REPORT

Spatial study North Seas 2030 – offshore wind development

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1 Introduction

Higher temperatures, more severe storms, greater periods of drought and sea level rises. Those are some of the consequences of climate change, as described in the latest report from the Intergovernmental Panel on Climate Change (IPCC), the United Nations climate panel. Human impact due to greenhouse gas emissions is no longer 'very likely' but 'indisputable', according to the IPCC. The need for a rapid transition from fossil energy to renewable energy is evident, and in the current European strategy (the Renewable Energy Directive and the RePower EU plan) offshore wind farms (OWF) play an indispensable role.

To fulfil the European and also national ambitions, several countries have made plans to increase the number of wind farms in the North Seas. These plans have been developed at a national level considering, among other things, the space required at the national level for other important values and uses at sea.

Now that these national plans have been drawn up, the question arises as to what the joint results and combination of effects will be on a regional sea scale when these plans up to 2030 are realised. The underlying three main questions in this regard are as follows:

1. How much energy will be produced by OWF in the North Seas by 2030? How does that compare with the ambitions set by individual countries and the EU? What does that mean for the required development of the associated infrastructure on a regional sea level (the grid)?
2. What are the combined potential spatial conflicts and opportunities of the national plans on the regional sea scale?
   a) What are the potential spatial conflicts of OWF (and grid) with other marine uses (ecology, fisheries, military and shipping) on a regional seas scale?
   b) What opportunities exist at the regional level that can be exploited by the collaborating countries to successfully develop OWF?
3. What are the conclusions and recommendations on a regional sea scale? What is needed to realise the possible solutions to potential spatial conflicts and capitalise on the opportunities? What parties, knowledge development, agreements, policy development and other requirements need to be put in place?

This report describes the findings of a high-level study of these three main questions. This study was commissioned by the North Seas Energy Cooperation, Support Group 2 (Maritime spatial planning including the environmental subgroup). The results will feed into recommendations for North Seas energy ministers on collaboration opportunities to prevent future spatial obstacles in offshore wind farm development and stimulate knowledge exchange and development.

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Explanation of the goals of the NSEC and the background of this study

The North Seas Energy Cooperation (NSEC) supports and facilitates the development of the offshore grid development and the large renewable energy potential in the region. At the NSEC ministerial meeting on 4 December 2019, the North Seas energy ministers from the NSEC countries and the Commission agreed that the conclusion from the meeting allows the NSEC to continue and reinforce the cooperation under the new 3-year work programme. The work programme will be implemented by four Support Groups mirroring the work streams in the work programme:

- Support Group 1: Hybrid and joint projects
- Support Group 2: Maritime spatial planning (MSP) including the environmental subgroup (CEAF group)
- Support Group 3: Support framework and finance
- Support Group 4: Delivering 2050

North Seas energy ministers have recognized in the 2019 Declaration that the space in the North Seas is finite and the demands of both traditional and non-traditional marine uses are increasing. There is a need to better understand the possible ecological limits of largescale wind development in the North Seas and the spatial implications related to other uses. Maritime Spatial Planning provides the tools to balance the spatial needs of different sectors, while at the same time protecting the environment and biodiversity.
Ministers invite the Support Group 2 to develop concepts for coordinated planning and development of offshore wind of the North Seas countries - also beyond national borders - including area mapping and to develop scenarios for designating further areas for offshore wind.

This study was conducted by Royal HaskoningDHV and partners in close collaboration with policymakers and subject matter experts from the eight countries involved. Information on the realisation of wind farms and the grid was provided by DNV. Information on aviation was provided by Cyrrus Ltd. This work is also built upon results from the NSEC EU co-financed project SEANSE.

Study area and scope of the study

The study covers the North Seas: the greater North Sea and the Celtic Sea (OSPAR areas II and III; see figure 1.1). Collaborating countries in SG2 are Belgium, Denmark, France, Germany, Ireland, the Netherlands, and Norway. UK policy information is incorporated.

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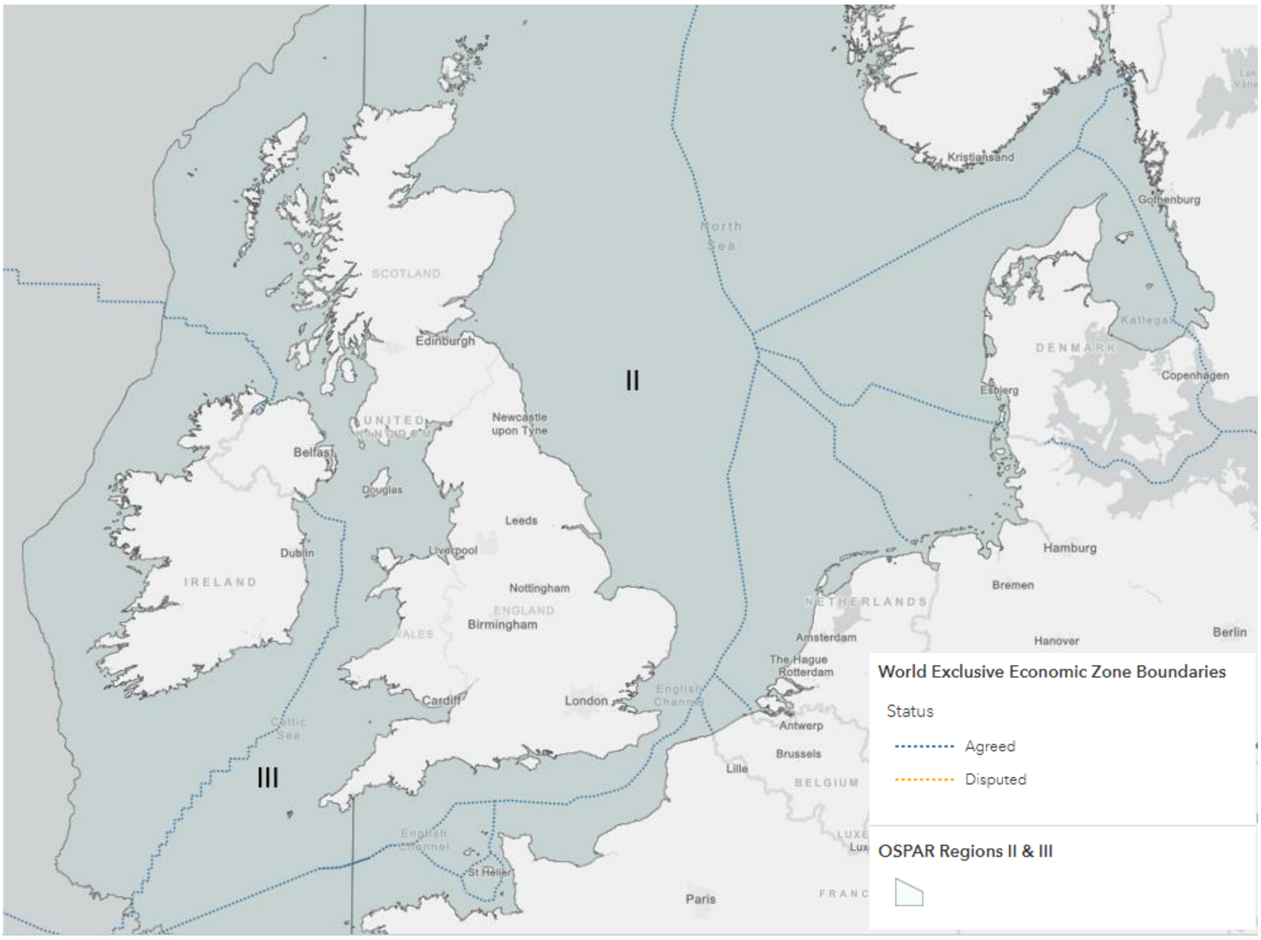

Figure 1.1 Study Area (OSPAR regions II and III)

This study focuses on the spatial effects on four other marine uses (ecology, fisheries, military and shipping) on a regional sea scale. The study is based on a bottom-up approach, which means that the assessment is built upon national data and information about marine spatial plans and policies. Within this study, no judgements are made about opportunities and impacts at the *nationa*l level or on *other marine uses*. This study concerns a high-level assessment of the situation in the North Seas in 2030, based on the judgement of policymakers and experts. No modelling studies or new monitoring results were used. See also Chapter 2 for a more detailed explanation of how the findings were arrived at.

Although the focus of this study is on the situation in 2030, the various meetings also briefly looked ahead to the period thereafter. Offshore renewable energy (still mainly wind energy) is expected to be developed probably even with higher ambitions after 2030. Spatial explorations are seen in many countries but in most cases have not led to claims or designated areas yet. In looking beyond 2030 towards 2050 it is assumed that large offshore wind developments will take place in line with what we already see, an emphasis on the southern part of the North Sea and the UK waters.

Reader's guide

This report is structured as follows:

Chapter 2 describes the working process.

Chapter 3 provides an overview of offshore wind and grid on the North Seas. This includes both the current situation and the situation in 2030 (ambitions and goals).
Chapter 4 discusses the potential spatial impact of offshore wind on four other uses (ecology, fisheries, military and shipping)
Chapter 5 describes the conclusions and recommendations for future collaboration between the involved countries; what are the most important potential spatial conflicts and opportunities, and what is needed and wanted in the cooperation to enable the collaborating countries to proceed in offshore renewable development in an optimal way.

2 Work process in this study

During this study, the following work was carried out:

a) Realisation of a spatial overview (an interactive viewer) of the current situation in the study area and the situation in 2030;
b) Assessment of the potential spatial conflicts and opportunities;
c) Drawing up of conclusions and recommendations.

In the paragraphs below, the work process for each of these activities is briefly described.

2.1 Interactive spatial overview (GIS viewer)

The comprehensive spatial overview is the backbone for all the work in this study and the possible follow-up (an exploration study into development options beyond the spatial designations for wind energy of the maritime spatial plans in a further future (2040–2050)). The interactive viewer makes it possible to identify and localise the potential spatial conflicts at a glance and to zoom in on the desired themes and focus areas.
For this reason, it is of great importance that this product is of the right quality and is easily accessible and usable for all members of the project team. Therefore, we paid a lot of attention on the data storage, visualisation and access.

To develop the viewer, we started by collecting data that originates from the Digitwin (https://digitwin.maris.nl/). This Digitwin was filled with the information on offshore renewable developments until 2030 according to national policy (and MSP) of the collaborating countries as delivered by the country experts over early 2022. By using this data we created our own viewer, which was reviewed multiple times by the collaborating countries. Furthermore, when necessary, some of the involved countries (e.g. Germany, the Netherlands and Ireland) provided us with additional (or more recent) data for the viewer.

2.2 Assessment of the potential spatial conflicts and opportunities

To develop the end report, the following steps were taken. First, there were multiple desk studies to (1) get an idea of the process of offshore wind development (see Appendix 1) and (2) create an image of the national approaches towards potential spatial conflicts of the North Seas (see Appendix 2). The main sources for these studies are the marine spatial plans of the eight countries involved.

To validate the information from the desk studies, we conducted interviews with the experts for ecology, fisheries, military, shipping and OWF. In the interviews we used the GIS viewer to identify potential spatial conflicts and the areas where these conflicts are most likely to occur. Additionally, an integration session was held with the experts, in which we discussed what overlapping areas of interests are and which areas are of concern.

An additional step to validate and collect ecological information, was to organise a workshop at the Conference on Wind Energy and Wildlife impacts (CWW) in Egmond aan Zee. In the workshop we presented a map based on our viewer, and discussed with participants whether they noticed mistakes or missing information on the map. Furthermore, we had a discussion about the potential spatial conflicts and opportunities for offshore wind in relation to ecology.

Lastly, a workshop was organised in Amsterdam with the goal to pitch the results of the expert sessions and, together with the members of the Support Group 2, enrich the results with an integrated view. We had several integrated discussion groups and identified potential spatial conflicts and opportunities on a regional scale. Additionally, we identified in what areas countries could work together to minimise or mitigate the potential conflicts.

During the whole process we had around eight meetings with the project team, which consisted of members from Germany, Denmark, the Netherlands and Ireland and a representative from the ecological subgroup (CEAF). Within these meetings the progress of the project was discussed, and feedback was given on the results of the study executed and presented by Royal HaskoningDHV.

2.3 Drawing up of conclusions and recommendations

The conclusions and recommendations were reached through a series of iterative steps. At the commissioning, we start with a short inventory of the most important conclusions and recommendations from previous processes and agreements (such as SEANSE and the political declaration of the NSEC). Based on this, plus our expertise and the knowledge from the marine spatial plans, we make an initial list of possible topics on which the conclusions and recommendations should be based. The experts are then asked if they could indicate what the conclusions and recommendations might be for their sector. These preliminary conclusions and recommendations were supplemented and refined during both the internal workshops, the PT meetings, Support group 2 meetings and the external workshops.

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3 Offshore wind and grid development in the North Seas

This chapter provides an overview of offshore wind and the corresponding infrastructure (grid) on the North Seas. This includes both the current situation (paragraph 3.1) and the plans and ambitions for 2030 (paragraph 3.2). Section 2.3 addresses the question of whether the EC 2030 ambitions are likely to be achieved.

3.1 Current situation of OWF in the North Seas

The current situation (2022) of existing offshore wind farms in the North Seas is shown in Figure 3.1. The capacity of these wind farms collectively adds up to over 25 GW, see also column 2 of Table 3.2.

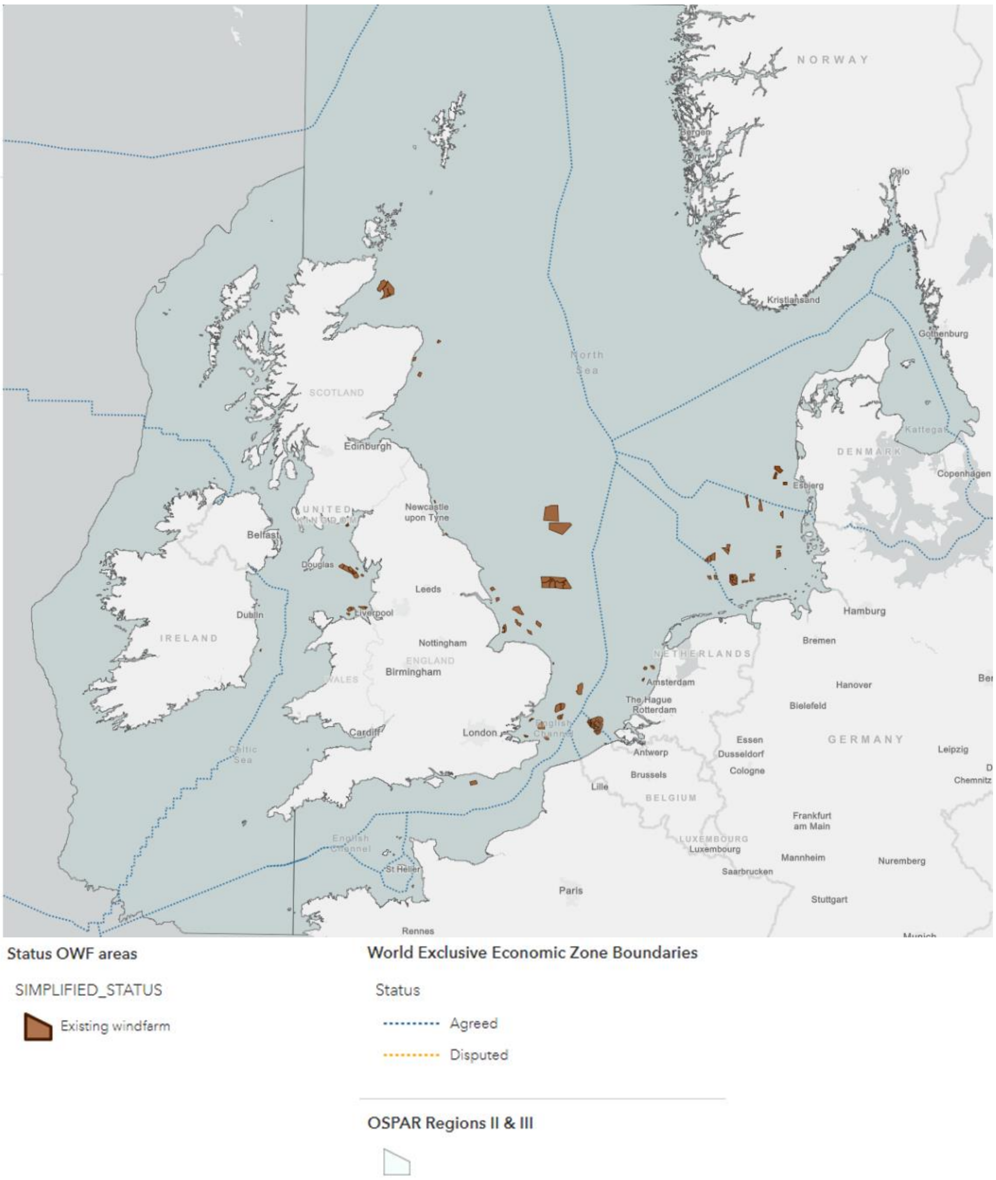

Figure 3.1 Current situation of the existing offshore wind farms in the North Seas

In terms of the grid, we note that so far mostly single connections have been made (from an individual wind farm or group of windfarms in the vicinity of each other in one country to the associated point on land). The information about this grid is available in the Digitwin (https://digitwin.maris.nl/).

3.2 Plans and ambitions for 2030

The following sections provide insight into both the geographic location of the wind farms and the expected capacity.

3.2.1 Locations of wind farms in 2030

In the period up to 2030, several additional wind farms will be built and put into operation. These include wind farms that are already licensed (but not yet in operation) and wind farms that are planned in designated areas. See Figure 3.2 for an overview of the existing and additional wind farms. The status of the wind farms is shown in five different categories. Table 3.1 explains how these categories are distinguished.

Table 3.1 Description of in the map legenda used categories of OWF development up to 2030 (as a note to Figure 3.2)

Category	Description
Existing wind farms	Wind farms that are currently in operation
Licensed wind farms	Wind farms that are under construction and/or have a licence/permit for construction
Designated wind farm area	OWF areas that are announced publicly (in the news or in reports), but which are still in the early phases of the process or; areas that are under review
Other	By competent authorities public shared information on OWF to be developed after 2030 or; areas where there is a plan or indication, but with a lot of uncertainty whether the developments will take place before or after 2030.
Other (partial OWF development)	This category refers to areas that will not fully be utilised for OWF development, but only partially

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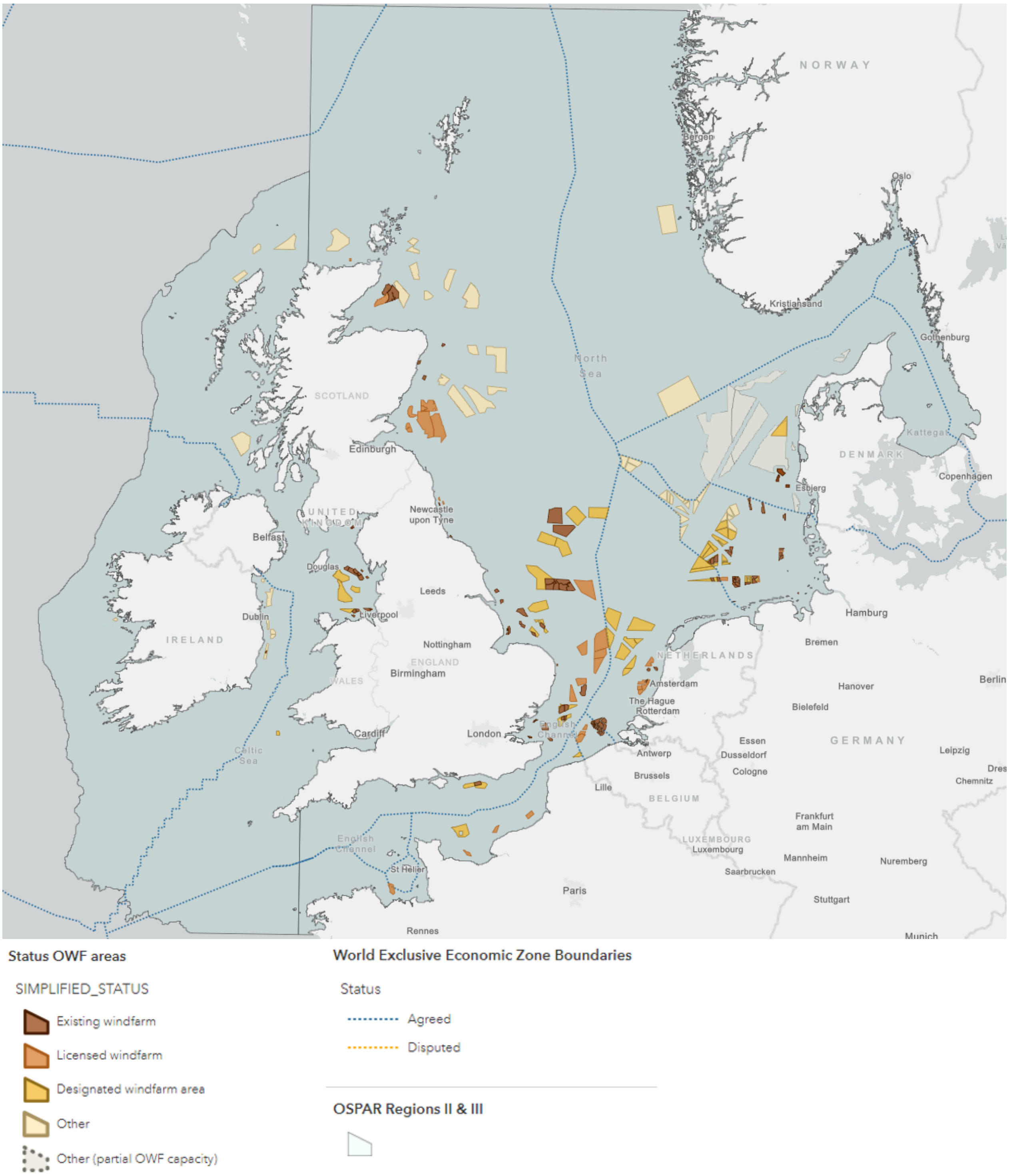

Figure 3.2 Overview of the current situation and OWF developments up to 2030

3.2.2 Grid development

With the rapidly increasing ambitions for offshore wind, it is likely that the grid will be optimised towards a meshed system with probably both electrical and hydrogen connections (See annex 1). These plans are currently under development. The figure below shows some of the first developments and initiatives that play a prominent role in this.

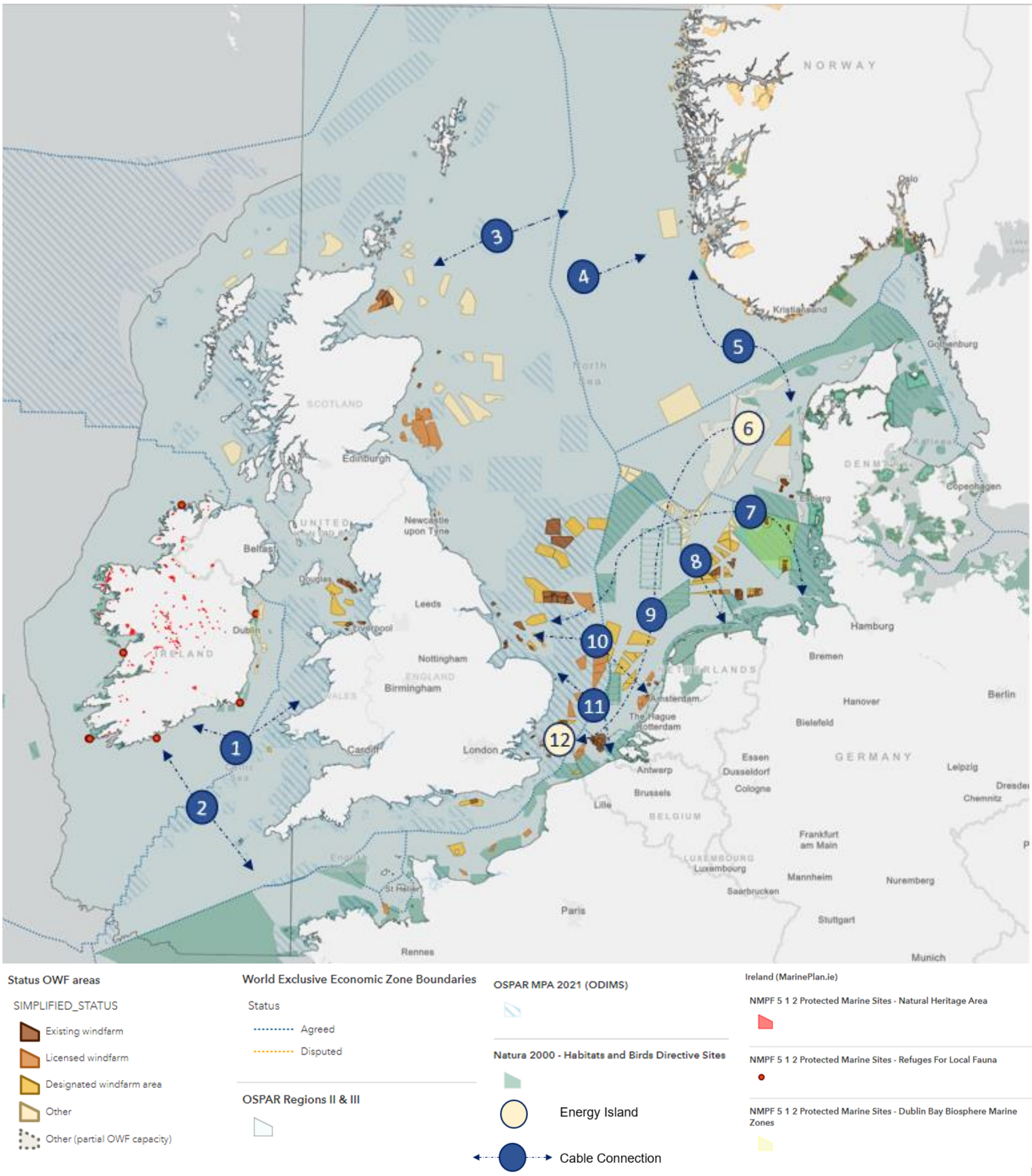

Figure 3.3 Recent joint initiatives in the development of a meshed/optimised grid. It is expected that all these developments will be realized before 2030.

1: Greenlink (IE & WSL)
2: Celtic (FR & IE)
3: NorthConnect Easternlink (SCO & NO)
4: CMS & Maali Link (NO)
5: Nordlink (NO & DE)

6: North Sea DK Energy Island
7: NeuConnect (DE & GB)
8: PAWOZ (NL)
9: Interconnector Danish Energy Island and Belgium Energy Island
10: WindConnector (UK & NL)
11: Nautilus Link (UK & BE)
12: Energy Island Belgium

The recent EU plan (RepowerEU, March 2022) notes that the Commission will also encourage the swift development of crucial offshore grid and cross-border hydrogen infrastructure.

3.2.3 Offshore wind capacity per country in the North Seas in 2030

Table 3.2 shows three types of information on installed capacity per country:

a) Existing capacity (column 2 of Table 3.2)
The information in this column consists of an aggregation per country of the current installed capacity of all existing wind farms.
This information is retrieved from the Digitwin (as provided by Support Group 2) and in some cases supplemented/improved by the delegate in the project team of the respective country

b) Planned capacity (column 3 of Table 3.2)
This information consists of an aggregation per country for the future energy capacity for all future wind farms per country in 2030.This information is retrieved from the Digitwin (as provided by Support Group 2) and in some cases supplemented or improved by the delegate in the project team of the respective country. Unfortunately, not all data is available. If the field says 'unknown' this means that the country did not provide this information on individual wind farms. Additionally, of the windfarms that are being in the early planning stages, it is not yet known which ones will actually be realized.

c) Ambition for 2030 (column 4 of Table 3.2)
This information is retrieved from the Marine Spatial Plans and shows the ambition of the countries for 2030. In the ideal situation, the sum of the existing capacity and the planned capacity is equal to the ambition. Additional information is delivered or improved by delegates from the project team of the respective country. If there was still information missing, the 'North Seas offshore wind study' (Annex 1) was used, which is based on reliable governmental sources.

Table 3.2 Overview of existing capacity, planned capacity and ambition for 2030 at the North Seas

Country	Existing capacity	Planned capacity	Ambition for 2030
		Sum of capacity of all planned offshore wind farms to be developed before 2030.	*Based on information retrieved from Marine Spatial Plans (MSP)/ other reliable governmental sources, or delivered by the countries.*
Ireland	0.025 GW	4,049 – 4,649	**7** GW
France	0 GW	5.3 GW	**5** GW
Belgium	2.3 GW	3.5 GW	**5.4–5.8** GW
Netherlands	2.5 GW	18.5 GW	**21** GW
Germany	7.7 GW	18.9 GW*	30 GW* (at least **19,8** at the North Seas)
Denmark	2.3 GW	10.5 GW*	12.8 GW* (at least **3,65** at the North Seas)
Norway	0 GW	Unknown	**4.5** GW**
UK	11 GW	Unknown	**50** GW
Total	25.8 GW	61 GW	At least 117 GW at the North Seas

* Capacity is not limited to the North Seas; this will also be partly developed in the Baltic Sea.
** It is not known yet exactly when the 4.5 GW will be developed.
The UK and Norway are not part of the EU.

3.3 Are the ambitions being met?

This section addresses the question of whether the ambitions of individual countries (with regard to installed capacity) are likely to be met as well as the ambition of the EU. This study considers two issues*: a) possible loss of production due to wake effects and b) the difference between concrete plans for offshore wind development and ambitions as stated in the Marine Spatial Plans.

*NB. There are, however, many more issues that play a role in whether ambitions are met. These include, for example, issues relating to the deliverability of the materials needed to build wind turbines, the speed of permit procedures and the availability of equipment and people to produce wind farms. However, these issues are beyond the scope of this study.

a) Possible loss of production due to wake effects
Wind farms are an obstacle to wind and cause a reduction in wind speed on the downstream side. If wind farms (or individual turbines) are located close to each other, decreases in energy production can also occur as a result. One turbine (or wind farm) then takes the wind 'out of the sails' of the other turbine or wind farm, as it were. This effect is called the 'wake' effect.
With more and more wind farms being built on the North Seas and the wind farms generally becoming larger, the likelihood of wake effects will increase. This is especially important at locations where wind farms are developed close to each other. The magnitude of the impact on any specific projects is highly project specific depending on the relative proximity, position towards dominant wind directions and design of neighbouring projects (see Annex 1).

Figure 3.4 below shows the locations (W1, W2, W3) where transboundary wake effects might occur. Here (based on expert judgement) a range of wake effects of up to 40 kilometres is assumed.

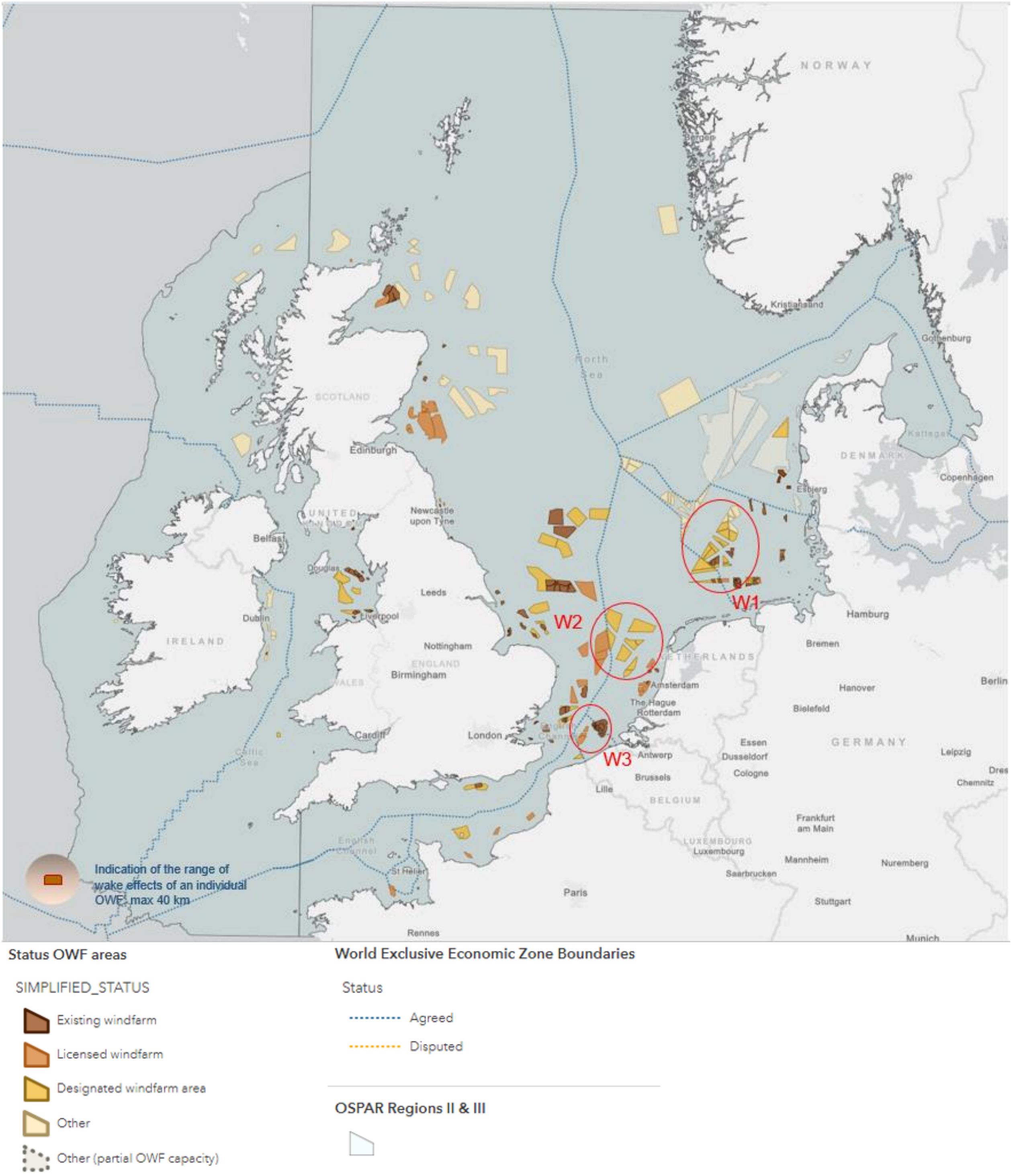

Figure 3.4 Locations where transboundary wake effects might occur (W1, W2 and W3)

Despite the fact that wake effects are expected to increase when plans are realised towards 2030, there is no reason to assume that the expected production of the planned wind farms (as shown in Table 3.2) will not be met due to transboundary wake effects. This is because the production of wind farms is positively influenced by other factors, such as the technological improvement of turbines (larger rotor diameters, higher hub heights) and improved wind farm control strategies.

There is therefore no reason to expect substantial impacts on the overall planned production until 2030 by transboundary wake effects .

b) Difference between concrete plans and ambitions per country
Table 3.2 contains data per country on the *ambitions* of countries (column 4) and the *concrete plans* for offshore wind development (column 3). In the ideal situation, the plans (plus existing offshore wind) equal the ambitions. In that case, there is already a certain degree of clarity about the locations where development should take place and planning has begun. Given that planning can take years, this is an important condition for realising ambitions by 2030. This situation occurs in the plans of France, Belgium, the Netherlands and Denmark.

For some other countries (Ireland, the UK and Norway), the information on concrete plans is not completely publicly available and it is not possible to determine whether these add up to the ambition in the Marine Spatial Plans. In the case of Germany, the ambition has not been formulated specifically for the North Seas and therefore a comparison at the North Seas level cannot be made.

In summary, for four countries we can conclude that the concrete plans add up to the ambition of the country concerned. For the four other countries, the comparison cannot be made due to lack of information.

At the **European level,** the ambition has been formulated for at least 60 GW by 2030 of offshore wind. This 60 GW relates to all seas of the EU (including the Mediterranean Sea, Atlantic Ocean, Black Sea and the Baltic Sea). Thus, less than 60 GW needs to be realised on the North Seas to meet the current EU minimum ambitions.
As can be seen from Table 3.3, the ambitions of the six European member states involved (Ireland, France, Belgium, the Netherlands, Germany and Denmark) already add up to at least 62 GW at the North Seas by 2030 (see Table 3.3). This is more than the European ambition of at least 60 GW for offshore wind. Together with the ambition of the UK (50 GW) and Norway (4.5 GW), this brings the ambition of OWF in the North Seas in 2030 up to at least 117 GW.

This means that within this study no reasons have been found to doubt the feasibility of the European 2030 targets for OWF. As noted earlier, there are other factors (such as availability of materials, equipment and people) that could potentially have a negative impact on the feasibility.

Table 3.3 Are the ambitions being met on a regional scale of the North Seas?

Country	Ambition
Ireland	**7** GW
France	**5** GW
Belgium	**5.4 – 5.8** GW
The Netherlands	**21** GW
Germany	30 GW* (at least **19.8** GW at the North Seas)
Denmark	12.8 GW* (at least **3.65** GW at North Seas)
Ambition of the European member states together	>= 62 GW (at the North Seas)
Norway	4.5 GW
UK	50 GW
Overall ambition at the North Seas	>= 117 GW
* Capacity is not limited to the North Seas; this will also be partly developed in the Baltic Sea.	

Recent developments

4 Spatial impact of offshore wind and grid on other uses of the North Seas

This chapter describes the impact of offshore wind development for four other users of the North Seas. This is an indication of possible impact on a regional scale. The impact was determined based on expert judgement in various interviews and workshops.

These four marine users considered are: ecology, fisheries, shipping and military activities. The following are described in succession for each of these users: geographical facts, potential spatial conflicts, opportunities, conclusions, and recommendations.

The section 'geographical issues' provides an overview map of the study area showing the locations of the wind farms in 2030 as well as the most important geographical information of the relevant other user. These figures also show the 'hotspots'. These areas have been identified (by experts and policy makers from the eight countries) as those where there is a high likelihood of spatial conflict.
The sections on potential spatial conflicts, opportunities and conclusions reflect the results of interviews, workshops and expert judgement regarding the impact of offshore wind on the other user.

4.1 Ecology

The impact of offshore wind development consists mainly of two issues: on the one hand the impact of the wind farms themselves, on the other hand the impact of the new connections between the wind farms and the land (the grid). This section describes both the effects of wind farms and the effects of potential new connections between the wind farms and the land.

4.1.1 Geographical facts ecology

Figure 4.1 shows the location of offshore wind in 2030 in combination with ecologically valuable areas. In terms of ecological data, the following were chosen to be included on the map:

- Marine Protected Areas (data retrieved from EMODNet)
- Natura 2000 areas (data retrieved from EMODNet)
- Main migration routes (based on expert judgement)

It can be seen from Figure 4.1 that there is little overlap between the current legally protected areas and the planned wind farms. An exception to this concerns the English part of the Dogger Bank as well as the Belgium southern part of EEZ.

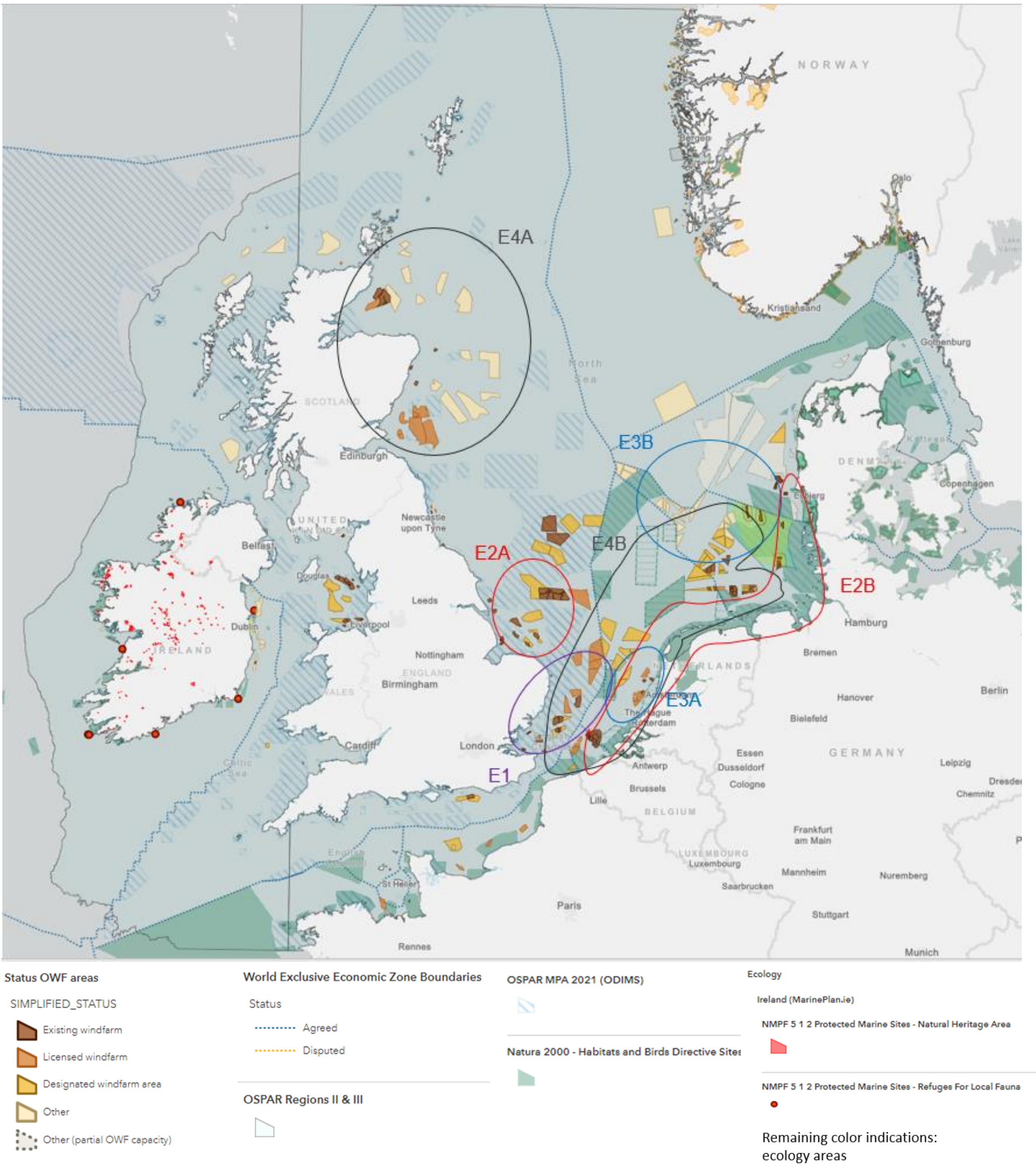

Figure 4.1 Offshore windfarms in 2030 and ecology (ecological valuable areas and 'hotspots')

For ecology, four types of hotspots have been identified:

E1: The area north-east of the English Channel: barrier for migrating birds and marine mammals;

E2: Ecological valuable areas that might be affected by landfall cables (new grid);

E3: Areas with potential stratification issues (large-scale wind energy development can influence the stratification of the water column and thus affect the whole ecosystem);

E4: Areas with potential conflicts for seabirds (concern for breeding colonies and key areas during other seasons).

4.1.2 Potential spatial conflicts ecology

Four types of potential hotspots have been indicated (see figure 4.1) for spatial constraints between the windfarms (including grid) and ecology.

Although these areas have the highest likelihood of negative impacts, the effects of OWF on ecology are not limited to these hotspots. The impact on the ecology of the North Seas is widespread, as species migrate far beyond protected areas and national borders and ecosystem effect are large scale effects. The following potential spatial effects are considered to be most important on a regional sea scale and are likely to increase with the increasing ambitions of the NSEC countries):

- Ecosystem effects: changes in stratification, sedimentation processes and hydromorphic changes due to large scale developments that can have impact on the primary production and thus on the food chain.
- Collision, displacement and barrier effects on birds (bird species that feed on sea and bird species migrating over sea).
- The effects of underwater noise during construction of OWF on different species with special concern for the Harbour Porpoise.

Best available model studies predict conflicts with N2000 regulations for 4 bird species populations (on a regional sea level in the North Sea) due to developments of OWF before 2030 (collision risk): Herring Gull, Northern Gannet, Black-Legged Kittiwake and Great Black-Backed Gull.
There are ambitious targets set in the new EU Biodiversity Strategy for 2030: 30% of the European sea area must be protected, 10% of the European sea area must be strictly protected. The Biodiversity Strategy will lead to increasing spatial competition. Locations for these protected areas are unknown in this stage and left out of this study.

4.1.3 Opportunities and expected developments ecology

To prevent, reduce or mitigate the potential spatial conflicts for ecology, some opportunities/expected developments are identified:

- Collaboration on a regional scale in preventive/mitigating measures (e.g. start/stop procedures of OWF during migration, alignment in pile driving, etc.)
- OWF can have positive effects on biodiversity through hard substrate or the introduction of 'no fishing zones' within the windfarms.
- In order to increase the effectiveness of mitigation and prevention, joint research and monitoring is necessary for:
    - Abundance of species and reasons for this abundancy
    - The impact of OWF at species level and on ecosystem level
    - The effectiveness of mitigation measures for birds and marine mammals and
    - Positive biodiversity effects of wind farms.
- An ecosystem based, more integral tool development and application in Marine Spatial Plans to improve the integration of ecology in MSP processes. An adaptive management approach as an integrated part of this tool can ensure the application of research results within spatial planning practice.
- With the rapidly increasing ambitions for offshore wind, it is likely that the grid will be optimized towards a meshed system with probably both electrical and hydrogen connections. It is possible that through this optimization some of the potential spatial conflicts with ecological areas can be

avoided or reduced. To achieve such an optimized network, it is important to develop a shared spatial vision for the network on a regional scale.

4.1.4 Conclusions ecology

In conclusion, four types of hotpots have been identified (E1, E2, E3 and E4) with substantial potential spatial conflicts of offshore wind farm development with ecology. One should note however that ecological effects in these areas can be amplified by the cumulation of effects occurring (far) outside these areas. The most pressing issues are the ecosystem effects of OWF and the displacement and barrier effects on birds.
As a result of these expected spatial conflicts, conflicts between N2000 regulations and OWF developments before 2030 are predicted. Future OWF development (beyond 2030) and EU biodiversity ambitions can increase conflict within EU waters (N2000 regulations) and might hamper OWF development.

4.1.5 Recommendations ecology

Recommendations:

- Ensure more intensive cooperation in mitigating/preventative measures on regional scale for 2030:
    - Use the four identified hotspots as a starting point (E1, E2, E3 and E4).
    - Focus on the most threatened species as identified so far (Herring Gull, Northern Gannet, Black-Legged Kittiwake, Great Black-Backed Gull and Harbour Porpoise)
    - For Harbour Porpoise: the schedule of new OWF realization (to reduce underwater noise). By ensuring that water noise does not occur simultaneously throughout a species' habitat, but stagger the implementation period so that a portion of the habitat that is not affected by noise always remains available.
- Stimulate the OWF industry to use 'nature inclusive designs' and nature restauration/multi-use by developing a regional strategy. For example: realization of additional hard substrate (artificial reefs) to improve benthic habitats (e.g. in combination with scour protection or cable crossings or in combination with the foundations of turbines)
- Enable collaboration and coordination of ecological research
- Create a joint marine research and monitoring program including the issues mentioned above (and monitoring in data poor areas with the potential to become OWF developing areas). Include an adaptive management approach to include research results in policy development.
- Support instrument development and application contributing to spatial planning with special attention for ecology on a regional scale for the planning period beyond 2030.
- Ensure spatial planning with special attention for ecology on a regional scale and in alignment with the execution of EU biodiversity strategy for the planning period beyond 2030.
- Develop a long-term spatial vision of how wind energy will be brought onshore, (involving collaborating countries and TSO's)

NB: These recommendations are in line with SEANSE's previous conclusions and recommendations https://maritime-spatial-planning.ec.europa.eu/projects/strategic-environmental-assessment-north-seas-energy-seanse

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4.2 Fisheries

This section describes the impact of offshore wind on fisheries. This study deals with the impact of the wind farms themselves and not with the impact of new cables (grid). The underlying reason is that the impact of new cables on fisheries is expected to be temporarily and relatively small.

4.2.1 Geographical facts fisheries

The effects of offshore wind on fisheries depend in part on the type of fishing and how any co-use within the windfarms is regulated. For that reason, in this section we provide insight into two main active fishing types that on this moment are not compatible with wind farms. These are 'demersal fisheries' (figure 4.2 and 4.3) and 'pelagic fisheries' with towed gear (figure 4.4). The ‘demersal fisheries’ are divided into fishing with impact at the surface level (sediment penetration up to 2 cm, figure 4.2) and at both the surface and the subsurface (> 2cm) level (figure 4.3). The data is retrieved from EMODnet.

These three figures (4.2, 4.3 and 4.4) show the intensity of the particular type of fishery. In the first two figures, the intensity is expressed as the Average Surface Swept Ratio. This is the quotient of the bottom area swept by demersal fishing and the surface area of a grid cell. In the third figure, the intensity is expressed in annual fishing effort. A search was made within EMODnet for three figures with this data with the same units, but unfortunately this was not available. For all figures: the darker the colour, the more intense the fishery. The choice for this data was made as this was the most recent and complete available dataset on this topic.

As part of this study, it was explored whether data is also available that gives an impression of the quantities of fish caught/ economic value of the fisheries per area. However, this turned out not to be available for the whole study area, which is why it was decided to work with intensity as a second best option. As a result, an indication of the importance of the intensively fished areas cannot be given within this study.

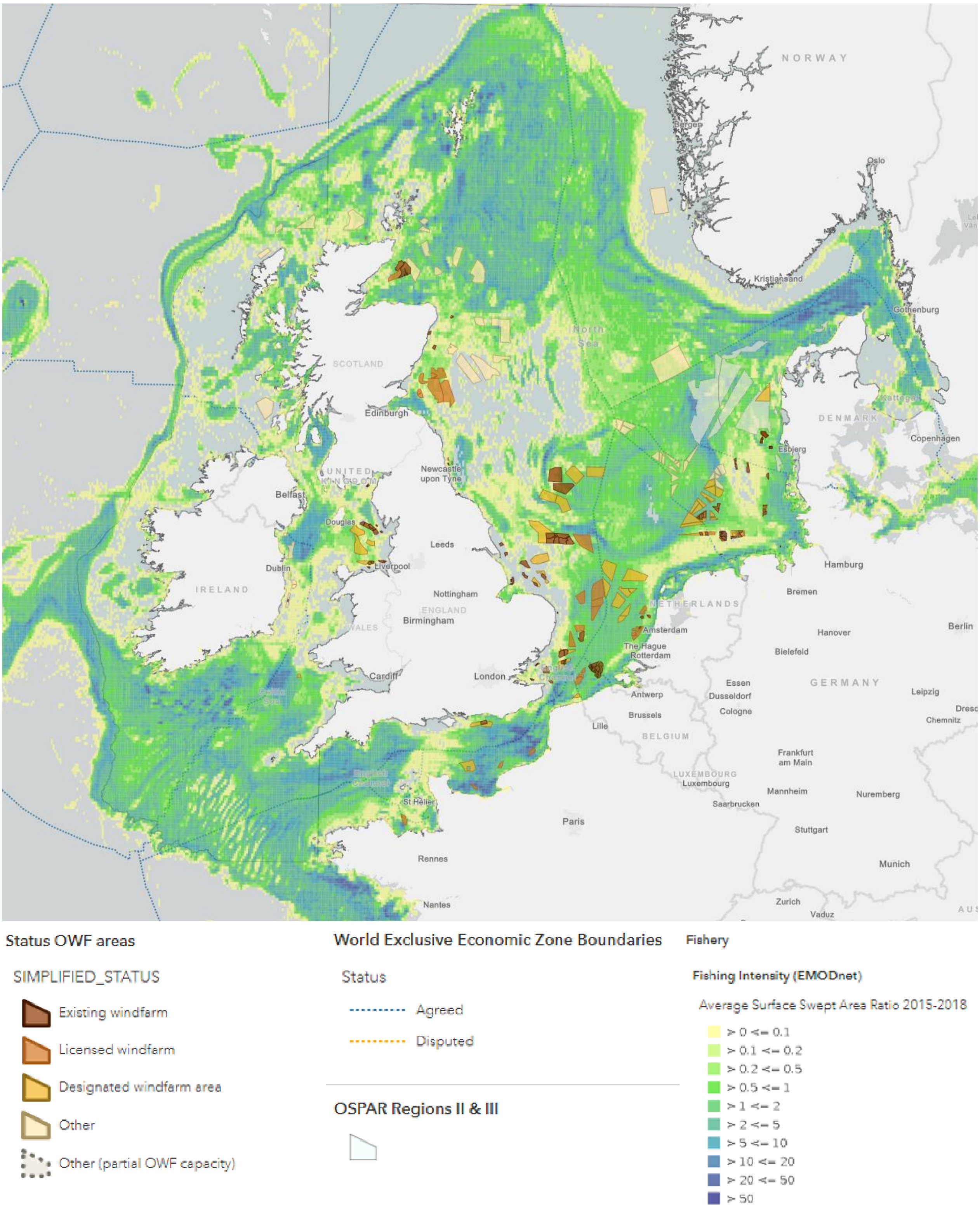

*Figure 4.2 Offshore windfarms in 2030 and demersal towed gear with a sediment penetration up to 2 cm (Average **Surface** Swept Area Ratio: How many km2 of the seafloor is swept by fishing gear with a given grid cell).*

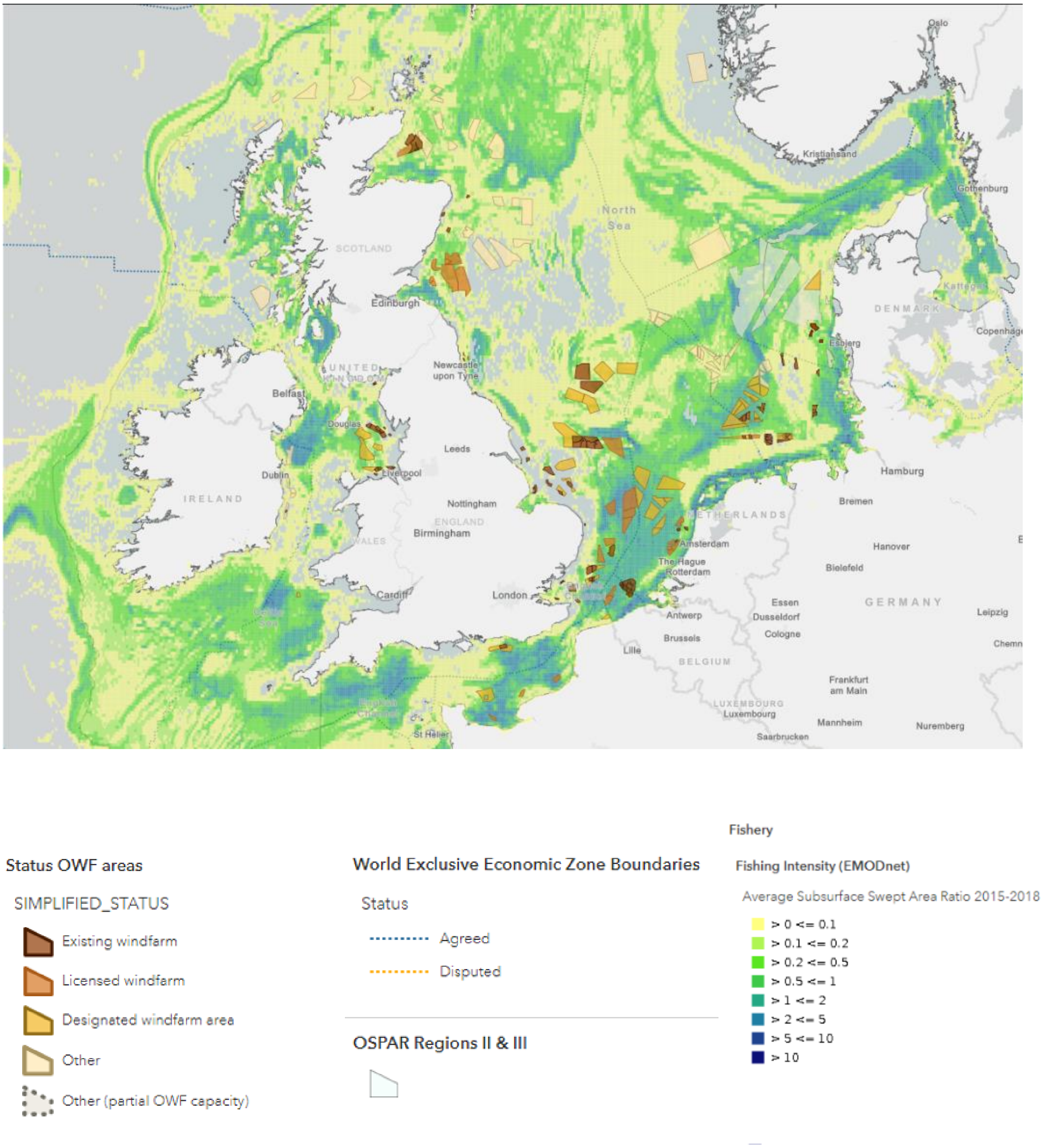

*Figure 4.3 Offshore windfarms in 2030 and demersal towed gear with a sediment penetration > 2 cm (Average **Subsurface** Swept Area Ratio: How many km2 of the seafloor is swept by fishing gear with a given grid cell)*

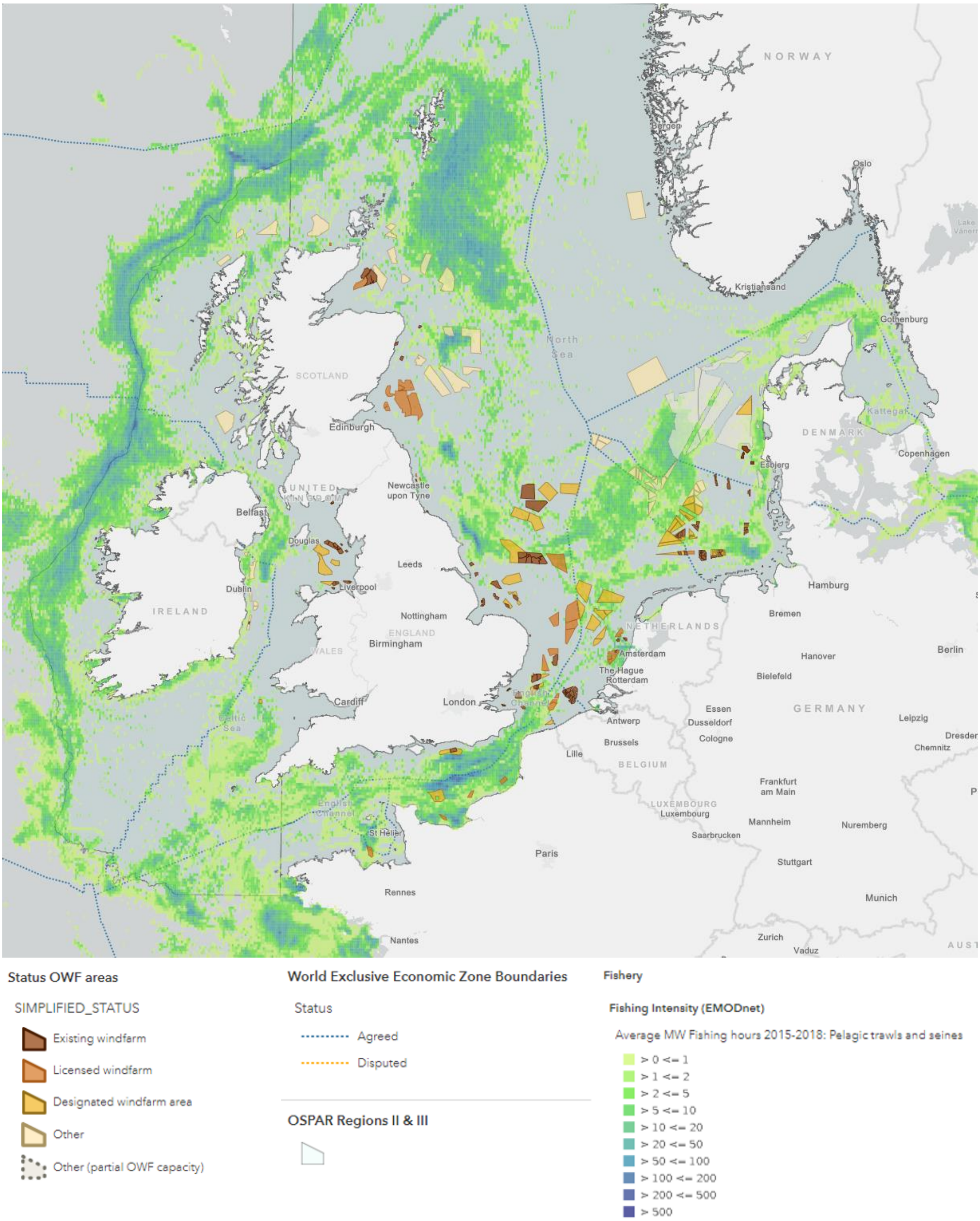

Figure 4.4 Offshore windfarms in 2030 and intensity of pelagic trawls and seines (expressed in mW fishing hours calculated by multiplying the time associated with each VMS report in hours by the engine power of the vessel concerned at the time of the activity)

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4.2.2 Potential spatial conflicts fisheries

The figures 4.2, 4.3 and 4.4 show the areas where the OWF 2030 development overlaps with areas that are used by the fishing industry. Table 4.1 gives an impression in the size of these OWF developments per country in relation to the size of the EEZ (within the OSPAR region) of the country concerned.

Table 4.1 Size of the OWF developments per country in relation to the size of the EEZ of the country

Country	Size of the OWF development in 2030 (km2)	Size of the EEZ within OPSPAR (km2)	Percentage of EEZ (within OSPAR) utilized for OWF (%)
Belgium	458	3.487	13,1
Denmark	1.464*	85.693	1,7%*
France	1.026	67.343	1,5
Germany	2.304	41.049	5,6
Ireland	572	148.849	0,4
Netherlands	4.339	62.142	7,0
Norway	3.568	170.413	2,1
United Kingdom	21.939	559.485	3,9
OSPAR Area II	**44.174**	**768875**	**4,2**
OSPAR Area III	**3.557**	**372145**	**1,0**

*PM. This number is based on the estimation that by 2030, Denmark will have used about 6% of its total designated area in the North Sea.

The conclusion from Table 4.1 is that the percentage of the EEZ used for OWF in 2030 is highest in Belgium (13,3%) and lowest in Ireland (0.5%). For the entire study area, these percentages are 4.2% (OSPAR II) and 1.0% (OSPAR III)

For fisheries, four types of main potential conflicts have been identified within this project:

- There is a reduction in fishing grounds for active (towed) demersal and pelagic gear. That's because in most countries it not allowed to use this gear within wind farms. In the countries where it is allowed, it is still rather unattractive for the fishing industry given the high cost of insurance (particularly to cover the risk of damage to cables by demersal towed gear).
- There is an increase in steaming time to steam around the OWF's, leading to increasing fuel expenditures and a decrease in fishing time. A fisherman can therefore catch less fish within one fishing trip and has more expenditures leading to a lower profit.
- There will be higher (collision) risks and higher costs for the search and rescue for the people who are working at sea, as OWF and its building and management traffic enlarge collision risks at sea, reduce manoeuvring space for fishing vessels outside shipping lanes and wind farms poses a barrier for SAR helicopters and ships.
- Stratification and underwater noise can have an impact on the reproduction and survival of fish stocks. See paragraph 4.1.2 (potential spatial conflicts ecology) To gain insight into this, it is important to conduct a further study into this.

It is noticed that the first two issues (reduction in fishing grounds and increase in steaming time) will be reinforced/amplified by the fact that European environmental legislation will also make an increasing claim on available space.

For more detailed information on the impact of offshore wind on fisheries in all European Seas, see: 'Impact of the use of offshore wind and other marine renewables on European fisheries' (Policy Department for Structural and Cohesion Policies, Directorate-General for Internal Policies, PE 652.212 - November 2020).

4.2.3 Opportunities fisheries

Some opportunities and expected development have been identified for fisheries:

- Cooperation between the eight countries can contribute to:
    - more effective use of cables and transformation stations.
    - to better and faster innovation of fishing gear and cable protection.

  This can increase the feasibility of co-use between fisheries and wind farms
- Sharing of best practices (technical, policy/regulations etc.) on a regional scale to increase the opportunities for co-use for sea food production.
- Allowing fisheries with static/passive gear in OWF's. With this selective gear it is possible to fish with very low impact on the seafloor.
- Potentially positive effects on fish stocks by large scale increase of hard substrate and fishing-free zones. To gain insight into this, it is important to conduct a further study into this.

4.2.4 Conclusions fisheries

In conclusion, as a result of the increase in OWF, the space available for fishing is decreasing. As a result, the required steaming time and fuel costs will increase. A fisherman can therefore catch less fish within one fishing trip and has more expenditures leading to a lower profit. These effects are likely to be amplified by the potential increasing demand for space with reduced opportunities for fishing as a consequence of the new European environmental legislation (Biodiversity Strategy).

Cooperation among the eight countries can help reduce technical and legislative barriers, but does not weigh out the consequences decreasing fishing grounds for OWF's on the fishing industry

4.2.5 Recommendation's fisheries

Recommendations:

- Stimulate innovation and sharing of best practices on a regional scale to increase the knowledge and opportunities about multi-use for sea-food production.
- Explore on a regional scale the effects on (commercial) fish stocks by the large-scale increase of OWF's.
- Utilize the Scheveningen Group, the North Sea Advisory Council and International Council of the Exploration of the Sea (ICES) for the above recommendations*

In addition to the above recommendations from the present study, we also highlight here the importance of two recommendations from the earlier study: 'Impact of the use of offshore wind and other marine renewables on European fisheries' (Policy Department for Structural and Cohesion Policies, Directorate-General for Internal Policies, PE 652.212 - November 2020):

- Develop best practice guidance for MSP on the implementation of mitigation measures to lower the conflict potential between fisheries and OR development and to promote co-operation between marine uses
- Enable more research to understand the effects of offshore renewable (OR) installations on the fishing sector, local communities and onshore economic activities to IPOL Policy Department for Structural and Cohesion Policies 14 provide guidance for marine spatial planning (MSP) to plan with fisheries and support their adaptive capacities.

** Both Scheveningen Group and the North Sea Advisory Council are (international) groups that represent the interests of fisheries. The ICES is an international research institute that executes important research to fisheries and fish quotas.*

4.3 Shipping

This section describes the impact of offshore wind on shipping. This study deals with the impact of the wind farms themselves and not with the impact of new cables (grid). The underlying reason is that the impact of new cables on shipping (as long as anchoring areas are avoided) is expected to be relatively small and temporarily.

4.3.1 Geographical facts shipping

Figure 4.5 shows the location of offshore wind in 2030 in combination with current shipping vessel density. This data is retrieved from EMODnet. As seen on the map, the shipping intensity is greatest in the north-south direction and in an east-west direction between the UK, Belgium and the Dutch coast. This includes the English Channel and its extension towards northern Denmark.

Figure 4.5. shows two hotspots (S1 and S2) where high shipping intensity goes together with a high density of offshore wind in 2030.

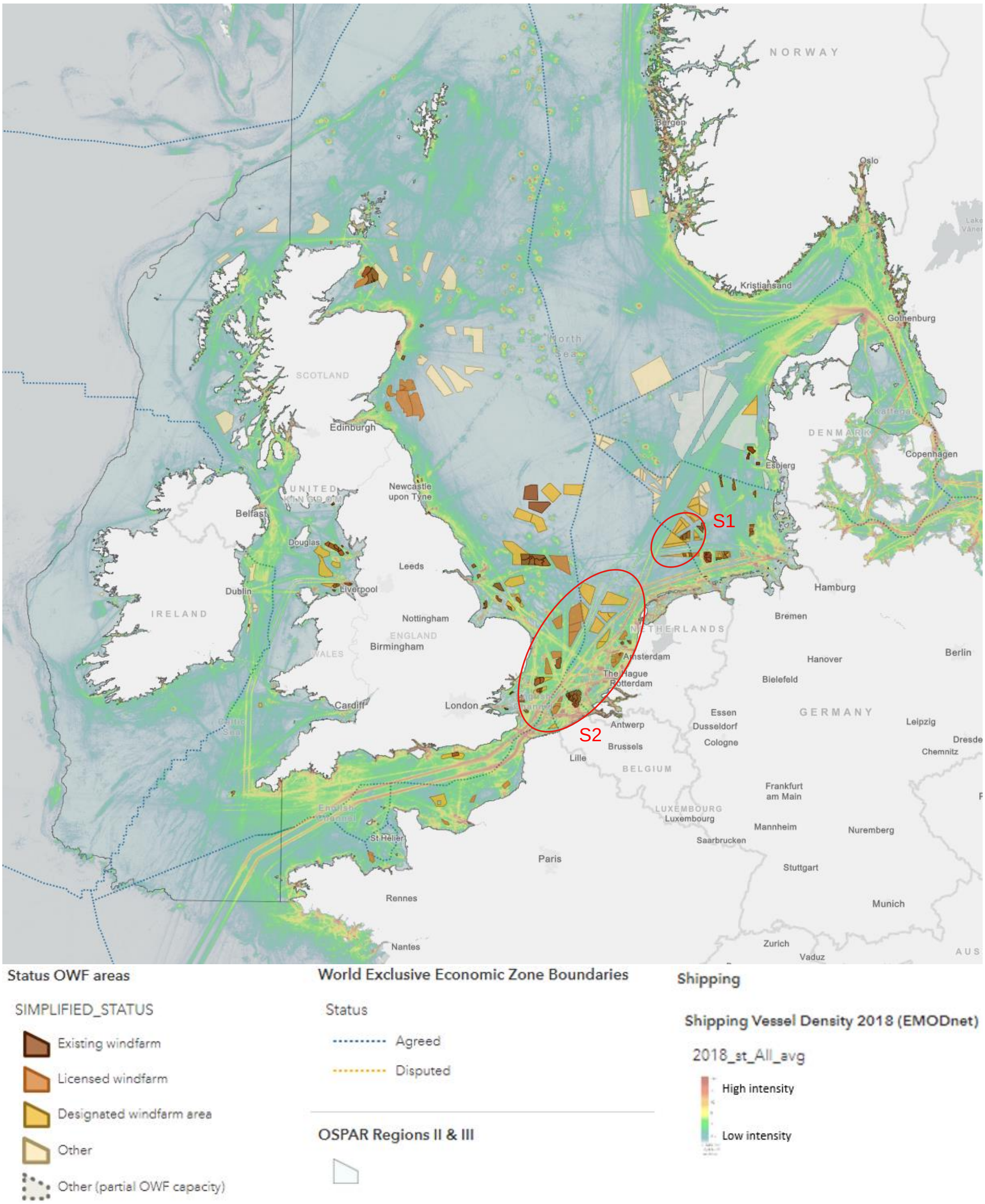

Figure 4.5 Shipping in relation to OWF 2030. Hotspots S1 and S2 identify areas with substantial constraints for shipping.

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4.3.2 Potential spatial conflicts shipping

The shipping lanes do not overlap with OWF, due to the application of both national and international (IMO) regulations in MSP. For most cases these rules are also established in the Marine Spatial Plans.

As shown on the map (figure 4.4), there are two hotspots (S1 and S2). These are areas with substantial constraints for shipping. The main potential conflicts that occur are:

- The increase of OWF potentially leads to increasing collision risk (ship-turbine & ship-ship), resulting in an increasing risk for crew, environment (oil spill, cargo loss) and vessel damage-loss.
- Costs for search and rescue and cleaning will increase as OWF poses a barrier for SAR operations by helicopters and ships and cleaning operations.
- Due to the decrease in space, there is a potential increase in sailing time and fuel costs for ships that are not bound to regulated routings.
- Countries are free to choose the safety margins they apply around shipping lanes and windfarms, therefore there are national differences. As a result, confusion could occur due to discontinuity in the width of shipping lanes in relation to OWF by border crossing.
  NB. The IMO rules considering these safety margins are as follows:
  "In planning to establish multiple structures at sea, including but not limited to wind turbines, Governments should take into account, as far as practicable, the impact these could have on the safety of navigation, including any radar interference. Traffic density and prognoses, the presence or establishment of routeing measures in the area, and the manoeuvrability of ships and their obligations under the 1972 Collision Regulations should be considered when planning to establish multiple structures at sea. Sufficient manoeuvring space extending beyond the side borders of traffic separation schemes should be provided to allow evasive manoeuvres and contingency planning by ships making use of routeing measures in the vicinity of multiple structure areas." (source: PIANC paper (MarCom Wg 161: Interaction Between Offshore Wind Farms and Maritime Navigation (2018))

Potential conflicts are expected to increase after 2030. This will be explored in Part 2 of this study.

4.3.3 Opportunities shipping

There is already an existing forum, the North Sea Shipping Group[1], where issues for the shipping industry are discussed at a regional level.

4.3.4 Conclusions shipping

In conclusion, due to the increase of OWF in the North Seas, the space available for shipping decreases and shipping intensity increases (management and building traffic). This results in a higher risk of collision (ship on ship, and ship with windfarm). In order to mitigate these risks, mitigating measures are being considered (e.g. bigger crew, more emergency towing vessels etc.). These measures will increase the costs for both shipping and countries involved.

[1] *The North Sea Shipping Group has similar goals as organizations like the Scheveningen Group.*

4.3.5 Recommendations shipping

Recommendations:

- Make use of the North Sea Shipping Group to exchange information on spatial conflicts on a regional scale, share knowledge and develop solution proposals in order to mitigate/solve spatial conflicts for shipping.
- For hotspot S1, it is recommended that the Netherlands, Germany and Denmark continue their efforts to discuss the spatial issues of these windfarms in relation to shipping. One of the designated areas could potentially conflict with shipping lanes. The involved countries are already bilaterally finding a solution for this problem.
- For hotspot 2, it is recommended that the Netherlands, Belgium, France and the UK take shared efforts to discuss these types of spatial issues on a regional scale.

4.4 Military activities

This section describes the impact of offshore wind on military activities. This study deals with the impact of the wind farms themselves and not with the impact of new cables (grid). The underlying reason is that the impact of new cables on military activities is expected to be temporarily and relatively small.

4.4.1 Geographical facts military activities

Figure 4.6 shows some, but not all, of the military areas – as this type of information is confidential in some countries. A distinction is made in military flight areas, submarine training areas and remaining military activities. Military training areas do not overlap with OWF.

4.4.2 Potential spatial conflicts military activities

There are no hotspots identified for military activities, but there are some potential spatial conflicts identified:

- There is a potential negative effect on countries Air Defence Surveillance due to impact on Primary Surveillance Radars (PSR)[2] used by the military. This impact is caused by disturbance of the radar as the radar might register the rotating blades of the turbines as aircrafts.
- There is an increase in collision risk of submarines and wind turbines. Submarines have to practice to manoeuvre in OWF areas.
- There are higher costs for search and rescue of people who are working at sea, as OWF pose a barrier for SAR helicopters and ships.
- Due to the increase in height of turbines, there is a higher chance of collision risk between military aircraft and turbines. Additionally, the increase of turbine height results in a decrease of uncontrolled airspace (which is mainly used by recreational aviation). This may also lead to an increased likelihood of collisions between recreational aviation and military flights

[2] The Primary Surveillance Radar (PSR) emits a radio wave. When the radio wave hits an aircraft (or other object, e.g. windfarm), the wave is reflected and part of the energy is returned back to the antenna (Primary Surveillance Radar (PSR) | SKYbrary Aviation Safety). The difference with a Secondary Surveillance Radar (SSR) is that the SSR works with a piece of equipment called a 'transponder'. An antenna rotates and transmits a pulse, which is received by the transponder. However, this radar only works when the aircrafts have a transponder. The radar is therefore not useful to detect 'hostile' aircrafts.

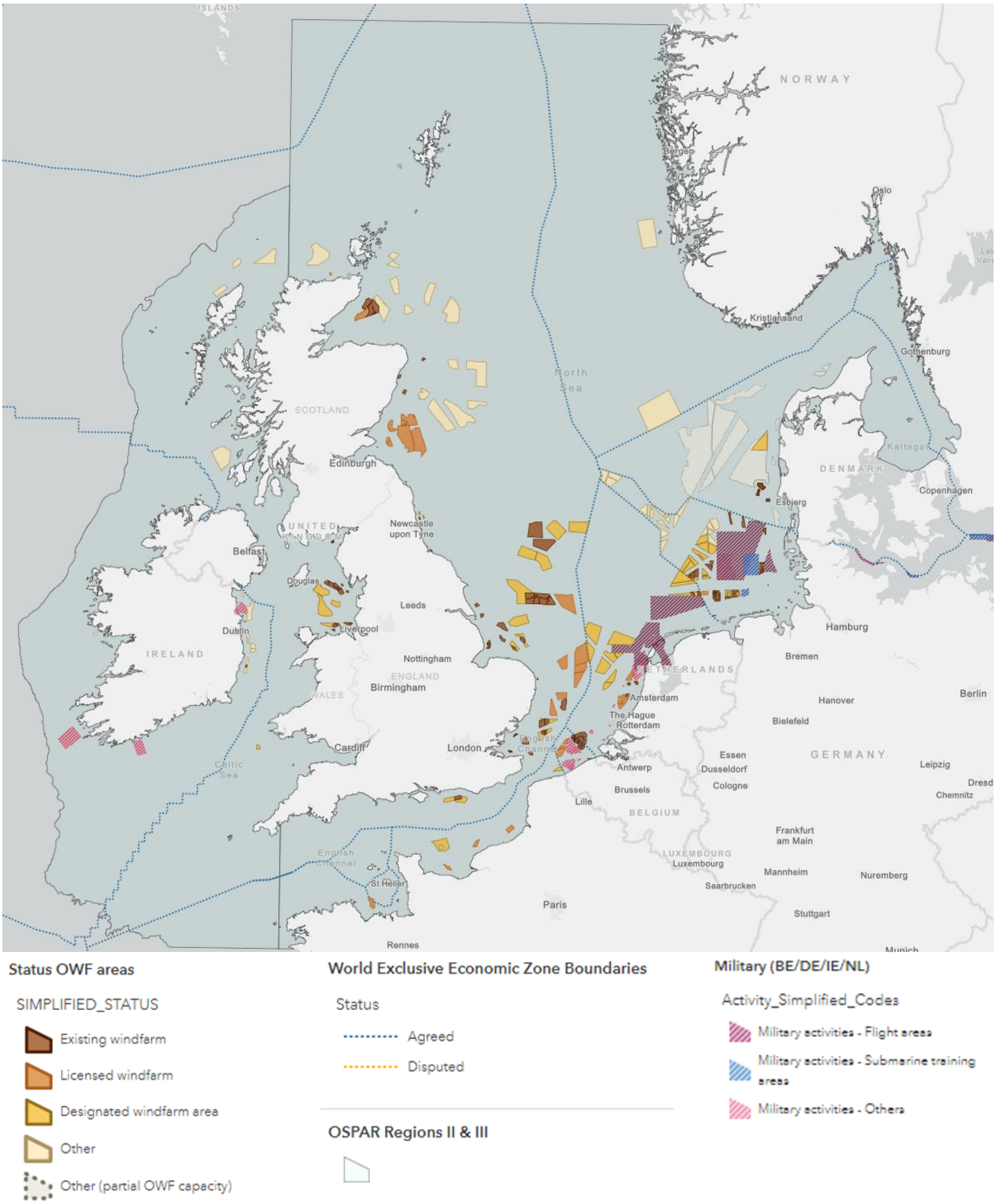

Figure 4.6 Military activities in relation to OWF in 2030.

4.4.3 Opportunities military activities

For the military there are some opportunities for research and ecology:

- Collaboration on a regional scale to solve the issue with the PSR radar by developing improved radar or turbine blade technology. Additionally, in order to reduce radar issues, the windfarm layout should be considered. Placing the windfarms in straight lines reduces the disturbance of the PSR.
- The military area might offer useful synergies with ecology, as military areas can prevent some types of environmental pressure, simply by excluding other pressures during exercises (e.g. noise, physical destruction, heavy metals from ammunition). When military training areas are restricted for other marine uses, this can have a positive effect on nature conservation. However, it depends whether the activities have more impact than the military activities.

4.4.4 Conclusions military activities

In conclusion, military zones and OWF do not overlap due to planning practices. However, it should be considered that not all information is available due to national policies. Potential spatial conflicts are currently limited to some disruption of (flight) radar. This can be resolved technically. In the future, the competition for space between OWF and military zones is likely to increase.

4.4.5 Recommendations military activities

Recommendations:

- Countries should work together to increase the visibility of turbines for radars.
- Discuss on bilateral and international level opportunities for redesignation, merging and partial use of military areas.

5 Summary, general conclusions and recommendations

This study is an initial exploration of the impact of offshore wind on the North Seas. The EEZs (within the OSPAR II & III areas) of eight countries are involved in this study: Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway and the United Kingdom.
The study is based on a desk study, GIS analyses, interviews and workshops. This chapter addresses the findings in relation to the three main questions of this study:

1. How much energy will be produced by OWF in the North Seas by 2030? How does that compare with the ambitions set by individual countries and the EU? What does that mean for the required development of the associated infrastructure on an regional sea level (the grid)?
2. What are the combined potential spatial conflicts and opportunities of the national plans on the regional sea scale?
   a) What are the potential spatial conflicts of OWF (and grid) with other marine uses (ecology, fisheries, military and shipping) on a regional sea scale?
   b) What opportunities exist at the regional level that can be exploited by all countries to successfully develop OWF?
3. What are the recommendations on a regional scale? What is needed to realise the possible solutions to potential spatial conflicts and capitalise on the opportunities? What parties, knowledge development, agreements, policy development and other requirements need to be put in place?

The findings around these three main questions are explained in the following three sections.

5.1 OWF energy production at the North Seas in 2030 in relation to the European ambition

The eight countries involved in this study have ambitions for the development of offshore wind in the North Seas that collectively add up to a capacity of at least 117 GW by 2030. The ambition for the six European member states already adds up to at least 62 GW by 2030.
For a significant part of these European ambitions (61 GW), concrete sites have actually been designated, see table 3.2 for more information. For the remaining part of the ambitions, these procedures are still ongoing.

To bring this large amount of energy on land, it is important that the grid is also expanded and optimized. A number of concrete transboundary initiatives have already been set in motion for this purpose.

The European Union has set an ambition of at least 60 GW installed capacity in 2030 in the European seas. It can be concluded from the present study that these European ambitions seem well achievable in the EU waters of the North Seas alone, based on the ambitions of the individual countries. It should be noted that this study did not investigate other aspects of feasibility, such as the availability of materials, equipment, people and finances.

5.2 Potential spatial conflicts and opportunities

On a regional sea level there is an increasing pressure on space in the North Seas. This increasing pressure is illustrated by Figure 5.1, 5.2 and 5.3.

The main spatial claims originate from OWF, grid and nature protection measures (MPA's and N2000).

Especially in the two hotspots that are indicated on the map (C1 & C2, Figure 5.1), this issue is pressing as many marine uses are coming together in the same area. The main potential spatial conflicts towards 2030 that occur in the North Seas are:

- Adverse effects on ecology e.g.: higher mortality/population effects for birds (and marine mammals)
- Less fishing grounds for the fishing industry and an increase in sailing time and associated fuel costs due to rerouting.
- Higher costs for the OWF industry and related infrastructure, due to the need for mitigation measures, higher density of turbines and deeper waters.
- Higher collision risks for vessels and increasing costs for the avoidance and mitigation of collisions.
- Possible negative effect on Countries' Air Defence Surveillance due to impact on military PSR (disturbance of the radar by turbines)
- Higher costs for transport and search and rescue of people working at sea, due to the barrier OWF poses for helicopters and Search and Rescue.

Future tensions after 2030

The spatial requirements for OWF and biodiversity is expected to continue to increase in the future. This will lead to a strengthening of the above mentioned spatial effects for all user functions, especially in the areas with already high spatial pressure (e.g. Southern North Sea). Although these areas have a high chance of negative impacts on ecology, the effects of OWF are not limited to the hotspots. The impact of OWF on ecology in the North Seas is widespread, as species migrate far beyond the national borders. Additionally, ecosystem effects, such as stratification, are large scale effects. Furthermore, it is expected that the increasing spatial claims for OWF will conflict with spatial claims for biodiversity (EU 2030 Biodiversity Strategy). As a consequence, the biodiversity goals might be incompatible with the goals for OWF. In addition, the increasing spatial claims for biodiversity might impact the fisheries.

Opportunities

Despite the increasing pressure on space, several opportunities have been identified for the successful development of offshore wind. These opportunities are mainly related to more intensive cooperation in planning, monitoring and research. These opportunities have been articulated as recommendations and are presented in the next section.

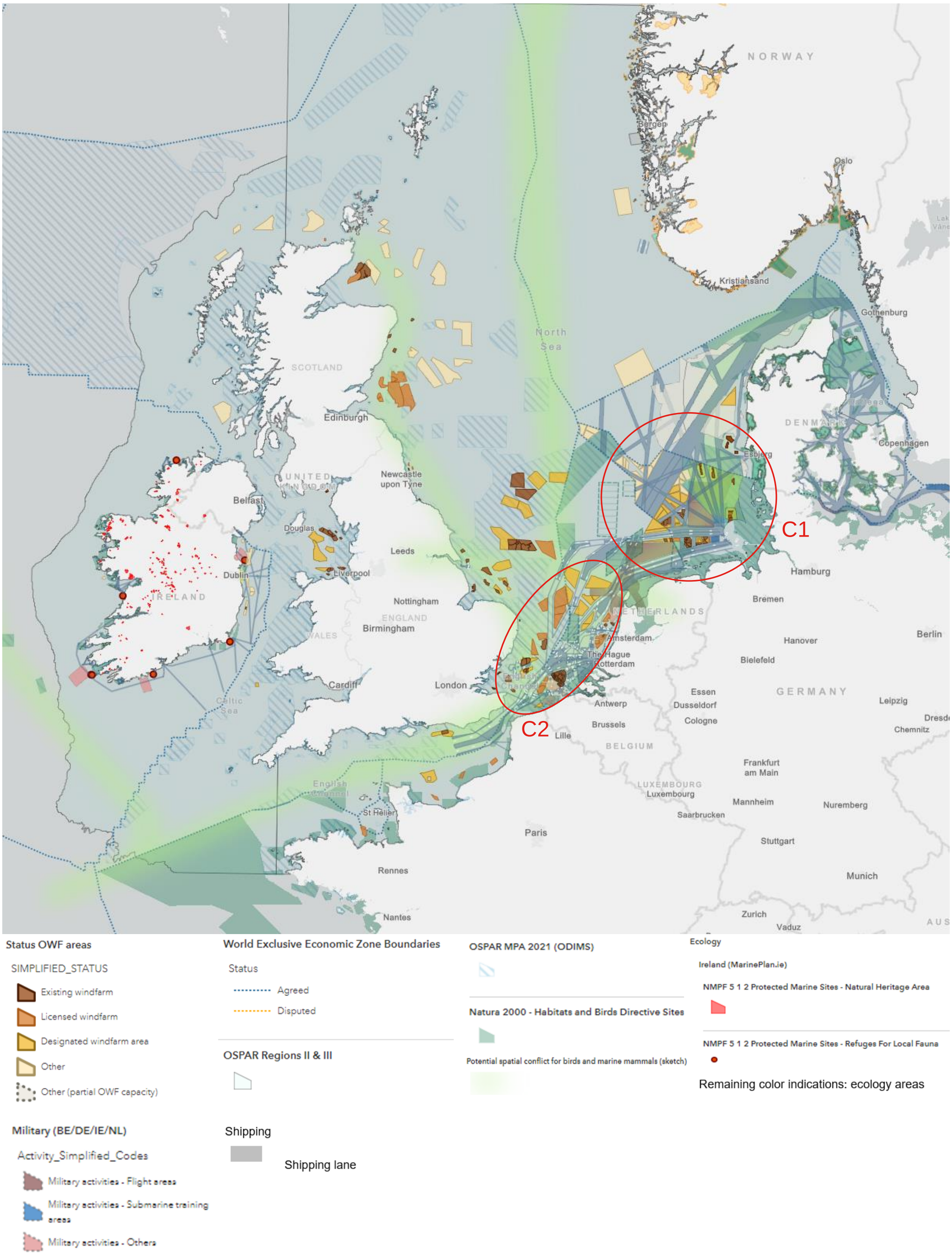

Figure 5.1 General concluding map. Hotspot C1 and C2 are both areas with substantial constraints for marine uses.

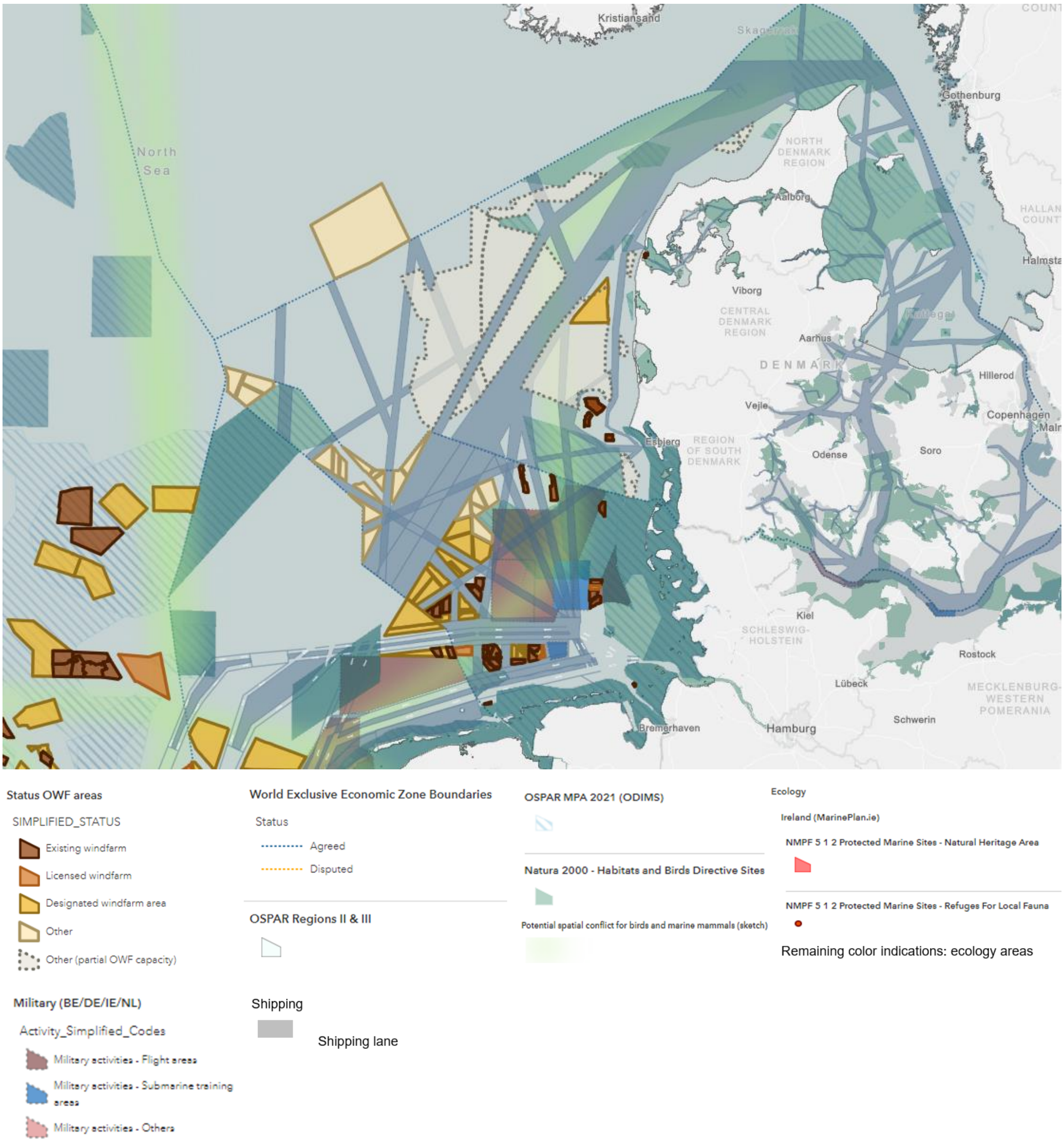

Figure 5.2 Detailed picture of hotspot C1

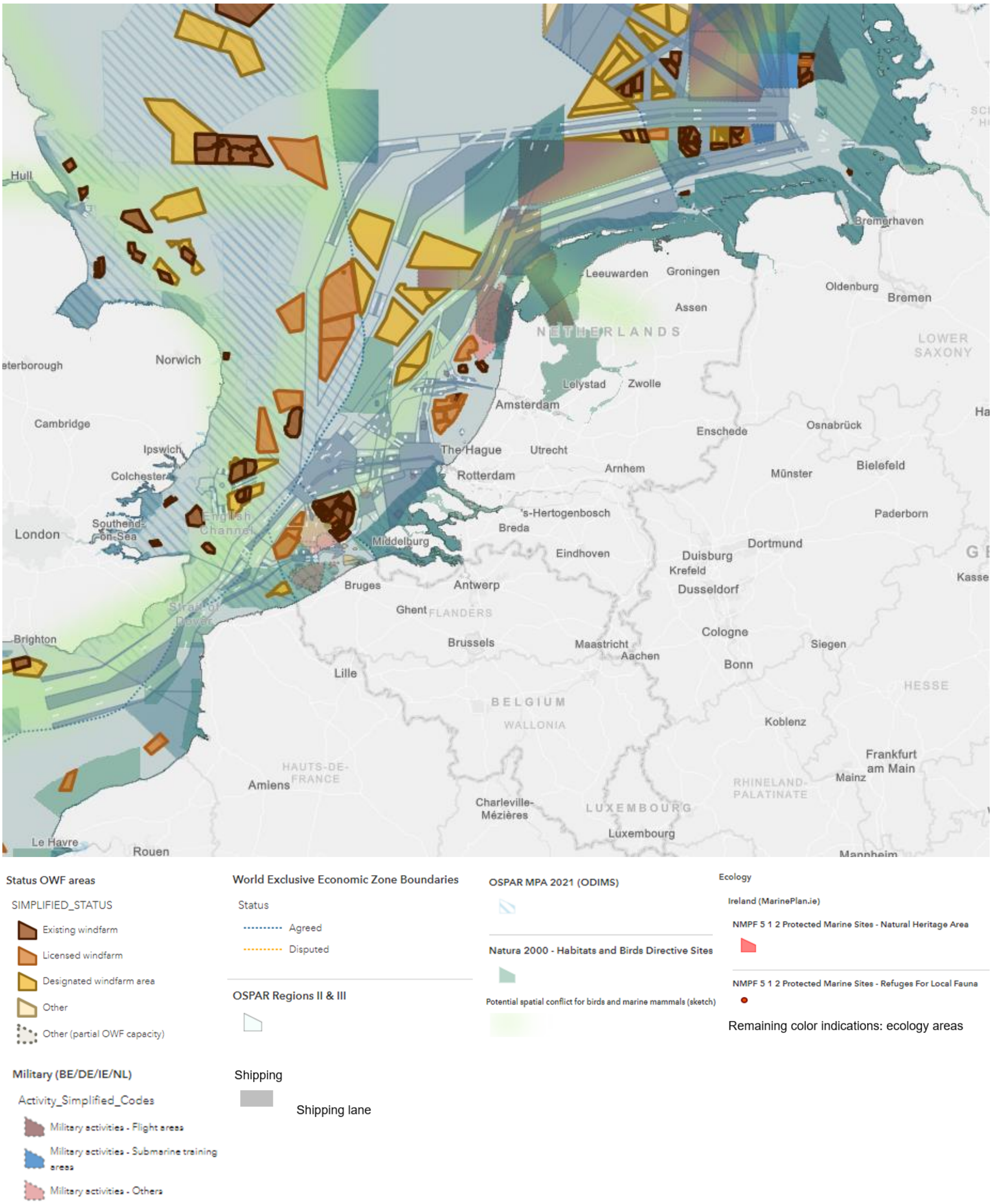

Figure 5.3 Detailed map of hotspot C2

5.3 Recommendations

In the table below the recommendations on a regional scale are presented. The recommendations are divided into two categories: a) those related to existing OWF plans up to 2030 b) those related to potential large scale OWF developments after 2030. Incidentally, even for this second category, these recommendations should be initiated well before 2030. The recommendations where the NSEC could play an active role are marked light blue. The recommendations in which the NSEC could play a stimulating role, but other bodies need to take it up are normal blue.

Table 5.1 Recommendations (Note: This table provides a more concise representation of the recommendations. For the complete wording of the recommendations, see sections 4.1.5, 4.2.5, 4.3.5, 4.4.5)

Theme	Towards 2030 (regional)	For the planning of Offshore Renewable Energy (ORE) beyond 2030 (regional)
Wake effects		1. Explore wake effects and options for solutions in more depth and put it on the agenda within regional MSP collaboration for new developments of OWF after 2030 in the Southern North Seas.
Grid		2. Develop a regional long term integral vision (including electrons and gas, land sea interaction, and spatial considerations)
Ecology	3. Ensure more intensive cooperation in mitigating/preventive measures on a regional scale: - Focus on hotspots - Focus on the most threatened species identified so far - Coordinate the schedule of OWF realization in order to reduce underwater noise 4. Stimulate OWF industry on 'nature inclusive' designs/nature restauration/multi use by developing a regional strategy. 5. Enable collaboration and coordination of ecological research 6. Create a joint marine research and monitoring program (including an adaptive management approach to include research results in policy development)	7. Support the development of a more integral instrument, contributing to the spatial planning of OWF with special attention of ecology on a regional scale for the planning period beyond 2030. 8. Ensure spatial planning of OWF: - With specific attention for ecology on a regional scale - In alignment with the execution of the new EU biodiversity strategy for the planning period beyond 2030.
Fisheries	9. Stimulate innovation and sharing of best practices on a regional scale to increase the knowledge and opportunities about multi-use	

	10. Explore on a regional scale the effects on (commercial) fish stocks by the large-scale increase of OWF's. 11. Utilize the Scheveningen Group, the North Sea Advisory Council and International Council of the Exploration of the Sea (ICES) for the above recommendations 12.* Develop best practice guidance for MSP on the implementation of mitigation measures to lower the conflict potential between fisheries and OR development and to promote co-operation between marine uses 13* Enable more research to understand the effects of offshore renewable (OR) installations on the fishing sector, local communities and onshore economic activities to IPOL Policy Department for Structural and Cohesion Policies 14 provide guidance for marine spatial planning (MSP) to plan with fisheries and support their adaptive capacities. *these last two recommendations (12 and 13) are from 'Impact of the use of offshore wind and other marine renewables on European fisheries' (Policy Department for Structural and Cohesion Policies, Directorate-General for Internal Policies, PE 652.212 - November 2020)	
Shipping	14. Make use of the North Sea Shipping Group to exchange information on spatial conflicts on a regional scale, share knowledge and develop solution proposals in order to mitigate/solve spatial conflicts for shipping. 15. For hotspot S1, it is recommended that the Netherlands, Germany and Denmark continue their efforts to discuss the spatial issues of these windfarms in relation to shipping. 16. For hotspot S2, it is recommended that the Netherlands, Belgium, France and the UK take shared efforts to discuss these types of spatial issues on a regional scale.	

Military	17. Countries should work together in order to increase the visibility of turbines for radars.	18. Discuss on bilateral and international level opportunities for redesignation, merging and partial use of military aeras.
General	19. Stimulate sharing of best practices to improve multi-use.	20. Develop an approach on coordinated spatial planning of offshore renewable energy (with the support of SG4) and explore for 2040-2050 what this means (pro's and cons) for costs of development, spatial uses and ecology to utilize the potential areas in the North Seas for renewable energy development.

The recommendations are mainly focused on actions that require regional action. There are also issues that are currently being discussed and resolved bilaterally by countries. This concerns, for example, wake effects between two countries and harmonization of safety margins of shipping routes. We recommend to continue such bilateral discussions and to include possible outcomes (as inspiring options) in spatial planning at the regional scale.

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Appendices

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