.
Calculations have not been made for all species because previous KEC exercises have shown that the effects on the population of many other species did not appear to be moving toward an unacceptable level of impact.

[4] In the report Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0) – marine mammals. Heinis F. (HWE), de Jong C.A.F., von Benda-Beckmann A.M., January 2022 also geophysical surveys are assessed.

3.2 Underlying principles

The description of the effects in KEC 4.0 (2022) is based on the most recent publicly available knowledge and the following underlying principles:

- transparency about knowledge gaps and assumptions;
- use of the precautionary principle assuming a realistic worst-case approach within the range of expected developments;
- absolute clarity about the geographical scale and time horizon of the calculated effects;
- use of substantiated expert judgements to address knowledge gaps;
- an emphasis on possible negative effects;
- only for those species for which significant negative effects cannot be excluded beforehand.

3.3 National and international requirements in law for plans and projects

Including cumulative effects in assessing plans and projects is required under international conventions and EU directives. Dutch legislation has also implemented this requirement in the Nature Conservation Act articles 2.7 and 2.8 and the Habitat Directive article 6(3). These legal obligations have been taken into consideration during the drafting of the KEC.

International conservation legislation

Below is a brief review of the relevant international conventions and laws and their requirements regarding cumulative effects. These international conventions have been implemented in Dutch legislation.

The aim of the OSPAR Biodiversity and Ecosystem Strategy, the EU Birds and Habitats Directives, the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) is to protect or restore generic ecosystem qualities or specific habitats and species. The Birds Directive and the Habitats Directive have been implemented in the Netherlands in the Nature Conservation Act (in the area and species provisions). This Act also applies to the entire Dutch section of the Continental Shelf. All this legislation places particular requirements on marine and other activities intending to achieve the specific objectives stated in this Act.

The aim of the EU EIA/SEA Directives, UNECE (United Nations Economic Commission for Europe) Espoo Convention and the OSPAR Strategies on Offshore Oil and Gas, Hazardous Substances and Radioactive Substances is to reduce the environmental impacts of activities. They require a full assessment of the effects caused by plans, projects and activities on the ecosystem. The Espoo Convention, the MSFD and the WFD require a Cumulative Effect Assessment (CEA). The WFD takes the ecological status of the coastal waters as its starting point, whereas the MSFD adopts an ecosystem approach. The Espoo Convention is crucial for bringing all stakeholders together before any environmental impacts occur. It obliges parties to assess the environmental impact of certain activities at an early stage of the planning process. It also lays down a general obligation on parties to notify and consult each other about activities expected to have significant negative effects across borders. The only directives that explicitly require a Cumulative Effect Assessment (CEA) are the EU EIA/SEA Directives and the Birds Directive and Habitats Directive. CEA is a mandatory part of the EIA in these cases.

National nature conservation legislation

The Nature Conservation Act (Wnb) implements the EU Birds and Habitats Directives. The area provisions protect natural habitats, species habitats and species

in designated sites, called Natura 2000 sites. These sites, combined with other EU Natura 2000 sites, form the EU Natura 2000 network of protected areas. The species provisions protect plant and animal species and their specific habitats. The species are protected throughout the Netherlands and not only within the boundaries of the Natura 2000 sites.

The Offshore Wind Energy Act states that the ecological impacts of offshore wind energy projects must be assessed during the drafting of a site decision, which means that no separate consent or discretionary permit is required under the Nature Conservation Act. For practical reasons, the present document refers to the Nature Conservation Act because the substantive assessment of the site decisions is in line with the Nature Conservation Act.

Offshore Wind Energy Act
The Offshore Wind Energy Act (2015) provides a comprehensive legal framework for the large-scale development of OWFs. It introduces a 'site decision' in which the government designates the areas where OWFs may be built. In the Act, the Ministers of Economic Affairs and Climate, Agriculture, Nature and Food Quality state the locations and the conditions for the development of wind farms and where the connections to the national grid are to be made. In the tender process, a developer is selected for each site and granted the rights to build the wind farm and connection to the grid. The developer will also be granted a licence giving exclusive rights to develop and operate the wind farm.

In 2018 the Offshore Wind Energy Act was amended. The essence of the Act remains unchanged. The amendments in the new bill consisted of establishing the new division of powers for the ministers and making the Act suitable for the future for energy carriers other than electricity. Finally, the procedure for granting licences through comparative assessment has been improved, and the possibility of auctioning licences has been added to the Act. The bill mainly affects the wind sector. The amendment to the Act relates to the granting of licences and not the designation of wind energy areas or site decisions. Other stakeholders in the North Sea such as shipping, fisheries, mining, and nature conservation organisations are not affected by the bill or only to a lesser extent.

An essential part of the site decision is the assessment of ecological impacts. In the Offshore Wind Energy Act, this assessment, which the Nature Conservation Act requires, is included in the site decision.

The site decision is a decree as referred to in Article 7.1(2)(c) and (b) of the Environmental Management Act. The decree states that an environmental impact assessment (EIA) must be carried out when preparing a decision to designate a site. If a wind farm could significantly affect a Natura 2000 site, an appropriate assessment (AA) must be drafted. The EIA and the AA must also investigate the cumulative effects.

The best available scientific knowledge has been used to assess whether the cumulative effects exceed the acceptable level of impact for the three species groups identified in this framework: marine mammals, birds and bats.

If the EIA and AA indicate that unacceptable negative effects may occur, a study is mandatory to determine whether these effects can be sufficiently mitigated by taking additional measures. These mitigation measures must be included in the site decision as conditions.

Cumulative effects assessment
The Nature Conservation Act requires a specific *ex-ante* assessment of projects and plans that are not directly connected with or necessary to the area's management. These projects and plans, on their own or in combination with each other, can negatively affect the quality of the natural habitats and species habitats in a Natura 2000 site. These negative effects can also result in significant disturbance of the species for which the Natura 2000 site in question has been designated. The ex-ante assessment also applies to activities outside a Natura 2000 site which may have consequences for protected habitat types, species habitats or protected species in Natura 2000 sites. In this case, an assessment must be made of whether the activities in question will affect the ecological values requiring protection in the Natura 2000 site. These are referred to as external impacts on Natura 2000 sites.

When consent is required under the Nature Conservation Act, the project or plan must be appropriately assessed, including an assessment of the cumulative effects in combination with other projects and plans. The assessment must include projects in which execution has been approved and has not yet taken place or projects that have been built but for which the consequences have not yet been incorporated into the background situation.

All protected species enjoy a generic level of protection under the species provisions of the Nature Conservation Act, which also applies outside Natura 2000 sites. An initiative with potentially negative effects on protected species can only be granted a discretionary permit under the Nature Conservation Act if the Act's requirements are met. These negative effects include mortality or the destruction/disturbance of permanent resting places or essential habitats. The requirement for most species is that their favourable conservation status must not be jeopardised. However, there are additional requirements for strictly protected species, such as the existence of a legitimate interest. When determining the consequences of the activities on the favourable conservation status of a species, the assessment under the species provisions of the Act must also take into account possible cumulative effects resulting from other activities. This requirement is described in the Birds and Habitats Directives[5] and is elaborated on in Section 2.5 (under the heading Species provisions and cumulative effects).

3.4 Legal and ecological approaches

The KEC distinguishes between a legal and an ecological approach because compliance with the legal requirements of the Nature Conservation Act does not necessarily mean that a favourable conservation status will also be achieved in ecological terms. In the Netherlands, the Nature Conservation Act implements the Birds and Habitats Directives by the designation and subsequent explicit protection of the Natura 2000 sites (the special protection areas under the Nature Conservation Act: the Natura 2000 sites). The intention is that all the habitats and species for which a conservation objective has been designated for these areas will acquire national favourable conservation status, as a result of the contribution made by all these areas to the protection of those habitats and species.

This area protection policy works well for the terrestrial ecosystems in the Netherlands, including the inland lakes, rivers and coastal waters. However, this approach is less appropriate for protecting species in the North Sea. Generally, the

[5] See page 65 of the 'Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC' from 2007.

species are distributed over areas far beyond the boundaries of the designated Natura 2000 sites and national borders.

Differences between 'land' and 'sea'
The natural functioning of the North Sea ecosystem is characterised by a high variation in the spatial and temporal distribution of species. The system is driven to a large extent by short-lived and local hydrogeographical conditions (such as weather fronts) to which animals respond. As a result, many species are highly mobile and not confined to the Natura 2000 network of protected areas. They include marine mammals (in particular, the harbour porpoise, common seal and grey seal) and seabirds but also some larger fish species (such as sharks and rays).

Due to the mobile nature of the species, the favourable conservation status of these species effectively has to be maintained at the biogeographical population level. However, because species distribution varies considerably within and between seasons and years, the value for certain species of specific areas within the North Sea by comparison with the rest of their range is hard to predict or establish. This limits the available possibilities for establishing good conservation status. For many species, the best available knowledge is insufficient to identify areas that fulfil a specific ecological function over a prolonged period.
For example, the Updated Conservation Plan for the Harbour Porpoise in the Netherlands (Ministry of Agriculture, Nature and Food Quality 2020) states that the areas of special ecological value (*GBEW*, Lindeboom *et al.* 2005) are not home to higher numbers than the surrounding areas. We may conclude that the level of protection in all these areas is insufficient to establish a favourable conservation status for the harbour porpoise and other migratory species. These species require protection throughout the North Sea. The broad protection is recognised in the designation decisions for Natura 2000 areas in the North Sea.
Although the harbour porpoise is explicitly mentioned, the same applies to many marine species, such as the various species of seabirds, dolphins and seals. Therefore, the KEC assesses the effects on the populations in the study area (see paragraph 5.2) to implement the objectives of Natura 2000 areas, which have a direct bearing on the species in those areas.

This does not alter the fact that for initiatives near Natura 2000, sites that have already been designated or are close to being designated with an additional or special function for some species (such as breeding grounds for seabirds like sandwich tern and lesser black-backed gull; resting, moulting and nursery habitats of common and grey seals; and moulting or foraging habitats of common guillemot, razorbill and northern gannet), the assessment of effects under the provisions of the Nature Conservation Act continues to require particular attention. Site-specific assessments will also remain necessary under the species provisions and must be conducted for the site decisions. The assessments should have to be in line with the KEC (for example, the applied methodologies).

Dutch legislation
The following aspects of Dutch nature conservation legislation are relevant to the following points:

1) The Nature Conservation Act applies only to activities on Dutch territory and the exclusive economic zone in the North Sea (Article 1.2(1) of the Nature Conservation Act). However, species and their habitats are not confined by national borders, as animals can migrate across borders and live in areas extending across many countries. So, when considering the ecology of a species, the area relevant for the whole population must be considered. The long-term conservation of a species depends on the quality of different habitats in different areas. A legal assessment of the acceptability of activities is therefore logically restricted to the national

borders of the Netherlands. Still, it should also consider the effects on protected species outside the territory of the Netherlands.

2) Under the Nature Conservation Act, it is necessary to establish beyond doubt that the effects of an activity or development are not significant negative and that the quality of a protected habitat will not deteriorate. Only then can a licence be issued, where appropriate subject to conditions that safeguard compliance with this requirement. The ecological reality is that the environment is complex, a great variety of factors influence species and habitats, and it is seldom possible to determine precisely the magnitude of the effect of an activity, which is why there is always a range of uncertainty for the identified effects. When there is too much uncertainty, the precautionary principle must be applied. The precautionary principle, on its own or combined with adaptive management, brings together the legal and ecological approaches.

3) The protection of sites requires that activities be assessed for any negative effects on the integrity of Natura 2000 sites as defined by the conservation targets set out in the designation decisions. If the range of a species extends far beyond the boundaries of a Natura 2000 site or beyond the borders of the Netherlands, it may still become extinct, even though the quality of the sites in the territory of the Netherlands is good. This may happen, for example, due to the effects of human activities in other parts of the species' range (such as the British coast for species that breed there but return to the Dutch Continental Shelf (DCS) in the autumn). Therefore, activities and developments should be assessed for their effects on the conservation status of the species.

4) A project or plan, on its own or combined, may have no significant consequences. Article 6(3) of the Habitats Directive requires a specific *ex-ante* assessment of projects and plans which are not directly related to or necessary for the management of a Natura 2000 site and which, individually or *in combination with other plans or projects*, could have significant implications for the site.

In addition to Article 6(3) of the Habitats Directive, Article 2.7 of the Nature Conservation Act requires an assessment of the cumulative consequences of plans and projects. This means that the cumulative impacts of 'other interventions' – as referred to in Article 2.7 of the Nature Conservation Act – do not have to be included from a legal point of view as they have already been included in the current situation. However, as these 'other interventions' could have a significant ecological impact (for example, seismic surveys), it would be relevant to take these into account from an ecological point of view.

Species provisions and cumulative effects

As described in Section 2.4, the species provisions of the Nature Conservation Act do not specifically state the approach required to address the cumulative effects of different projects. From a legal point of view, one could argue that the assessment based on the species provisions does not have to take cumulative effects into account. However, case law indicates that cumulative effects do have to be included in the assessment. This also follows from the Birds and Habitats Directives[6].

It is unclear how cumulative effects should be assessed. This assessment is necessary because the assessment of the impact of a project must include its effect

[6]See 'Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC' (2007) page 65: (60) Such monitoring could also be seen as a part of the general surveillance obligation under Article 11 of the Directive. It would be reasonable for such surveillance to be sensitive to the effects (including cumulative effects and the effects of compensation measures) of derogations implemented for species for which derogations are regularly granted or which are in an unfavourable conservation status (and are nevertheless the subject of derogations).

on the favourable conservation status of the relevant habitat type, plant or animal species. If other implemented or to be implemented projects also affect the same habitat type(s), plant or animal species, they will have to be assessed to estimate the effects on the conservation status. If this is excluded, there is a risk that species will not be adequately protected.

A good example is the impact of OWFs on bats. Natura 2000 sites have been designated for three bat species: the pond bat (*Myotis dasycneme*), Geoffroy's bat (*Myotis emarginatus*) and the greater mouse-eared bat (*Myotis myotis*). These species are not expected to be found at sea. This means that an assessment of the effect of the development of OWFs on all other bat species protected by the species provisions of the Nature Conservation Act needs only consider the effects of individual wind farms. There is a low probability that a single wind farm would cause such high mortality that the favourable conservation status of any bat species would be endangered. However, it is possible that all the wind farms combined as planned in the NSP 2022-2027 and in combination with all other existing and planned wind farms in the rest of the international areas of the North Sea, could cause a significant mortality rate. A consequence of this could be that the favourable conservation status of the bat species that migrate across the North Sea will be negatively impacted.

A failure to consider cumulative effects would not do justice to maintaining the designated species' favourable conservation status. Even though cumulative effects are not explicitly mentioned in the wording of the law, an assessment is implied in the Birds and Habitats Directives. The conclusion must be that cumulative effects should be included in the assessment. Otherwise, a sound estimate of the project's effects on conservation status cannot be made.

Ecological and legal approaches: flexible application
Meeting the legal requirements makes it possible to issue development consent or a discretionary permit, specifically for offshore wind energy, to adopt a site decision. A purely legalistic approach to cumulative effects will not always be adequate to ensure that nature conservation objectives are met. Adopting such an approach could lead to legal risk if certain agreed nature conservation objectives cannot be met.

Therefore, the KEC primarily assesses the cumulative effects on non-location-specific species at the biogeographical population level. In the event of a positive assessment, this implies compliance with the species and area provisions of the Nature Conservation Act. The reason is that specific effects that affect these species' populations will also affect the sub-populations in the protected areas. Not only does this meet the nature conservation objectives, but it also provides adequate space for offshore wind energy development. A location-specific EIA and AA are still mandatory.

In legal terms, the assessment is based on the conservation objectives of the Natura 2000 sites. Effects on sub-populations of species restricted to specific protected areas (such as some breeding colonies) may differ from the effects at the biogeographical population level. In those cases, the project EIA and AA for the site decisions must include specific consideration of these effects.

The ecological effects are assessed at the level of the biogeographical population. KEC 4.0 (2022) focuses on:

- Assessing effects at biogeographical scales;

- Assessing effects on the conservation status instead of at the scale of one or more individual Natura 2000 sites;
- Including transboundary effects;
- Excluding uncertainties by applying the precautionary principle;
- Including wind farms and wind farm areas, even if permits have not yet been granted for those farms;
- Including foreign OWFs, which are expected to be built in the period leading up to 2030 (see Annex 1) for the national and international wind farm scenarios.

In practice, the KEC assesses the population on the DCS or the southern North Sea.

3.5 Netherlands Commission for Environmental Assessment

The Netherlands Commission for Environmental Assessment prepares mandatory and voluntary advisory reports for the government (national, provincial and local) on the scope and quality of EIAs. The Commission has assessed KEC 3.0 and its intended application (cMER, 2019).

The Commission appreciates the clear distinction KEC makes between ecological and legal points of attention. The improvements included in the updated version lead to a valuable instrument for assessing the cumulative effects of all OWFs. The Commission has a few more recommendations for the KEC:

- Indicate how the precautionary principle will be applied to the Potential Biological Removal (PBR) results until a better alternative is available. This is especially necessary for species with small and vulnerable populations.
- Explain the new translation of the disturbance of harbour porpoise by underwater noise to population effects.
- The effects of underwater noise should also be considered for seals.
- Indicate how the cumulative effects of wind farms with other activities such as the Offshore Grid and seismic surveys should be assessed.

The new methodology of thresholds has addressed the first point, the Acceptable Levels of Impact (ALIs) (Potiek et al., 2022). The second and third points are addressed in the *Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0) – marine mammals (*Heinis et al., 2022). The last point, the offshore grid activity, is included in the report from Heinis et al. (2022). Other activities are not (yet) in the scope of the KEC.

4 Approach to the assessment of cumulative effects

This chapter describes the steps to be taken at a generic level to make an adequate assessment of the cumulative effects of proposed developments. The corresponding sections in the subsequent chapters examine these steps specifically for OWFs. Each step contains a description of what is necessary from a legal and ecological point of view (to the extent that these differ).

The description and assessment of the cumulative effects of plans and projects in the KEC is a step-by-step procedure based on the DPSIR method. This method systematically identifies the drivers, pressures, state, impacts and responses in six steps (Platteeuw et al., 2017).
The first two steps are iterative and are carried out together.

- Step 1: Identify the relevant pressures the envisaged activity could cause;
- Step 2: Identify the habitats and species that may be affected by these pressures;
- Step 3: Describe all other pressures (resulting from both the same and from other drivers) that could affect the same species;
- Step 4: Describe the nature and scale of the cumulative effects of all the activities selected in Step 3 on the selected habitats and species for the relevant[7] populations of those species (*impacts*);
- Step 5: Evaluate the significance, through comparison with the legally established conservation targets, of both the *state* (e.g. conservation objectives) and the *impact* (on ecosystem biodiversity, for example) of the effects on the selected habitats and species;
- Step 6: If necessary, adapt the activity by taking mitigation or compensatory measures (*response*) so that it does not contribute to any significant effects.

The procedure is represented schematically in the diagram below. The diagram also shows that when activities, pressures and species are added, the number of operational steps or calculations that must be made increases exponentially. This asks for selecting only the most relevant species and pressures to keep the required calculations within manageable proportions. From a legal point of view, this is insufficient since it has to be established beyond doubt that the initiative(s) will not contribute to significant negative effects on the favourable conservation status of the habitat types of species potentially at risk.

[7] In this context, the 'relevant' population is understood to mean the population of the total geographical area in which the intended activity will take place.

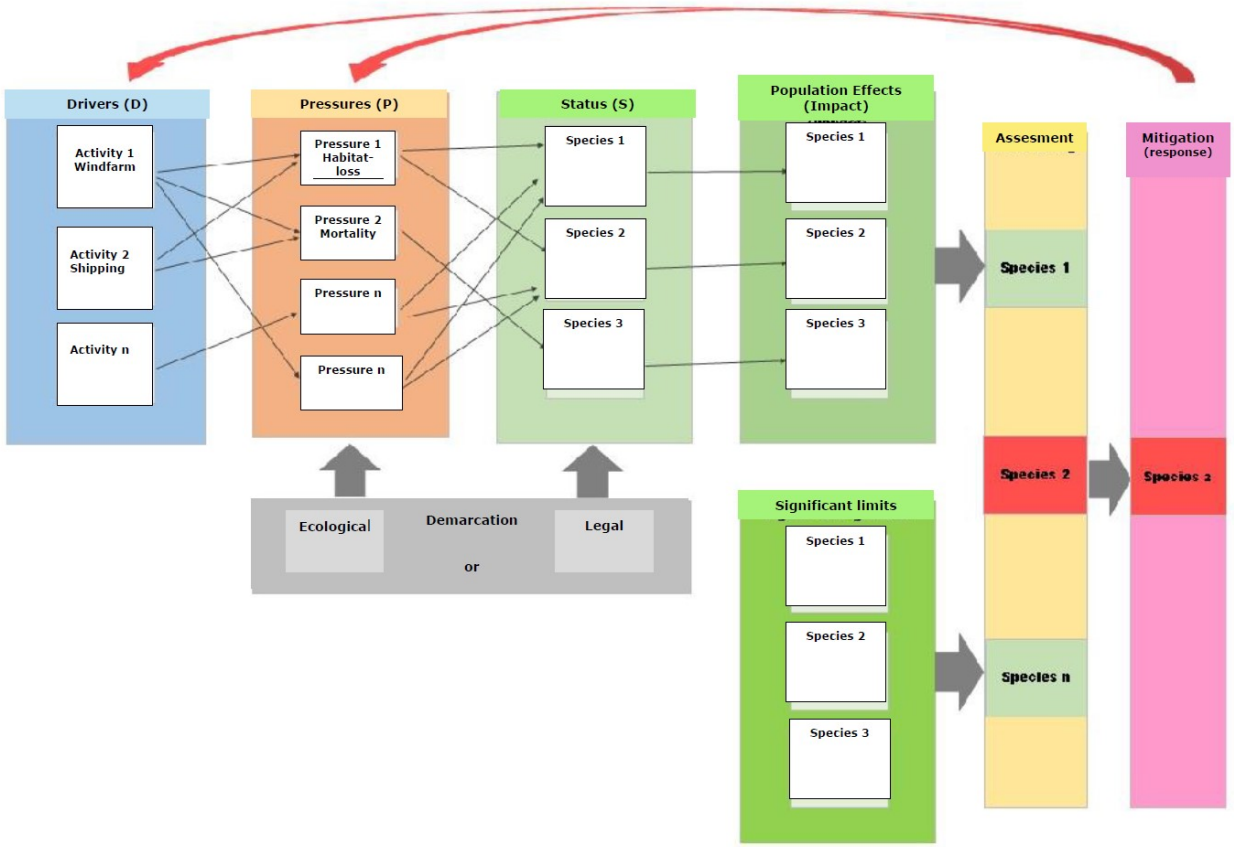

Figure 2: Schematic diagram of the DPSIR steps

4.1 Identification of pressures from the activities to be assessed (Step 1)

The activity to be assessed is the human activity that may impact species, habitats or other ecological values of prime concern for the assessment. The pressures from the activity (i.e. installing and operating OWFs, induced by the driver of energy transition) to be assessed are described in conjunction with Step 2 as there is a strong relation between the described pressures and identified species and habitats.. Pressures are those aspects of the activities that might cause impacts. Examples of pressures are:

- disturbance caused by mechanical activities and obstacles;
- disturbance caused by light;
- disturbance caused by sound;
- habitat loss;
- toxic effects of contamination;
- animal mortality or injury;
- shifts in ecosystem functioning, resulting from hydromorphological changes induced by massive, large-scale instalment of OWFs (e.g. sedimentation/erosion patterns, large-scale patterns in seasonal stratification, a substantial increase in filter-feeding benthic organisms in higher water layers, etc.), potentially resulting in knock-on effects in the trophic chain;
- changes in species composition through the introduction of species or new habitats.

Pressures are only relevant if species and/or habitats are sensitive to themIdentifying the pressures starts with a detailed description of the proposed activity, its physical characteristics, dimensions and duration for all phases. These phases include preparation, construction, operation, decommissioning and removal. Different activities occur during each phase, and these activities exert different pressures. For example, the activities for OWFs include shipping movements, excavation, construction, operations and maintenance, and decommissioning. The spatial dimensions of these pressures must then be identified. This cannot be seen in isolation from the sensitivity of habitats or species. For example, if a species is affected by sound above a certain level, the spatial dimension of this pressure is the area within which the sound is louder than the maximum acceptable level to the species. The level of detail required when identifying and describing the pressures must be determined in conjunction with Step 2.

DPSIR in relation to offshore wind, step 1

The relevant pressures from the construction, operational, and decommissioning phases of the wind farms are listed below. It is a provisional list because new knowledge and new insights can expand this list.

Construction phase

The main pressure in the **construction phase** is underwater sound, resulting from the piling of the foundations. Other pressures include:

- disturbance caused by mechanical activities, such as vibration and sound;
- attraction to and disturbance caused by light;
- disturbance caused by intensive shipping activity during construction;
- disturbance caused by excavation;
- disturbance caused by depositing material (scour protection for foundations with riprap).

Operational phase

In the **operational phase**, primarily the wind turbines themselves and the total area taken up by the wind farms can negatively affect animals. The following pressures are relevant in this phase:

- habitat loss, possibly resulting in habitat fragmentation;
- disturbance of the migration routes of birds and bats;
- vibrations and sound;
- attraction to and disturbance caused by light (lighting);
- disturbance caused by maintenance vessels;
- contamination caused by the release of substances such as anti-corrosion and antifouling products;
- change in hydromorphological processes (such as currents and sedimentation);
- death or injury caused, for example, by collisions or near-collisions with turbines;
- change in species composition and food availability or competition for food through the introduction of new hard substrate habitats, such as foundation piles and riprap around piles;
- effects of certain uses in wind farms (such as fishery types);
- electromagnetic fields generated by cables.

Decommissioning phase

In the **decommissioning phase**, the most important pressure will likely be underwater sound and excavation. Little or no experience has been acquired with this phase, so it is not yet possible to include the effects in this framework.

4.2 Identification of sensitive species and habitats (Step 2)

4.2.1 Ecological

The next step is identifying species and habitats that could be affected by the pressures from the activities under consideration. In this step, a species list is made of species present in the pressure's influenced sphere and sensitive to the pressures identified in Step 1. The pressure's significance depends on how sensitive a certain species or habitat is to a given pressure, and whether there is overlap in space and time between the pressure and the species/habitat.

DPSIR in relation to offshore wind, step 2 Ecological

New activities with potentially negative effects on the species should be assessed in any event on the DCS to determine the scale and severity of these effects. An example is the construction of wind farms. The current environmental impact assessments and other studies for the development of OWFs have shown that underwater sound in the construction phase may have negative effects on marine mammals. In the operational phase, it is primarily the wind turbines that may have negative effects on birds and bats**.**

Marine mammals
The most relevant species in the group of marine mammals are the harbour porpoise, the common seal and the grey seal. In addition to these species, the white-beaked dolphin (*Lagenorhynchus albirostris*), common minke whale (*Balaenoptera acutorostrata*), humpback whale (*Megaptera novaeangliae*) and common bottlenose dolphin (*Tursiops truncatus*) are occasionally present on the DCS. It has been assumed for the time being that the harbour porpoise is the most sensitive species in the North Sea to the effects of piling sound during the construction of OWFs.

Fish
The North Sea contains large numbers of saltwater fish and migratory fish species, and these species are expected to be affected by underwater sound during the construction of wind turbines.
However, there are still knowledge gaps relating to the effects of underwater sound on fish. Their behaviour may be affected, which may affect their availability as a source of food for predatory species or influence the distribution of these species.

Birds
The birds found in the North Sea area can be divided into three main groups:
1. 'True' seabirds, which spend all of their time at sea except for the breeding season;
2. Coastal birds, which breed or rest on or near the coast and fly over the Dutch North Sea every day during either the breeding or the whole period they are present in Dutch coastal waters;
3. Migratory land birds and water birds generally are not ecologically bound to the coast or the sea but display migratory tendencies in spring and autumn. The birds migrate parallel to the coast between the European mainland and the British Isles. The migration direction along the coast is NE–SW or E–W, or both between the European mainland an the British Isles.

All three bird groups should be taken into account when assessing effects.

The species that are assessed in the KEC are:
- Brent goose *Branta bernicla*
- Bewick's swan *Cygnus (columbianus) bewickii*
- Common shelduck *Tadorna tadorna*
- Eurasian curlew *Numenius arquata*
- Red knot *Calidris canutus*
- Black-legged kittiwake *Rissa tridactyla*
- Great black-backed gull *Larus marinus*
- Herring gull *Larus argentatus*
- Lesser black-backed gull *Larus fuscus*
- Sandwich tern *Thalasseus sandvicensis*
- Common tern *Sterna hirundo*
- Black tern *Chlidonias niger*

- Great skua *Stercorarius skua*
- Arctic skua *Stercorarius parasiticus*
- Common Guillemot *Uria aalge*
- Razorbill *Alca torda*
- Atlantic puffin *Fratercula arctica*
- Red-throated diver (diver sp.) *Gavia stellata (Gavia* sp.*)*
- Northern fulmar *Fulmarus glacialis*
- Northern gannet *Morus bassanus*
- Common starling *Sturnus vulgaris*

Bats
Research has shown that bats (in wind farms) are more common at sea than previously assumed. For several years, it has been known that among others Nathusius' pipistrelles (*Pipistrellus nathusii*) cross the North Sea from the European mainland to the United Kingdom and vice versa. During the migrations across the North Sea, the bats pass OWFs and are at risk of collision.

Ecosystems
For ecosystems, a generic qualitative assessment was made.

4.2.2 Legal

The first point to note from a legal perspective is that not all species enjoy the same level of protection. In the Netherlands, species habitats are protected by the area and species provisions of the Nature Conservation Act (see Section 3.4). The various species and habitats protected by this Act enjoy different protection regimes. The species provisions of the Nature Conservation Act provide different levels of protection. Species listed in Annex I of the Birds Directive and Annex IV of the Habitats Directive enjoy the highest level of protection.

This step involves consideration of those species on the list of sensitive species drawn up in 4.2.1 that are protected under area or species provisions. However, care should also be taken to consider any indirect effects on protected species resulting from negative effects on non-protected species (e.g. via the food web). The abiotic structure and ecological function of habitats are also protected. These are not described as clearly as the above-mentioned species lists but are just as relevant.

DPSIR in relation to offshore wind, step 2, legal

In the Dutch sector of the North Sea (including the coastal waters), there are three habitat types designated special conservation zones (Habitats Directive areas). These are sandbanks which are permanently covered by sea (H1110), mudflats and sandflats not covered by seawater at low tide (H1140) and reefs (H1170). On the DCS, three areas have been designated (Vlakte van de Raan, Voordelta and North Sea coastal zone) along the coast and two other areas in the open sea (Dogger Bank and Cleaver Bank). In addition, the Frisian Front has also been designated to protect the Common Guillemot under the Birds Directive. Also, the Brown Ridge is a Natura 2000 site under the Birds Directive. So far, these areas have not been nominated for wind farm developments, and therefore, the protected habitats in these areas will not be negatively affected by the planned wind farms. There is also no question of external factors that affect protected habitats in designated Natura 2000 sites (in other words, factors outside a Natura 2000 area that affect a conservation objective for that area). Concerning habitats and species, effects are conceivable as a result of barrier effects, the loss of external habitat (together with potential source areas for (re)establishing certain 'typical' species, indicative of habitat quality) and/or the structural decline of populations as a result of a structural increase in annual mortality.

The harbour porpoise enjoys high legal protection under the Nature Conservation Act and is covered by Articles 3.5 and 3.8 of Section 3.2. The protection status of common and grey seals is less strict: these animals are covered by Section 3.3 (Articles 3.10 and 3.11) of the Nature Conservation Act. There are additional protection criteria for the harbour porpoise, common seal and grey seal in the marine Natura 2000 sites and along the coast: conservation objectives have been set explicitly for these species under the Habitats Directive.

The Nature Conservation Act protects only a few species of fish. Depending on the fish species, species and area protection may apply. Natura 2000 areas have been designated for the allis shad *Alosa alosa*, twaite shad *Alosa fallax*, houting *Coregonus oxyrhinchus*, river lamprey *Lampetra fluviatilis*, salmon *Salmo salar* and sea lamprey *Petromyzon marinus*. In addition**,** under Article 3.5 of the Nature Conservation Act, a strict protection regime applies for sturgeon *Acipenser sturio* and houting. Additional regulations may be introduced (Article 3.7) for the allis shad, twaite shad, river lamprey and salmon**.** Finally, Article 1.11 of the Nature Conservation Act[8] establishes a general duty of care for all animals living in the wild.

The European Marine Strategy Framework Directive (MSFD) aims to protect and restore the European seas and oceans and promote their sustainable use.

The MSFD obliges every European Member State to draw up a Marine Strategy. This strategy must focus on protecting, preserving and restoring the marine environment (a good environmental status), where sustainable use of the North Sea is also guaranteed. The Member States must take the necessary measures in their marine waters to achieve this aim. To do this, they must work together as EU Member States and with other countries in their marine region. The Framework Directive recommends as much as possible the use of existing regional marine conventions

After approval by the European Parliament, the European Commission enacted the European Marine Strategy Framework Directive in 2008. In 2010, the Netherlands integrated the impact of the Directive in the Decree on Water Management, which is part of the Dutch Water Act.
The 11 descriptors of the Marine Strategy Framework Directive are been viewed in the perspective of possible effects of OWFs.

4.3 Inventory of other relevant activities with effects (Step 3)

4.3.1 Ecological

This step identifies all the other relevant activities in or near the plan area. It is important to realise that proximity to the plan area is not necessarily as significant for the inventory of other relevant activities as the area where the relevant effects on the species or habitats could occur. The areas within which relevant effects could occur are large for highly mobile animals, such as birds and marine mammals (apart from migratory fish or bats). Effects and animal populations do not stop at national borders, meaning the assessment should be made from an international perspective.

Only those activities that lead to cumulative effects are considered in this step. The activities to be included should be identified based on their ecological effects and the relevance of those effects, not based on their legal status. Activities are relevant only if they can influence the habitats and species identified in Step 2, either via the same pressures identified earlier or entirely different pressures (or even entirely different *drivers*). For example, when assessing the effects of the construction of a wind farm on marine mammals, it is important to consider the influence of the construction of other wind farms and other activities (for example, fishing or seismic surveys) in the distribution areas of marine mammals. Other effects on habitats or species populations than those identified in Step 2 will not be considered.

[8] Article 1.11 (1): All persons shall exercise adequate care with respect to Natura 2000 sites, special national nature sites, and wild fauna and flora and their immediate living environment. Article 1.11 (3): The first paragraph shall not apply to acts or omissions in accordance with the provisions of, or pursuant to, this Act or the provisions of the 1963 Fisheries Act.

DPSIR in relation to offshore wind, step 3, ecological

Other activities, especially in relation to wind farms and the effects on marine mammals, could be seismic surveys (in space and time), military activities (sonar and shooting exercises and the clearance of unexploded ordnance) and geophysical surveys (studies of the structure of the bed) for the wind farms. All these activities produce underwater sound.
For the KEC, only the geophysical surveys have been included for the sound calculations.
Underwater sound from seismic surveys for oil and gas, military activities, shipping, etc., is not included.

Other important non-included factors are mortality due to by-catch in certain types of fishing, disturbance by and possible collision with vessels, pollution and disturbance as a result of coastal leisure activities (for seals).

For birds and bats, factors that may cause the decrease in the size/quality[9] of the habitat and other forms of additional mortality resulting from human activities (such as collisions, hunting, poisoning, traffic, or other forms of indirect disturbance or loss of habitat) are primarily other wind farms on land and sea, professional shipping, professional fishing, to a certain extent mining (including sand and shell extraction) and marine activities involving the Armed Forces. Pollution in the form of oil, microplastics and bioaccumulation of microcontaminants also play a role. Also, other factors that influence b.e. the breeding colonies (disturbance, predation, erosion, etc.) or other threats to the birds life (high voltage electricity cables, urbanisation, etc.) play a role. These activities have not been included in the KEC.

4.3.2 Legal

The legal requirement in the Nature Conservation Act is that, when assessing plans and projects, the cumulative effects of their combined impacts with other plans and projects must be taken into consideration. More detailed requirements are provided in the case law of the Dutch Council of State and the Court of Justice of the European Union. As the species provisions of the Nature Conservation Act do not mention cumulative effects, they also contain no requirements relative to what should or should not be included in a cumulative effect assessment. However, because it is necessary to make an assessment of effects on the favourable conservation status, each activity which could have an negative effect on the favourable conservation status must be included in the assessment unless it can be considered to have been already incorporated into the estimated conservation status used for the assessment.

[9] The quality of the habitat in a wind farm could probably also improve as a result of an improvement in the food situation but, as long as seabirds do not become accustomed to the presence of wind farms and tend to avoid those areas, it will obviously not be possible for them to benefit from this. It is not yet possible on the basis of the existing research data to determine whether habituation of this kind occurs. In addition, habituation in the case of northern gannets, for example, could suddenly lead in turn to an increased risk of collision because then foraging individuals do indeed fly regularly at rotor height and, in addition, they are predominantly looking downwards at such times…

DPSIR in relation to offshore wind, step 3, legal

The activities which must be included are the Dutch and foreign wind farms in the North Sea, as well as other licensed activities that have not yet been carried out, such as mining, sand extraction and seaweed cultivation. This is because the net effects cannot already have been incorporated into the current conservation status of the selected species. Legally speaking, 'other interventions' (such as seismic surveys) do not need to be included in the cumulative effects.

4.4. Determination of the cumulative effects of all activities (Step 4)

This phase describes the effects of all the activities selected in Steps 1 and 3 that could affect the selected species and habitats in Step 2. However, drawing up a list of priorities based on expert judgement is advisable. The initial selection should be based on a qualitative assessment of the cause-effect relationships between pressures and species/habitats that could lead to significant negative cumulative effects. The key criterion is the protection of the most sensitive species. Other, less sensitive species will often benefit from the mitigation measures required for the most sensitive species. After a list of priorities (which must be made explicit) has been established, a more detailed study will have to be done of those aspects that could lead to significant negative effects, including those where significance is questionable.

This more in-depth study, where possible, based on quantitative research or modelling studies, should indicate for each activity the extent of the pressure's effect on each habitat or species. If this is not possible, the extent of the effect should be determined qualitatively by expert judgement.
The set of effect assessments determined for each pressure by species or habitat forms the basis for the analysis to determine whether and to what degree the various effects of the pressures act to enhance or weaken each other. For instance: a seabird that experiences a loss of habitat resulting from the presence of a wind farm will avoid the area and therefore be less affected by collisions. An example of effects that could enhance each other is when habitat loss and a barrier effect co-occur: not only is the habitat reduced in area, but the remaining area is less accessible.

DPSIR in relation to offshore wind, step 4

In the KEC, only the presumed largest effects of OWfsand the effects of geophysical surveys are studied, and all other effects are not studied.
The effects that are studied in the KEC are listed below:

Underwater sound and marine mammals
Up until now,research has shown that the harbour porpoise is more sensitive to disturbance by underwater sound than the seals in the southern North Sea. Hence it is assumed that adequate protection measures for the harbour porpoise will also provide sufficient protection for the other marine mammal species. The underwater sound disturbance contours from wind farm construction (both in the Netherlands and other North Sea countries) were determined to establish a picture of the total area disturbed by piling sound (impulsive sound) for a certain period of the year. These contours can be compared to the distribution of the harbour porpoise to estimate the number of harbour porpoises that will be disturbed, and for how many days, by the construction of the proposed wind farms (**harbour porpoise disturbance days).**
The studies for the common seal and the grey seal are done in the same way as the harbour porpoise.

The cumulative effect of underwater sound on the harbour porpoise and seals was calculated in Step 4 by using the expert model Interim PCoD (*Population Consequences of Disturbance*). The model can state the consequences of disturbance based on the number of harbour porpoises, determined in Step 3. The consequences for the species population is compared to the situation without the proposed activity. A more detailed explanation of how this PCoD model is used in the KEC can be found in the Annex to Part B (Heinis *et al.,* 2022).

Birds
Wind farms affect birds in four ways:
1. Avoidance of the areas where the wind turbines are situated, leading to the displacement of certain species that no longer recognise the wind farm as part of their habitat. As long as there is no habituation, this diminishes the area in which these species live.
2. Barrier effects of wind farms. Suppose wind farms are located in essential routes for birds flying from their nesting/resting to their foraging areas at sea. In that case, the birds may be forced to go around or through the farms. In addition to natural factors such as wind strength and direction, this may lead to greater energy use, loss of foraging time, loss of condition and/or a much higher risk of collision with rotating turbine blades (see 3).
3. Collision fatalities or injuries. These mainly involve birds that fly through areas with wind farms, either while foraging or during seasonal migration in spring and autumn along the coast and/or over the southern North Sea.
4. Attraction of bird species that see enhanced foraging opportunities, resting opportunities and food supplies ("better habitat quality").
5. Large-scale ecosystem effects. Birds (and marine mammals) can be affected by large-scale ecosystem shifts. These ecosystem shifts are potentially caused by OWF induced changes in hydromorphologial processes, changes in seasonal stratification patterns and/or shifts in carbon flows due to excessive filter feeding activity in benthic communities establishing on the turbine foundations. The shifts potentially cause knock-on effects on food availability for both seabirds and marine mammals.

Effects 2 and 4 are not studied in the KEC 4.0. Effect 5 is, for the time being, only briefly and qualitatively addressed but will require further attention in the future.

Ecosystem
Effects of OWFs on the ecosystem start with affecting the hydro-morphological processes. These changes in the basic conditions affect seasonal stratification patterns. A modelling exercise showed that using realistic hypothetical upscaling scenarios in the North Sea, the effect on stratification differs. Some areas show significant stratification pattern changes, while others are less affected. Shifts in carbon flows are also likely due to excessive filter-feeding activity in benthic communities established on the turbine foundations. These fundamental changes will have knock-on effects on the food web and eventually the higher trophic levels. Research is needed to gain a reliable insight into the contribution of indirect effects of OWFs on the population size of protected species.

Not studied in the KEC 4.0 are:

Fish
Based on current knowledge, fish are only affected by sound levels higher than those affecting the harbour porpoise. Therefore, it is assumed that adequate protective measures for the harbour porpoise will protect fish species (excluding, for the time being, the more indirect ecosystem level shifts mentioned before). This assumption could change in the light of new research and insights.

Bats
There are still many knowledge gaps relating to bats. For example, population size and behaviour in relation to operational wind farms. Furthermore, there is no reliable model for estimating the number of collision victims at sea for this species group. Estimating effects at the population level is not yet possible because there are no reliable population estimates.
The conclusion is that there is still insufficient knowledge available to estimate the numbers of bat victims that can be used in a CEA other than by expert judgement.

4.5. Assessment of cumulative effects (Step 5)

4.5.1 Ecological

This step involves assessing the effects. Determining the size or scale of the effects in Step 4 is a value-free exercise. An objective assessment is made of whether effects occur, not yet of the severity of those effects. The latter assessment takes place in Step 5. Step 5 assigns a value to an effect. In other words, the changes in the status of the protected species at the population level and the reduction in the size or quality of protected habitats are measured against a threshold value (limit of acceptable change). This threshold is determined for species based on population change in line with the principle that there should be no structural decline in population numbers. The threshold for habitats is based on the favourable conservation status; there must be no reduction in the size and/or quality of habitat in relation to the conservation objective of a site. If there is an objective for improving a habitat type, this objective must not be endangered due to individual or cumulative effects. In legal terms, if such a decline or deterioration is probable, the effect will be described as 'potentially significant'.

The ecological effect assessment seeks to establish the extent to which negative effects of the activity can significantly influence a conservation objective (such as the area or habitat quality or the population of a species). The natural size of a healthy species population is limited mainly by the amount of food and other environmental factors, such as the area of safe reproduction and roosting habitats required and the presence of natural predators. A temporary increase in the mortality rate may be compensated for by higher survival rates of the remaining animals and the ability to raise more offspring (density-dependent factors). Additional mortality in animal populations (for example, due to virus infection) may be caused by unexpected temporary or permanent changes in environmental factors. The likelihood of a population recovering from a disturbance depends on the magnitude and the speed at which it occurs.

The mechanism described above gives the population a certain degree of 'resilience' against additional mortality resulting from individual or cumulative effects of human activities. But if the mortality increase continues year after year, the natural carrying capacity will be affected. If recovery is not possible, the species will eventually become extinct or disappear from part of its range. If a population is already under pressure from human influences such as pollution and disturbance, additional , cumulative negative effects will produce a significant effect sooner. The 'resilience' argument is only valid for direct negative effects on the size and/or quality of a species' habitat if an offset occurs by positive effects, such as natural migration, habituation and a better environment in the remaining areas.

The outcome of this step is an assessment of whether the cumulative effects on a habitat or species are within acceptable limits. Suppose the cumulative effects permanently reduce the size of a species population or pose a structural threat to the favourable conservation status of a habitat. In that case, the activity in its proposed form is not permissible in the current form and/or without measures.

From an ecological perspective, the thresholds must ensure that the conservation status of the habitat is not negatively affected and the population does not decline as a result of the cumulative effects of the initiative in combination with other human activities. The ecosystem's carrying capacity for the protected species populations must be maintained at favourable conservation status.

DPSIR in relation to offshore wind, step 5
Step 5 consists of 2 phases: 1) calculating effects and 2) assessing these effects with the thresholds.

Calculation of the cumulative effects
Harbour porpoises, common seal and grey seal
The effects of underwater sound on the harbour porpoise and seal populations were calculated in a series of stages:

1. Sound propagation per piling strike;
2. Disturbance area;
3. Number of disturbed animals;
4. Animal disturbance days per offshore project and total;
5. Population size development over the years (using the interim PCoD model).

The final model results are presented as a reduction in the harbour porpoise, common seal and grey seal populations in the years leading up to 2030. The exact steps taken and assumptions made in this project are described in the background report of Part B. The calculations are based on scenarios with different assumptions for the number of considered OWFs. The reports in part B describe the scenarios; see Annex 2. For the time being, the potential indirect effects that might result from OWF-induced ecosystem shifts are left out of consideration.

Birds
The calculation of cumulative effects on birds included habitat loss and the effects of bird collisions. Habitat loss is based on the assumption that 10% of the displaced birds die or that the animals that suffer this loss of habitat emigrate definitively, or in any event are removed from the population of the southern North Sea. This assumption is based on WMR's interpretation of Bradbury *et al.* (2014), which does not contain any further discussion of this factor. The stochastic Collision Risk Model was used to estimate collision victims. Also, population models were used to tentatively quantify the effect on the population from habitat loss and/or collisions. For the time being, the potential indirect effects that might result from OWF-induced ecosystem shifts are left out of consideration.

Bats
A lot is still unknown about the presence, behaviour, and therefore the sensitivity of bats at sea to operational wind farms. In combination with the analyses of the relationships between weather conditions and bat observations offshore, expert judgement was used to produce indicative estimates of possible effects. Mitigation measures were then proposed in line with the precautionary principle.

Ecosystem effects
In the cumulative effect assessment, ecosystem effects are not taken into account. There is only insight into the effect on hydromorphological processes; what this might mean for birds and marine mammals is still obscure.

Thresholds

Harbour porpoises, common seal and grey seal
For the construction of wind farms (2016-2030), an acceptable level of impact needs to be set for the harbour porpoise, common seal and grey seal. For this,

their conservation status has to be considered (for harbour porpoise, see Siemensma, 2020). It was decided that the harbour porpoise population and the populations of both seals should not fall below 95% of the current population level. A further requirement is that there must be a high level of certainty (95%) that the population will not decline further. Under the Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS), the interim target set for the harbour porpoise is that the population should not fall below 80% of the carrying capacity. It is not known what this capacity is on the DCS. It can be considered a safe choice to maintain the populations of harbour porpoise, common seal and grey seal at a minimum of 95% of their current size.

Birds
Two methods are presently used to determine the threshold for significant effects on birds:

1) ORNIS criterion
According to this criterion, which the ORNIS Committee drew up, each increase in mortality of less than one per cent of the annual natural mortality rate[10] of the population concerned (average value) may be considered not to be significant in the absence of any contrary scientific evidence. The Court of Justice uses this criterion as its benchmark for assessing whether an effect is significant or not (e.g. case C-79/03 (Commission/Spain)). In this regard and from a legal point of view, it should be realised that a better assessment method should be used as soon as it becomes available. In practice, when adequate data are available on the mortality rate of a population, it can be used to determine whether it is possible to rule out any significant effects. If the extra mortality rate of a species due to the effects remains below the threshold, it no longer has to be considered in the assessment. However, if it exceeds the 1% threshold, the effect may be significant and a more detailed investigation of population effects is necessary.

2) PBR -> ALI
In the KEC (2015, 2016, 2019), the acceptability of the effects for birds and bats is based on the Potential Biological Removal (PBR). PBR uses population size and a recovery factor to determine the order of magnitude of a possible decline or reduction in the population that is acceptable from the perspective of the population dynamics. The smaller the recovery factor, the more sensitive a population is and the lower the number of individual victims. The use of PBR as an acceptable measurement has been criticised (for example, by O'Brien *et al.,* 2017; Buij ***et al***., 2018[11]) for not being sufficiently cautious.
That is why a new methodology for identifying Acceptable Levels of Impact (ALIs) is defined**.**

For this novel method, population models have been created for the species of interest in the southern North Sea (van Kooten ***et al***., 2019; Potiek ***et al***., 2019). These models provide more insight into the current expected population trajectory and the possible effect of additional mortality. A method is described to determine thresholds for determining ALIs, which can be assessed using population models (Potiek ***et al***., 2022).

The required thresholds will consist of two parts:

- A threshold population decline 30 years after the onset of a continuous prolonged impact, as a percentage X of the projected population size without the impact, is still considered acceptable.

- A threshold probability Y that X is below this acceptable level after 30 years is considered an acceptable risk.

Together, X and Y lead to an ALI expressed as: 'the probability of a population decline of X% or more, 30 years after the onset of a continuous prolonged impact, cannot exceed Y'.

The method is consistently applicable to mortality due to the consequences as well as habitat loss as collisions with turbines. Additionally, the general framework of the method could be applied to assess any (combination of) impact(s). The requirement for application is a well-formulated matrix population model, for which there is a long and rich tradition in conservation biology.

Ecosystems
At the moment, it is impossible to assess ecosystem effects, as there is not enough knowledge to understand them. How this effect adds to the direct effects on population size cannot be quantified.

Legislative requirements
Under the species provisions of the Nature Conservation Act, the effects on the animal species listed above must be assessed at the level of their biogeographical populations to determine the effect on the conservation status of the species in question. The assessment can be carried out in two ways:

1. Effects on populations in the southern North Sea. These have a direct bearing on the presence of the species in the Natura 2000 areas. This applies specifically to mobile species that move across national borders and for which protection in Natura 2000 sites does not safeguard the continued survival of the populations (see Section 3.4). This means that significant negative effects on conservation objectives cannot be excluded if the expected effects exceed the acceptable standards.
2. For initiatives near Natura 2000 sites with an additional or special function for some species, a location-specific assessment must be drafted under the Nature Conservation Act (in project-related EIAs and appropriate assessments). This assessment must include a determination of whether the cumulative effects of the initiative inside the boundaries of Natura 2000 sites impinge on the integrity of the sites with respect to the size, quality and carrying capacity of the habitat types and species habitats in the Natura 2000 sites.

Because of its location-specific nature, the second approach should be elaborated in project EIA/AAs, in site decisions and in the designation of new wind energy areas.

Individual and cumulative effects of proposed activities on habitats should be assessed in terms of whether and to what extent they cause a measurable reduction in the total area of the relevant habitats and/or a measurable decline in the quality of those habitats. The relevant criteria are provided in the guidance document on significant effects ("Leidraad significantie"[12]) published by the former Ministry of

[10] It should be noted that it will be possible to determine the annual mortality of a species only if enough population-dynamic parameters for that species have been measured in the field.

[11] Kwetsbare soorten voor energie-infrastructuur in Nederland : overzicht van effecten van hernieuwbare energie-infrastructuur en hoogspanningslijnen op de kwetsbare soorten vogels, vleermuizen, zeezoogdieren en vissen, en oplossingsrichtingen voor een natuurinclusieve energietransitie, Buij et al, 2018

[12] update leidraad bepaling significantie versie 27052010 (commissiemer.nl)

Economic Affairs, Agriculture and Innovation in 2009. This approach is not included in the KEC because no offshore wind proposals are located near or in Natura 2000 sites with habitat-type conservation targets.

4.5.2 Legal

Assessing the effects of activities on the favourable conservation status of protected species or the conservation objectives set out in the designation decisions for Natura 2000 sites under the Nature Conservation Act is important.

As defined in the Nature Conservation Act, the conservation status of a species defines the *favourable conservation status*. This implies:

a. that data relating to population dynamics for the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats;
b. the natural range of the species is neither being reduced nor likely to be reduced within the foreseeable future;
c. there is, and will probably continue to be, a large enough habitat to maintain the populations on a long-term basis.

The *conservation objectives* are defined in the Nature Conservation Act as follows:

- The conservation objectives as referred to in Article 2.1(4):
  "*Article 2.1(4): A decision referred to in paragraph 1 shall include conservation objectives for the area. This shall include, in any event, the conservation objectives related to:*
  a. the habitats for bird species, as they are required for the implementation of the Birds Directive, or
  b. the natural and species habitats to the extent necessary to implement the Habitats Directive."

Conservation is defined as:
"*A set of measures required for the conservation or restoration of natural habitats and populations of wild fauna and flora at a favourable conservation status.*"

The *conservation objectives* have been described for:

- Bird species: in terms of the size and quality of habitat with a carrying capacity for a population of a certain number of birds (seasonal average)[13]
- Species covered by the Habitats Directive: in terms of the size and quality of the habitat for the population;
- Habitat types: in terms of area and quality.

The conservation objectives may be targets for maintenance, expansion or quality improvement of a habitat. The minimum requirement for all bird species is a maintenance target, but there may be an improvement requirement in some cases.

The consequences of activities for species can be assessed using rules of thumb such as the ORNIS criterion established by case law. The ORNIS criterion assumes that if the effect of an initiative causes less than 1% of the annual mortality of the species, there will be no demonstrable effect on the size and/or trend of the population of the species and, therefore, no negative effect on the favourable conservation status of the species. It is important to realise that the ORNIS criterion will no longer be mandatory as soon as a better assessment method becomes available for the effect assessment. It will always be possible to use the best-known set of criteria at any time as long as sufficient evidence can demonstrate that those criteria provide adequate safeguards for the conservation objectives. The guidance

[13] For some bird species (for which fewer quantitative data are available) a target number of this kind has not been explicitly included in the designation decisions.

document on significant effects from 2009 can be used to assess the effects on habitats[14].

4.6 Reduction of cumulative effects (Step 6)

4.6.1 Ecological

Suppose the outcome of Step 5 indicates that the project or plan may have significant negative effects. In that case, this should lead to a *response* where measures are taken to reduce or eliminate the effects of the activities (*mitigation*) or ensure the maintenance of the conservation status of the affected species (*compensation, see below for the AIC assessment*).

4.6.2 Legal

If there is a likelihood that a project will have significant negative effects on a conservation objective that could endanger the favourable conservation status of a protected species or habitat (either as a result of the effect of the project or of cumulative effects produced in combination with other projects or plans), the next step is to investigate whether the consequences of the project can be limited to such an extent that the negative effects are no longer significant and that the favourable conservation status is therefore no longer jeopardised. This step is called mitigation.

If despite mitigation measures having been taken into consideration, significant negative effects on the conservation objectives can still not be ruled out, Article 2.8 of the Nature Conservation Act requires an 'AIC' assessment. For this assessment, the first step is to examine whether there are alternative solutions (A) for the activity concerned. If there are no alternatives, the next step is to investigate whether there are imperative reasons for the overriding public interest (I). If there are none, the final step is determining whether compensatory measures (C) can be taken. Compensatory measures offset the negative consequences of the activity, for example, by creating new areas of habitat to meet the objectives for the relevant species or habitats. In principle, compensation should be completed and demonstrably effective before implementing the initiative.

Although the species provisions of the Act do not specifically mention mitigation or compensation, these are both possible under the Act when an negative effect on the favourable conservation status of a species cannot be ruled out.

When an application is made for a discretionary permit involving a strictly protected animal species, the Act requires an assessment in all cases of whether other satisfactory solutions have a less negative effect on the species in question. A discretionary permit is granted only when there is an interest in the development or activity designated by law.

Mitigation measures follow from the Nature Conservation Act. An examination will also be required of whether there are alternatives or solutions for the project and how the project will be implemented, if there is the possibility of an infringement of a prohibition, so that the damage can be limited. In addition, mitigation measures are required by the duty of care in Articles 1.11(1) and (2) of the Nature Conservation Act. Articles 1.11(1) and (2) of this Act state that everyone must take adequate precautions to care for wild animals, plants, and their immediate living environment. The duty of care implies that anyone who knows or can reasonably be expected to suspect that negative consequences may be caused to wildlife by his actions or failures to act should refrain from such actions. If refraining from those

[14] Ministry of Agriculture, Nature and Food Quality, Nature 2000 Policy Research Centre, 2009

actions cannot be reasonably required, take the measures necessary to prevent the consequences. In the case prevention is impossible, they should be limited or rectified as much as possible. Should the mitigation and compensatory measures not reduce the negative effects to an adequate degree, it would be theoretically possible to look for possible reductions in other pressures.

5 Assumptions for the assessment of OWF areas within the North Sea Programme

This chapter describes the assumptions used for calculating the effects, i.e. turbine parameters, region and other relevant activities that are not included. The calculations themselves can be found in the Part B reports.

5.1 Assumptions about the wind farm areas and wind turbines

The future planned wind farms leading up to 2030 were included in the 2030 scenario assessment. During this process, the bandwidth and measures were included in the cumulative effects for which the known (because of a permit or a site decision) requirements were in place. Logically, the future OWF will be included as more generic units (see Annex 1). The site boundaries for the various OWFs are unknown yet. Therefore, restrictions for other activities such as mining, cables, pipelines, and the distances between them have not yet been considered.

In general, the assumptions about the OWFs are:

- Year-round pile driving;
- The use of monopiles;
- If MW is unclear until 2025: 12 MW in accordance with Haliade-X, after 2025 until 2030: 15 MW in accordance with Vestas 236, after 2030 20 MW;
- 1 tip highest level, 1 tip lowest level, 1 tower height;
- Number of MW/km^2 = 10 MW/km^2;
- More extensive areas have been reserved for the search areas. This gives an unrealistically large footprint. That is why the surface is estimated based on 10 MW/km^2. This is a more realistic surface. The estimated value is leading for habitat loss;
- Pile driving energy in kJ amounts to 2000 kJ up to a maximum capacity of the wind turbine of 12 MW; with a capacity of 12 MW or more, a pile driving energy of 4000 kJ is assumed. Work is currently underway on a 4500 kJ pile driver;
- RPM between 7 and 8 rpm;
- Floating rOWFs are not to be included for underwater noise.

Table 1 Reference turbines for the production of 12, 15 and 20 MW

	Haliade-X (GE)	**V236-15.0 (Vestas)**	**20MW**
MW	**12-13-14 MW**	**15 MW**	**20 MW**
Rotor diameter	**220**	**236**	**280**
Blad lenght	**107**	**118**	**140**
Axis height	**±135**	**143**	**165**
Tip highest level	**245**	**261**	**305**
Tip lowest level	**25**[15]	**25**	**25**
Rotor swept area	**38.000**	**43.000**	**62.000**
Rpm	**7,81**	**7-8**	**7-8**

[15] Despite the fact that the manufacturer has put 260 as a tip height in the public information, they themselves indicate that the tip lowest level is 25 meters.

The calculation variants in Table 2 have been used for the North Sea Programme assessment.

Table 2 North Sea Programme calculation variants

Roadmap 2023 and Roadmap 2030	**Calculation variants 2027 – 2030 (acceleration – 2030)**		
	I	**II**	**III**
Borssele III/IV	Hollandse Kust (west) southern part	Hollandse Kust (west) southern part	Hollandse Kust (west) southern part
Borssele I/II	IJmuiden Ver North	IJmuiden Ver North	IJmuiden Ver North
Borssele V	Search area 5 (east)	Search area 5 (east)	Search area 5 (east)
Hollandse Kust (south) I/II	Search area 2 (east)	Search area 2 (east)	Search area 2 (east)
Hollandse Kust (south) III/IV		Search area 1 (south)	Search area 1 (south)
Hollandse Kust (north)			Search area 1 (north)
Hollandse Kust (west) VI/VII			
North of the Wadden islands			
IJmuiden Ver			
Ca. 10 GW	**10,7 GW**	**12,7 GW**	**16,7 GW**

5.2 Identification of the region

On pragmatic grounds, it was decided to define a study area at a biogeographical region during identifying effects. This area is the southern North Sea. The decision was primarily based on the characteristics of the area and its function for relevant species. The southern North Sea is a relatively shallow (predominantly less than 200 m deep), warm and sheltered part of the North-East Atlantic region. Further north, the North Sea 'bottleneck' becomes widerthe water becomes deeper and colder and the direct impact of the Atlantic Ocean is felt more strongly, providing a habitat for other species. The southern North Sea is a highly variable area with influences of cold Atlantic water and eutrophic water from the land.

Study area birds

Gulls, terns, divers and common guillemots are the most relevant birds in this area. The most relevant marine mammals are harbour porpoises, common seals and grey seals.

Moreover, the south of the North Sea is an important flyway between the European mainland and the United Kingdom, and it acts as a bottleneck for several north-south migration routes, mainly for land birds. In consultation, Wageningen Marine Research (WMR) and Rijkswaterstaat drew the boundaries of the southern North Sea (see Figure 3) so that the entire Dogger Bank is included in the study area. It now consists of the southern North Sea between 51°N (about the latitude of Calais) to 56°N (just to the north of the point where the three national continental shelves meet at the northern tip of the DCS, and from the British coast to the European coastline (excluding the Wadden Sea and the Zeeland sea inlets behind the delta barrier)).

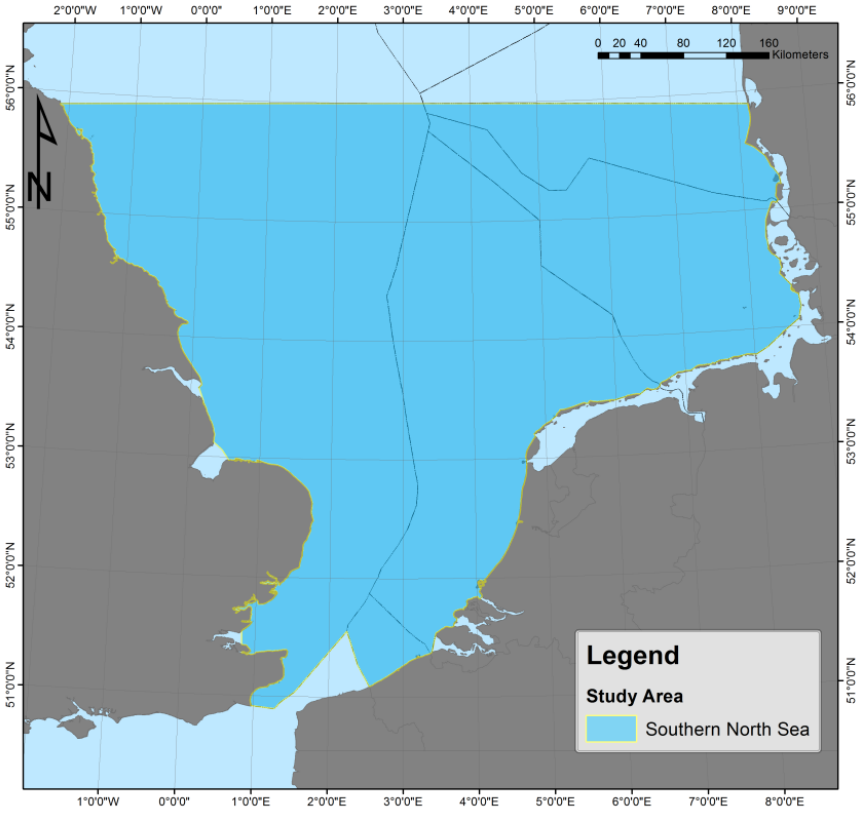

Figure 3: Study area for birds and bats

Study area marine mammals

Under water sound is a key factor as sthe harbour porpoise is the most sensitive to under water sound.The management units defined by ICES at the request of the European Commission and the OSPAR Commission (see Figure 4) were adopted as a relevant sub-population for the harbour porpoise. This allocation to sub-populations is therefore internationally recognised. As the DCS population of the harbour porpoise is part of the North Sea management unit population, the DCS sub-population was adopted as the basis for calculating international scenarios.

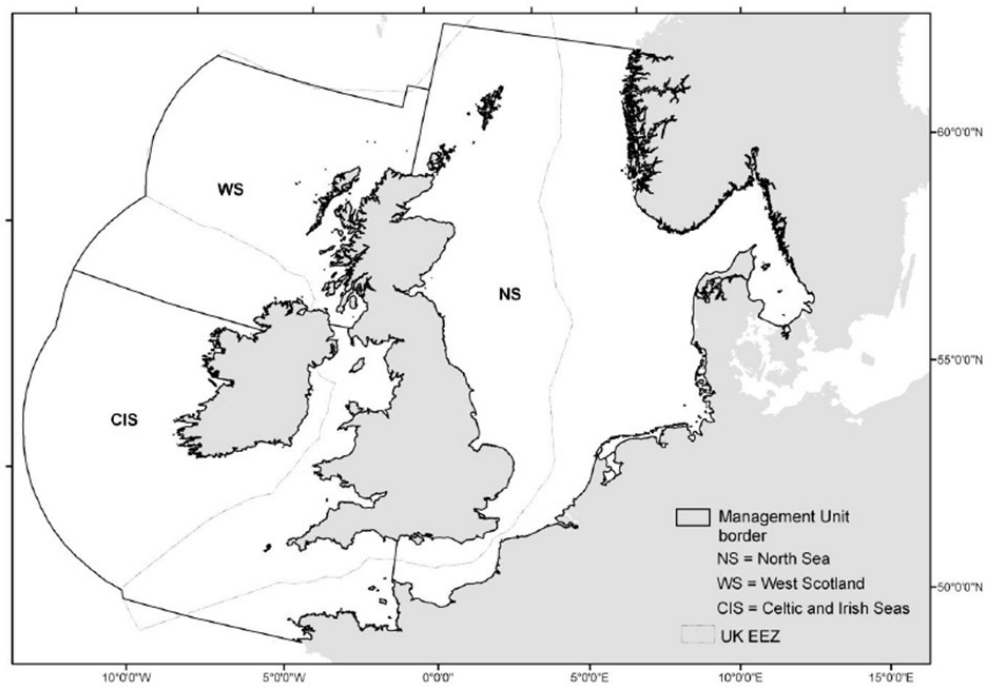

Figure 4: Study area for harbour porpoises

5.3 Inventory of other relevant activities that are not included in the calculations

The calculation of underwater sound effects on harbour porpoises is based on the activities from the offshore wind energy sectors (national and foreign OWF in the southern North Sea). The information available about military activities (particularly clearing unexploded ordnance) was not included in the calculations of the cumulative effects because it is impossible to predict whether, where or when these will occur.
Seismic surveys were excluded because one could argue that the sound resulting from oil and gas prospecting has been present for many years. Given the decision to adopt population dynamics parameters, this factor has already been implicitly considered in the interim PCoD model. It is assumed that prospecting activities are, on average, comparable in all years.However, it is not clear which activities on what scale will be deployed by the industry leading up to 2030. The effects calculations for the OWF areas include the geophysical surveys for the Dutch OWFs that will be built from 2024 onwards (see Part B report, Heinis *et al*., 2022).
Effects from continuous underwater noise are not included. However, soon research will be carried out in operational parks, so the effects of operational underwater noise (b.e. maintenance shipping) can be included.

The calculations for birds included the effects of national and foreign OWFs in the southern North Sea. The disturbance caused by major shipping lanes has not been included in KEC 4.0. It was found in KEC 1.1 and 3.0 that this disturbance added little to the total effect of habitat loss.

Effects from b.e. dredging, sand extraction, fishery, oil- and gas extraction, disturbance of breeding colonies and other negative effects of activities are not included in de cumulative effects.

6 Marine Strategy Framework Directive descriptors in relation to OWFs and KEC; a first exploration

This chapter is a first exploration of an approach for a methodology. Additionally, development directions concerning the effects of offshore wind on the 11 Marine Strategy Framework Directive (MSFD) descriptors are explored, including development perspectives and knowledge gaps.

The main question is whether there are also possible effects on the 11 MSFD descriptors and associated indicator that are currently not yet included or even considered as possibilities.
The MSFD descriptors have not been included in the cumulative effect prediction.

There are three phases in the 'life cycle' of an OWF, each with its potential effects. These are:

1) construction phase
2) operational phase
3) decommissioning phase.

For all descriptors, the key question is: is a potential effect (qualitatively) verifiable?

6.1 Exploration by descriptor

An exploration of the 11 descriptors leads to the following analysis per descriptor. However, many descriptors are interrelated. For example, a cumulative effect of underwater sound on marine mammals through the construction OWFs (phase 1) affects D1 (biodiversity) but also D11 (energy supply, including underwater sound). For each descriptor, the desired outcome is described (*italic*), how it relates to OWFs and how this descriptor could be assessed.

D1 Biodiversity (coherence with D2 to D11)
Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with the prevailing physiographic, geographic and climatic conditions.

D1 is an overarching descriptor that touches on many other, if not all, descriptors. There is a knowledge assignment for seabirds regarding the cumulative effects of collisions and habitat loss; for harbour porpoises and seals, there is a knowledge assignment regarding the cumulative effects of underwater noise on these species. For the benthic and pelagic habitats, there is a knowledge assignment for ecosystem effects due to the presence of OWFs and how benthos develop in OWFs without fisheries that disturb the seabed (seabed integrity).

Assessment:
KEC 4.0 assesses the impact of offshore wind on species (birds, marine mammals and bats). Assessing the impacts on benthic and pelagic habitats is more difficult. Potentially the study on ecosystem effects can provide more insight into this.

D2 Exotics
Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.

One of the questions here is to what extent do you change the ecosystem by introducing OWF and co-occurring hard substrate in the marine ecosystem? Is hard substrate, foreign to the area, a place for settlement and expansion of non-

indigenous species? To what extent does this OWF-related increment in artificial hard substrate availability contribute to undesired opportunities for non-indigenous species, independent of other structures (e.g. wrecks)? This is a search for a semi-quantitative assessment. Potential effects are possible, and many knowledge gaps exist on this issue.

Assessment:
Align with MSFD monitoring for indigenous species and expand monitoring in OWFs.

D3 Commercial Fish Stocks
Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

The fisheries sector is concerned about the possible consequences of OWF development for commercial fish species. Many concerns have been expressed about the potential effects of electromagnetic fields (fish behaviour), the vibrations of operational OWFs and the effects of the construction phase. The fisheries sector is concerned that it will influence fish behaviour, spawning areas and the dispersal of juvinile fish. The question is whether and how effects can be tested based on the D3 indicators.

D3-C1 considers fishing mortality and whether it is less than or equal to the Maximum Sustainable Yield (MSY). For example, could pile driving impact a year class cod?

D3-C2 considers the impact on spawning mass. The question is whether OWFs have a (lasting) effect on spawning.

D3 – C3 considers population age and size distribution. Can OWFs have a positive effect if no bottom trawl fisheries take place in OWFs? And if so, for which fish species is this relevant?

Knowledge of behaviour and fish species is important and can help estimate potential positive and/or negative effects. Can fish species with a high site fidelity (such as cod) profit from OWFs with relatively low fishing activity? Can pelagic species profit from turbines or offshore solar panels as shelter areas? What is the effect of scour protection on the settling of marine organisms?

There are still many knowledge gaps, which should become apparent from current research efforts focusing on the effects of nature-inclusive construction options for OWFs.

Assessment:
Unknown

D4 – food web (relationship with D1, D3, D5, D7)
All elements of the marine food webs, to the extent thatthey are known, occur at normal abuncance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

There is a knowledge assignment for the effect of OWFs on the food web, which requires much monitoring. How is the food web affected by changes in stratification, the primary production process, and sludge flows? Research on this topic is

underway, including research on trophic levels via stomachs of predatory fish and isotope analysis. Another food web indicator is algae production in relation to zooplankton. It is difficult to measure an impact on top predators based on the food web. The NEA Panacea project that started in early 2021 aims to integrate the assessment of eutrophication (pressure) and biodiversity (state).

With the roll-out of OWFs, there will also be an increase in other activities that may affect commercial fish species and the food web, such as the increase of filter feeders in the North Sea. What is the impact of an increase in mussels, oysters and other shellfish (filter feeders) on the food availability of young fish? What is the impact of this on primary production?

What also is important in the food web context is to look beyond the impact on a local scale. What happens in the Dutch part of the North Sea may also affect other parts, such as the Wadden Sea, and vice versa.

Assessment:
Unknown

D5 Eutrophication (relationship with D7)
Human-induced eutrophication is minimized, especially adverse effects thereof, such as loss of losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

This descriptor relates to D7. A direct effect of OWFs on eutrophication is difficult to assess. In addition, there may be an indirect effect due to an increase of filter feeders growing on the turbines (hard substrate benthic species, like mussels and anemones) and an increase in marine aquaculture in or around OWFs.

Assessment:
Unknown

D6 Soil floor integrity
Sea -floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

The construction of OWFs jeopardizes the integrity of the seafloor, but at the same time, there may be a positive influence by excluding bottom-trawling fisheries. Within OSPAR, there are thresholds under development for habitat *destruction*. Thresholds for *disturbance* have already been developed. A threshold value for disturbance is expected to be set in June 2022. This threshold amounts to a formulation where a minimum percentage of the sea floor (divided into grids) must be undisturbed. No more than a certain maximum percentage will be allowed to be heavily disturbed. A similar threshold is foreseen for seafloor destruction. The scale/grid size influences the exceedance level. The larger a grid cell, the sooner a threshold percentage is likely to be exceeded.

When installing OWFs, an artificial hard substrate is created, and a certain amount of natural soft substrate is destroyed. The turbines and the cables are currently considered a disturbance and not a destruction of the seafloor.

Assessment:
Unknown

D7 Hydrographical conditions (relationship with D6, D1, D3, D5)
The permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

A knowledge assignment has been identified for changes in hydrographical conditions due to the upscaling of OWF development. There is an ongoing study on this topic.

Assessment:
Unknown

D8 Hazardous Substances
Concentrations of contaminants are at levels not giving rise to no pollution effects.

The question is how much OWFs add to contaminants from shipping, oil and gas installations (antifouling). There are already rules for this internationally (OSPAR's Hazardous Substances & Eutrophication Committee, HASEC). The rules should also apply to OWF maintenance and construction, and permits regulate this.

A knowledge gap is what causes the resuspension due to OWF effects. It is still unknown if resuspension occurs due to offshore wind or to what extent this relates to natural causes, e.g. storms.

One of the criteria under D8 is significant pollution events. Work is underway to define when something is a significant event.

Assessment:
Unknown yet

D9 Hazardous substances in fish
Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

Not relevant for OWFs.

D10 Litter
Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

If OWFs significantly affect hydrographical conditions, what does it do to marine litter distribution? Is this an indirect effect?

Assessment:
Unknown

D11 Energy supply, including underwater sound
The introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

The KEC assesses underwater noise. A cumulative effect on marine mammals is present during the construction phase. Mitigation measures are required, which is achieved by implementing a noise threshold level. New construction methods other than piling require a new assessment. The operational OWFs effect on underwater

noise (maintenance, vibrations) and habitat quality are still unknown and investigated.

The impact of electromagnetic fields is still relatively unknown, but ongoing studies suggest potential effects on elasmobranchs (sharks and ray, harbour porpoise and possibly on other fish.

International guidance

OSPAR
OSPAR is setting up an intersessional correspondence group (ICG) on renewable developments which will contribute to delivering OSPAR North-East Atlantic Environment Strategy 2030's Strategic Objectives. The scope of the ICG is expected to be broad and related to all offshore renewable energy developments and their potential pressures on the marine environment in the OSPAR maritime area.

OSPAR has developed guidance on environmental considerations for the development of OWFs. The guidance recommends best practices to assess, minimize and manage the potential impacts of OWF. Many OWF environmental impacts can be mitigated through national licensing procedures, ensuring that the OSPAR guidance is followed. In practice, this means that sites are selected to avoid important seabird feeding areas, construction is timed to minimize effects on spawning fish, and routes taken by construction vessels are positioned to minimise the disturbance to seabirds. Monitoring at operational marine renewable sites will provide the basis for better management in the future.

The Quality Status Report (QSR) 2023 aims to assess the environmental status of the North East Atlantic.

ICES
The Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED) of the international council for exploration of the seas (ICES) looks at benthal and renewable energy-related research, cause-effect relationships and develops guidelines to aid future research.

Through international collaboration, the group aims to:
1. Increase scientific efficiency of benthal renewable energy-related research.
2. Specify the various cause-effect relationships caused by ORE installation construction and operation.
3. Develop guidelines.
4. Create an overview of existing data for cumulative impact research

The outcomes will assist in improving monitoring concepts for offshore renewable energy constructions and be set within the context of marine spatial planning strategies and future ecosystem-based management approaches

Conclusion
From the first exploration of the potential effects of OWF developments on the 11 MSFD descriptors carried out in the previous paragraphs, it has become apparent that many facets and knowledge gaps are already included in KEC 4.0 and Wozep's research.

The assessment of the cumulative effects of OWFs on marine species (and non-marine species) is performed, acknowledging there are still knowledge gaps for

several species making a proper assessment challenging and sometimes impossible. However, mitigation is applied or required when negative (cumulative) effects have been identified (D1, D11). However, not all potential impacts are necessarily assessed along all MSFD descriptors.

With the knowledge gap on ecosystem effects and conducted research so far, several knowledge gaps about the impact on the marine ecosystem are identified (D1, D4, D5, D7).

Effects on (commercial) fish species seem less directly verifiable by the MSFD indicators. At the same time, due to an anticipated long-term decrease in bottom trawling- fisheries in OWFs, this may offer opportunities for benthos habitats and possibly pelagic species. Any effects of increased filter feeders on (commercial) fish species are potentially a risk for the food web (D1, D3, D4, D6).

Soil floor integrity and assessment depend on how the threshold values will be established. The grid size is a determining factor for this. From a legal point of view, it is also important whether an OWF development is regarded as destruction or disturbance of the soil. And if it is considered temporary or permanent (D6).

Regarding hazardous substances, there are opportunities to bring offshore wind in line with existing (international) regulations for shipping and the oil and gas industry (D8).

D9 and D10 are not or less relevant for OWF development.

In terms of regional and national coordination, the OSPAR QSR 2023 is a process that offers opportunities to apply the MSFD assessment. It seems obvious to include OWF development and the cumulative impacts in assessing the environmental status and other pressure factors through the QSR process and using the guidance from ICES, particularly for benthos.

For the EIA procedure for Wind Farm Site Decisions, it seems useful to integrate the MSFD descriptors and OSPAR guidance where this is lacking. A more standardized approach to the EIA procedure might add to a consistent assessment of offshore wind impacts on the marine ecosystem.

Recommendations
It is recommended to further explore this first approach for methodology and development directions concerning the effects of offshore wind on the 11 MSFD descriptors. From an ecosystem perspective, merging existing international and national processes and standardizing assessment approaches would be useful to explore further. Improving the coherence between assessments and linking the assessment of pressures on the marine environment with its state (biodiversity) seems obvious but requires collaboration and effort.

7 Knowledge gaps and follow-up actions

7.1 Knowledge gaps and additions to the models and methods used

There are still a considerable number of knowledge gaps relating to methodological (process, ecological, legal) and ecological aspects. Some gaps have been filled by assumptions based on expert judgement; others have been remedied by making pragmatic assumptions and setting up and conducting research, as in Wozep and in the future MONS research programme. However, the assumptions must be validated in due course, preferably based on future research results (Wozep). In addition, the ecological knowledge gaps are covered in the research reports in Part B.

The research community is always on the move. Research is underway on the effects of OWFs on marine life, both in the Netherlands and abroad. These studies will deliver partial answers to the research questions. In addition, research to fill the knowledge gaps began in 2016 (Wozep). Several studies under the Wozep programme have resulted in changes to the assumptions for the calculations made in Part B.
Developing knowledge on time so it can be incorporated into policy decisions is important. For example, by using the knowledge in the KEC.

7.2 Ecological carrying capacity after 2030

This Framework for Assessing Ecological and Cumulative Effects (KEC) has been developed to ensure that the effects of the development of OWFs do not exceed the ecological carrying capacity of the North Sea ecosystem. This means that if the effects of an initiative remain within the limits of the acceptable level of impact the initiative can be permitted from both an ecological and a legal point of view. However, when a subsequent initiative is assessed, the remaining ecological carrying capacity in the ecosystem and thus its resilience will decrease. This is why it was decided to assess the development of OWFs as described. The KEC was used to identify and assess the total cumulative effects of the North Sea Programme, as far as this referred to the implementation of OWF development, despite the fact that there is no legal reason to take into account planned wind farms that have not yet been granted a permit. Adopting this approach makes it possible to ensure that the latest wind farms can also be built and operated without causing any ecological or legal significant effects. This approach also provides an early warning if there are any potential negative effects.

The KEC 4.0 does not look further ahead than 2030(+). The North Sea ecosystem must maintain sufficient ecological carrying capacity, even after 2030, for either offshore wind energy or other initiatives. Therefore, it makes sense to consider the ecological space before further implementing OWFs in the North Sea. One way to do this would be to deploy mitigation measures for each wind farm site to avoid damage to ecological values as much as possible. Initially, this may involve high investments, which can be recouped in the long run by harvesting the benefits of maintaining ecological space in the North Sea ecosystem.

The generic approach taken by the KEC, as described in Chapter 4, will also be applicable to very different interventions in other places but other options should be used for defining pressures, species, calculation models and assessment frameworks.

Annex 1: Assumptions for the Framework for Assessing Ecological and Cumulative Effects

The scenario for the wind farms for KEC 4.0 requires a scenario (national and international) and assumptions. Scenario means, among other things, the number of turbines, the size of the turbines, pile driving energy, etc. So more about what the parks look like. Variants refer to where the parks are located, what combinations of parks there are.

Below are the assumptions that are used when drawing up the national and international scenario. The assumptions are:

- That the scenarios have been established in a careful manner and after consultation;
- The scenarios are aimed at making a good model prediction over the entire implementation period.

And in relation to the future plot decisions:

- that in plot decisions, bandwidths are used, in view of the state of the art at that time,
- and that it is possible that the permitted bandwidth of a specific site decision for a species concerned may have a marginally more negative or positive effect than on which the model is based across the board

National scenario

- Roadmap 2023 as constructed/tendered
- Roadmap 2030 as in Roadmap 2030, where clarity about turbine type, etc. include this.
- Assuming year-round pile driving.
- Assuming monopiles
- If MW unclear until 2025: 12 MW in accordance with Haliade-X, after 2025 until 2030: 15 MW in accordance with Vestas 236, after 2030 20 MW.
- 1 tip highest level, 1 tip lowest level, 1 tower height

	Haliade-X (GE)	**V236-15.0 (Vestas)**	**20MW**
MW	**12-13-14 MW**	**15 MW**	**20 MW**
Rotor diameter	**220**	**236**	**280**
Blad lenght	**107**	**118**	**140**
Axis height	**±135**	**143**	**165**
Tip highest level	**245**	**261**	**305**
Tip lowest level	**25**[16]	**25**	**25**
Rotor swept area	**38.000**	**43.000**	**62.000**
Rpm	**7,81**	**7-8**	**7-8**

- Number of MW/km2 = 10 MW/km2
- Larger areas have been reserved for the search areas. This gives an unrealistically large footprint. That is why the surface is estimated based on

[16] Despite the fact that the manufacturer has put 260 as a tip height in the public information, they themselves indicate that the tip lowest level is 25 meters.

10MW/km2. This is a more realistic surface. The estimated value is leading for habitat loss.
- Pile driving energy in kJ amounts to 2000 kJ up to a maximum capacity of the wind turbine of 12 MW; with a capacity of 12 MW or more, a pile driving energy of 4000 kJ is assumed. Work is currently underway on a 4500 kJ pile driver.
- RPM between 7 and 8 rpm

TenneT platforms and cables
- 1 platform per 2 GW for search areas and IJver Noord
- 1 platform per 700 MW for HKWNorth and HKWSouth and HKW lower part
- 1 cable strip per platform, in accordance with KEC 3.0 (check KEC 3.0)
- Islands/molecule transport not yet taken into account -> possible overestimation of number of cables and pile platforms
- In accordance with principles and assumptions KEC 3.0 underwater noise report (see appendix)

International scenario
- Same area demarcation as in KEC 3.0
- Assuming year-round pile driving.
- Assuming monopiles
- Pile driving energy in kJ amounts to 2000 kJ up to a maximum capacity of the wind turbine of 12 MW; with a capacity of 12 MW or more, a pile driving energy of 4000 kJ is assumed. Work is currently underway on a 4500 kJ pile driver.
- RPM between 7 and 8 rpm
- Source C4Offshore, SEANSE
- Southern North Sea only, from ca. Calais to ca. Skagerrak
- If MW unclear until 2025: 12 MW in accordance with Haliade-X, after 2025 until 2030: 15 MW in accordance with Vestas 236, after 2030 20 MW.
- 1 tip highest level, 1 tip lowest level and shaft height
- Parks of 1 pole or 2 poles (pilots etc) not included
- Estimates of c4Offshore with regard to Analyst certainty with regard to low are included, unless no MW is included, so that no project data is available.
- Floating parks not to be included for underwaternoise
- Larger areas have been reserved for the search areas. This gives an unrealistically large footprint. That is why the surface is estimated based on 10MW/km2. This is a more realistic surface. The estimated value is leading for habitat loss.
- No cables, no platforms

Extra information
- Approx. 10% of the turbines shut down in the spring/summer due to management and maintenance during daytime operational hours (7:30 AM – 4:30 PM).
- Rpm:

MW	rpm	m/s
15	8,4 rpm	
3.4	16 rpm	84,6 m/s
3.2	14,4 rpm	85,2 m/s
6	11,0 rpm	88,7 m/s
8.0	10,3 rpm	90 m/s
11,0	8,6 rpm	90.0 m/s

MW	**rpm**	**m/s**
14,0	7,8 rpm	90,7 m/s
12,0	7,9 rpm	
154 m en hoger		Ca 90 m/s

Annex 2 Differences between KEC 1.1 (2015) & 2.0 (2016), KEC 3.0 (2019) en KEC 4.0 (2022)

Birds, general:

- Population estimates come from the same density maps as the input for the calculations rather than from a range of less easily comparable literature sources. The calculated numbers should not be used separately;
- KEC 4.0 Birds new data ESAS data, added to the data (till 2020)
- Collision casualty estimates calculated using the stochastic Collision Risk Model, instead of the Band model;
- KEC 4.0 Acceptable level of Impact used, such as defined by LNV;
- Casualty estimates translated to annual mortality probabilities based on population estimates from density maps;
- KEC 4.0 Input parameters (demographic rates) for population models updated based on new literature;
- KEC 4.0 Apportionment victims among age classes if possible based on offshore age distribution; this follows an analysis of ESAS data within WOZEP;
- KEC 4.0 Population models used for population assessment of OWF-induced mortality and test of exceedance ALI threshold;
- KEC 4.0 more species calculated than KEC 3.0. New populations models generated for little gull, red knot, bar-tailed godwit, common tern, common starling;
- Existing population models were adjusted to include collision mortality as well for sandwich tern and northern gannet.

Bird habitat loss:

- No new knowledge that can be used for a new KEC;
- IBM (as developed in WOZEP) used for habitat loss mortality estimation of the northern gannet;
- KEC 4.0 Two new population models generated (northern fulmar and Atlantic puffin);
- Shipping not included;
- Barrier effects not included.

Bird collision probabilities

- KEC 4.0 sCRM used for defining collisions;
- New knowledge on the flight speed for black-legged kittiwake and shelduck and recalculated for the stochastic Collision Risk Model for the Bewick's swan, brent goose, curlew and red knot;
- Standard deviations of flight speed included in collision rate calculations for all species;
- Flight height distributions were sampled from GPS data or from modelled height distributions for 1.000 iterations;
- New insights on offshore distribution of Black Tern (cf. Potiek *et al.* 2019 Wozep study);
- New data on fraction of time flying for great black-backed gull, northern gannet and black-legged kittiwake;
- Updated fluxes for Bewick's swan, brent goose and black tern (cf. BirdLife International 2015, 2019);
- New information on avoidance rates from peer-reviewed literature (Cook *et al.* 2018);
- 90% of operationality of wind farms during daytime hours in spring and summer.

Harbour porpoises, harbour seal and grey seal, underwater sound:

- KEC 4.0: the staged procedure was also used to calculate the effects of impulsive sound on the populations of harbour seal and grey seal
- Stage 1: As in KEC 3.0, the Aquarius 4 model which was developed in the context of WOZEP was used for the calculation of the sound propagation in the KEC 4.0. The use of the Aquarius 4 model results in ~~more reliable~~ calculation results that are a ~~better~~ good match for the broadband sound levels measured in the field (de Jong *et al.* 2018);
- Stage 2: To calculate the size of the disturbed area, a dose-effect relationship for the occurrence of a significant behavioural change in harbour porpoises and seals was used in KEC 4.0 instead of discrete threshold values of SELss = 140 or 143 dB re 1 mPa^2s that were used for harbour porpoises in KEC 4.0;
- Stage 3: Mo~~re~~st recent data on local densities of harbour porpoise and seals were adopted (Gilles *et al.,* 2020; Aarts *et al.,* 2021);
- Stage 4: No changes;
- Stage 5: As in KEC 3.0 for harbour porpoises, the possible impact on both the population of harbour porpoises and the populations of harbour seals and grey seals was estimated using the Interim PCoD model (version 5.2), that was fully updated in 2018;
- Stage 6: In principle, KEC 4.0 is based on the same ecological standard as KEC 3.0 (2019). This means that the population decline estimated with a high degree of certainty as a result of the construction of wind farms on the DCS in the period leading up to 2030 may not exceed 5% (and that it must preferably be less).

Bats:

- No new PBR calculations were made for bats because there is no new information about population sizes or collision probabilities;
- Data about numbers present (WMR 2018) were analysed further in relation to weather data and time (Bureau Waardenburg 2018);
- This resulted in a proposal for the optimisation of a mitigation measure with regard to date, time of night, wind direction, temperature and wind speed.
- KEC 4.0: no new insights or calculations

References

M. Boonman, Bureau Waardenburg, 2018; Mitigation measures for bats in offshore wind farms. Evaluation and improvement of curtailment strategy.

Bradbury et al, 2014; Mapping Seabird Sensitivity to Offshore Wind Farms.

E.L. Bravo Rebolledo & A. Gyimesi, Bureau Waardenburg, 2018; Workshop Memorandum, 12 July 2018.

Buij et al, 2018; Kwetsbare soorten voor energie-infrastructuur in Nederland : overzicht van effecten van hernieuwbare energie-infrastructuur en hoogspanningslijnen op de kwetsbare soorten vogels, vleermuizen, zeezoogdieren en vissen, en oplossingsrichtingen voor een natuurinclusieve energietransitie.

cMER 2019; Kavelbesluiten VI en VII Hollandse Kust (west) Advies over reikwijdte en detailniveau van het milieueffectrapport 12 september 2019 / projectnummer: 3369.

Collier M.P, Potiek A., Hin V., Leemans J.J, Soudijn F.H., Middelveld R.P, Gyimesi. A, March 2022; Northern gannet collision risk with wind turbines at the southern North Sea. Extension of the impact assessment for KEC 4.0, additional analyses of the assessment framework.

van Duren L., November 2021; Advice on future assessment of ecosystem effects from offshore wind farms. Advice for KEC.

Framework for Assessing Ecological and Cumulative effects for the roll-out of Offshore Wind Energy, Part A - Methods - 2016 update Chapters 1.5 and 5.6.

Framework for Assessing Ecological and Cumulative Effects and the roll-out of Offshore Wind Energy, Part B - Description and assessment of the cumulative effects assuming the implementation of the Offshore Wind Energy Roadmap - Version 2.0 26 May 2016.

Dr. A. Gyimesi, *ir.* J.W. de Jong, Dr. A. Potiek, E.L. Bravo Rebolledo MSc, Bureau Waardenburg 2018; Update of KEC bird collision calculations in line with the 2030 Roadmap.

Dr. A. Gyimesi & J.L. Leemans, Bureau Waardenburg, 2018; Memorandum: Adding OWEZ and PAWP to the KEC 3.0 calculations.

Gyimesi, A., J.W. de Jong & R.C. Fijn, 2017a. Review and analysis of tracking data to delineate flight characteristics and migration routes of birds over the Southern North Sea. report nr. 16-139. Bureau Waardenburg, Culemborg.

Gyimesi, A., J.W. de Jong & R.C. Fijn, 2017b. Validation of biological variables for use in the SOSS Band model for Lesser Black-backed Gull *Larus fuscus* and Herring Gull *Larus argentatus*. report nr. 16-042. Bureau Waardenburg, Culemborg.

Hammond et al 2017; Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys.

F. Heinis, HWE, C.A.F. de Jong, S. von Benda-Beckmann & B. Binnerts, TNO, 2018; Framework for Assessing Ecological and Cumulative Effects – 2018. Cumulative effects of offshore wind farm construction on harbour porpoises.

Heinis F. (HWE), de Jong C.A.F., von Benda-Beckmann A.M., January 2022; Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0) – marine mammals.

Imares, 2015; A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea.

van Kooten, T., F. Soudijn, I. Tulp, C. Chen, D. Benden & M. Leopold, 2019; The consequences of seabird habitat loss from offshore wind turbines. Report C063/19. Wageningen Marine Research, IJmuiden.

Lindeboom *et al.* 2005; Gebieden met bijzondere ecologische waarden op het Nederlands Continentaal Plat.

O'Brien, Cook, Robinson, 2017; Implicit assumptions underlying simple harvest models of marine bird populations can mislead environmental management decisions.

Platteeuw M., J. Bakker, I. van den Bosch, A. Erkman, M. Graafland, S. Lubbe & M. Warnas 2017; A Framework for Assessing Ecological and Cumulative Effects (FAECE) of Offshore Wind Farms on Birds, Bats and Marine Mammals in the Southern North Sea. In: J. Köppel (ed.). Wind Energy and Wildlife Interactions. Presentations from the CWW2015 Conference. Pp. 219-237.

Potiek, A., M.P. Collier, H. Schekkerman & R.C. Fijn, 2019a; Effects of turbine collision mortality on population dynamics of 13 bird species. Bureau Waardenburg Report 18-342, Bureau Waardenburg, Culemborg.

Potiek A., Leemans J.J, Middelveld R.P, Gyimesi A. March 2022; Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea. Analysis of additional mortality using collision rate modelling and impact assessment based on population modelling for the KEC 4.0.

Potiek A., IJntema G.T., van Kooten T., Leopold M.F., Collier M.P., March 2022; Acceptable Levels of Impact from offshore wind farms on the Dutch Continental Shelf for 21 bird species. A novel approach for defining acceptable levels of additional mortality from turbine collisions and avoidance-induced habitat loss.

Ministry of Agriculture, Nature and Food Quality, 2020; Updated Conservation Plan for the Harbour Porpoise Phocoena phocoena in the Netherlands Maintaining a Favourable Conservation Status.

Skov, H., S. Heinanen, T. Norman, R.M. Ward, S. Mendez-Roldan & I. Ellis, 2018; ORJIP Bird Collision and Avoidance Study. Final report–April 2018. The Carbon Trust, United Kingdom.

F.H. Soudijn, F.H., Hin v., van der Wal J.T., van Donk S., March 2022; Cumulative population-level effects of habitat loss on seabirds 'Kader Ecologie en Cumulatie 4.0'.

Soudijn F.H., Chen C., Potiek A. van Donk, S. March 2022; Density maps of the herring gull for the Dutch continental shelf. Memo to supplement the seabird assessment reports within KEC ("Kader Ecologie en Cumulatie") 4.0.

TNO 2014; Cumulative effects of impulsive underwater sound on marine mammals.

J.T. van der Wal, M.E.B. van Puijenbroek, M.F. Leopold, WMR 2018; Cumulative effects of offshore wind farms: loss of habitat for seabirds. Update for five seabird species until 2030.