ENERGINET

MARINE ENVIRONMENTAL STUDIES – NORTH SEA I

TECHNICAL REPORT - RADAR (CIVIL) AND RADIO INTERFERENCE

27TH OF MAY 2024

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INDHOLD

Abbreviation	Explanation
ADF	Automatic Direction Finder
ADS B	Automatic Dependent system - Broadcast
AIS	Automatic Identification System
AAL	Aalborg
ANS	Air Navigational Service
ATC	Air Traffic Control
BLL	Billund
CSV	Comma Separate Values file format
CTO	Chief Technical Officer
DALO	Danish Ministry of Defence Acquisition and Logistics Organisation
DME	Distance Measuring Equipment
DMI	Danish Meteorological Institute
EGNOS	European Geostationary Navigation Overlay Service
ESB	Esbjerg
ESPOO	Espoo Convention, Convention on Environmental Impact Assessment in a Transboundary Context
GLONASS	GLobalnaya NAvigazionnaya Sputnikovaya Sistema (Russian GNSS)
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ILS	Instrumented Landing System
INMARSAT	Satellite service provider, offering mobile satellite communication
JRCC	Joint Rescue Coordination Center
KAR	KARup Airport
KYRA	KYstRAdar – coastal surveillance radar
LOS	Line of Sight
LYRA	LYngby RAdio
MF	Medium Frequency band
MLAT	Multilateration
MSL	Mean Sea Level
MSSR	Monopulse Secondary Surveillance Radar
NAVIADS	NAVigational AIDs
NDB	Non Directional Beacon
NMOC	National Maritime Operations Center
NSI	North Sea I. The name of project area containing Area 1 (See NSI.1) and Area 2
NSI.1	North Sea I, area 1. The name of area including all three OWF areas (A1, A2 and A3) and the shipping corridors in between the three subareas
OLC	Obstruction Light Control- radar system
OWF	Offshore Wind Farm
PMR	Private Mobile Radio
Pre-investigation area	The pre-investigation area are the three offshore wind farm areas (OWF-A1, OWF-A2 and OWF-A3) and the two shipping corridors between the three OWF areas.
Abbreviation – Cont.	**Explanation**
PSR	Primary Surveillance Radar

rLOS	Radar Line of Sight
SAR	Search And Rescue
SFDI	Styrelsen for Dataforsyning og Infrastruktur
SINE	SIkkerhedNEttet –Danish emergency services shared communication system
SSR	Secondary Surveillance Radar
TACAN	TACtical Air Navigation system
TETRA	Terrestrial Trunked Radio
TMA	Terminal Manoeuvring Area
UHF	Ultra High frequency – used for i.e. voice radio communication
VHF	Very High frequency – used for i.e. voice radio communication
VOR	VHF Omnidirectional Range
VTS	Vessel Traffic Separation
WAM	Wide Area Multilateration
WTG	Wind Turbine Generator

1 SUMMARY

In order to accelerate the expansion of Danish offshore wind production, it was decided with the agreement on the Finance Act for 2022 to offer an additional 2 GW of offshore wind for establishment before the end of 2030. In addition, the parties behind the Climate Agreement on Green Power and Heat 2022 of 25 June 2022 (hereinafter Climate Agreement 2022) decided), that areas that can accommodate an additional 4 GW of offshore wind must be offered for establishment before the end of 2030. Most recently, a political agreement was concluded on 30 May 2023, which establishes the framework for the Climate Agreement 2022 with the development of 9 GW of offshore wind, which potentially can be increased to 14 GW or more if the concession winners – i.e. the tenderers who will set up the offshore wind turbines – use the freedom included in the agreement to establish capacity in addition to the tendered minimum capacity of 1 GW per tendered area.

In order to enable the realization of the political agreements on significantly more energy production from offshore wind before the end of 2030, the Danish Energy Agency has drawn up a plan for the establishment of offshore wind farms in three areas in the North Sea, the Kattegat and the Baltic Sea, respectively.

The North Sea I area 1 (form now on NSI.1) has a total area of 1.400 km^2 which is divided into three sub-areas planned for offshore wind farms (A1, A3 and A3). The NSI.1 is located 20-80 km off the coast of West Jutland and from each of the three sub-areas there will be corridors for export cables connecting the offshore wind farms to the onshore grid.

The document provides a technical background report for the North Sea I, area 1 (NSI.1) and its potential impact on existing radar and radio systems due to the establishment of offshore wind turbines.

NSI.1, an area of 1420 km^2, has been designated for the installation of offshore wind turbines off the west coast of Jutland. The closest distance from NSI.1 to the coastline is 20 kilometres and the western most distant part of the area is located between 46 and 56 kilometres from the coastline.

The installation and operation of offshore wind turbines has the potential to adversely affect radar and radio systems through shadowing, reflections, and/or multipath[1]. For radar systems in particular, there is a risk of false and/or ghost echo detection. In addition, if offshore wind turbines are placed in the transmission path of radio waves, such as radio link communications, they can shadow or attenuate the signals for communication and data transmission.

The purpose of this technical background report is to map and assess existing radar and radio systems located in or near the NSI.1, that could potentially be affected by the establishment of the planned offshore wind farms (A1, A2 and A3) within the pre-investigation area. The report covers radar and radio systems used for civil purposes. The report assesses and describes the potential impact and also aims to identify radar and radio systems, where it is recommended to perform further detailed technical analysis of the individual systems. It also highlights the importance of clarifying and coordinating mitigation measures between stakeholders and authorities owning the equipment and suggests early clarification to assess the risks before detailed project design and construction work commence.

The methodology for the mapping is described, as well as the respective stakeholders that have been consulted. The report describes the different types of radar and radio systems in use cf. section 5 and subsequently assesses and describes the potential negative impacts identified for the relevant systems in section 6. The report uses the international classification and designation for different types of radio systems.

The report is intentionally written, to the extent possible, in layman's terms and with supplementary explanations.

The results of the survey and mapping are as follows.

1.1 RADAR SYSTEMS

Regarding radar systems, the report identifies that the establishment of offshore wind farms in the North Sea I area 1 (NSI.1) may have the most significant impact on the coastal radar systems of the Danish Defence in Thyborøn and at

[1] Multipath: Is a radar or radio reception/-s that originates from reflections of electromagnetic waves on large objects. It is a non-desired signal source with the potential - for i.e. radar - of causing false echoes in ambiguous directions and range.

Blåvands Huk. It also highlights the potential impact on the future Obstacle Light Control (OLC) radars for the Vesterhav Syd offshore wind farm.

The NAVIAIR-owned ATC TMA radar system in Billund is in radar line of sight of NSI.1 but assessed not to be under influence at the given range. Assessment is based on the terrain induced shadow at the range of 88 to 100 km which equals the eastern board of the OWF, the anticipated WTG total height MSL and the operational impact of TMA radar usage.

Additionally, it is assessed that DMI's meteorological radar on Rømø is likely to be affected, and it is recommended to engage in discussions with DMI regarding the need for possible further technical analysis or the potential implementation of mitigation measures.

1.2 RADIO SYSTEMS

There are no radio links or point-to-point licenses for radio links established over the NSI.1, and there are no known radio links established under 'flade tilladelse' in the area where the use of the services will be affected.

The establishment of offshore wind farms in the NSI.1, will potentially affect existing maritime VHF and MF communication and possibly coastal VHF radio direction finders for use in Search And Rescue (SAR) operations. It is recommended to enter into dialogue with the Danish Defence and CIBICOM on the need for any further technical analyses, supporting measures to clarify the eventual need to implement mitigation measures. The Danish Defence has raised concerns about the presumed impact on the performance of the radio systems (Communication, 2023).

1.3 FURTHER ACTIONS AND ANALYSES

The final OWF layout, e.g. the size, number, and spacing of offshore wind turbines, can influence the extent of the impact on a radio or radar system, factors that contribute to inducing e.g. areas of constructive and destructive interference. Destructive interference means that in areas where detection would be expected, blind zones/areas have arisen. These areas can be identified with simulation software, which can calculate the mutual interference of radio waves in the area. It is not possible to predict the final effect of the influence of induced interference from the factors alone.

The details of mitigation measures must be clarified and coordinated between stakeholders/authorities who own the equipment. It is recommended, that the clarification is made well in advance, so that it can be risk assessed before detailed design and construction work begins (SFDI, 2023; Guidelines-EUROCONTROL, 2014).

The potential impact on radar installations should be carried out according to EUROCONTROL guidelines and/or based on the Danish Defence or NAVIAIR specifications (Guidelines-EUROCONTROL, 2014; Guideline-DALO, 2019).

See Table 1 for an overview of the main findings of this report.

Table 1. Summary of the main conclusions.

System type	Systems that are possibly impacted	Commentary
RADIO COMMUNICATION		
Maritime public services	Coastal radio stations and VHF rescue stations in the NE edge of the North Sea I area and radio coverage in the southern part of the wind farm area	Possibly reduced coverage of Coastal radio stations and VHF rescue stations in the NE edge of the North Sea I area and a minor impact on radio coverage in the southern part of the wind farm area. Alternative form of communication is available. Need for further analysis assessed by the asset owner or service provider
Aeronautical communication	Air-Ground-Air VHF communication from Børsmose and Bovbjerg	Critical service. NAVIAIR should be consulted regarding potential analysis needs
RADIO LOCATION		
Radar for airspace surveillance		
Primary radar system	Civil ATC TMA PSR radar	No impact of significance is expected.
Secondary radar system	Civil ATC SSR radar ESB	Critical service. NAVIAIR should be consulted regarding the need of analysis
ADS-B and multilateration		No significant impacts are expected. It is recommended to consult NAVIAIR based on suspicion of possible impacts
Radar for maritime surveillance	Coastal radar Thyborøn and Blåvands Huk Gap Filler radar on OWF North Sea North	Technical analysis initiated by Energinet Possible impact on Gap filler depends on the instrumented range of the gap-fill radar
Radar for meteorological monitoring	DMI meteorological radar Rømø	DMI should be consulted regarding the analysis needed
Radio direction finder equipment	Coastal rescue stations' VHF direction finders.	Used in SAR operations. Bearing accuracy can be affected. Operational risk is unknown, Danish Defence should be consulted

2 INTRODUCTION

2.1 BACKGROUND

In order to accelerate the expansion of Danish offshore wind production, it was decided with the agreement on the Finance Act for 2022 to offer an additional 2 GW of offshore wind for establishment before the end of 2030. In addition, the parties behind the Climate Agreement on Green Power and Heat 2022 of 25 June 2022 (hereinafter Climate Agreement 2022) decided), that areas that can accommodate an additional 4 GW of offshore wind must be offered for establishment before the end of 2030. Most recently, a political agreement was concluded on 30 May 2023, which establishes the framework for the Climate Agreement 2022 with the development of 9 GW of offshore wind, which potentially can be increased to 14 GW or more if the concession winners – i.e. the tenderers who will set up the offshore wind turbines – use the freedom included in the agreement to establish capacity in addition to the tendered minimum capacity of 1 GW per tendered area.

In order to enable the realization of the political agreements on significantly more energy production from offshore wind before the end of 2030, the Danish Energy Agency has drawn up a plan for the establishment of offshore wind farms in three areas in the North Sea, the Kattegat and the Baltic Sea, respectively.

The North Sea I, area 1 (from now on NSI.1) allocated for offshore wind has a total area of 1.400 km^2 which is divided into three sub-areas planned for offshore wind farms. The NSI.1 is located 20-80 km off the coast of West Jutland and from each of the three sub-areas there will be corridors for export cables connecting the offshore wind farms to the onshore grid.

The purpose of this background report is to map existing civilian radio and radar systes that could potentially be affected by the establishment of offshore wind farms in the North Sea I, area 1 (NSI.1), and to assess the potential impact of the offshore wind farms on these systems. The military radar systems are assessed and analysed in detail in a separate background report under the auspices of Energinet, and in-depth analysis requirements are specified by the Danish Defence.

Mapping includes existing radar, radio navigation systems, radio communication, and radio chains.

The geographical location of the overall North Sea I area is illustrated in Figure 1.

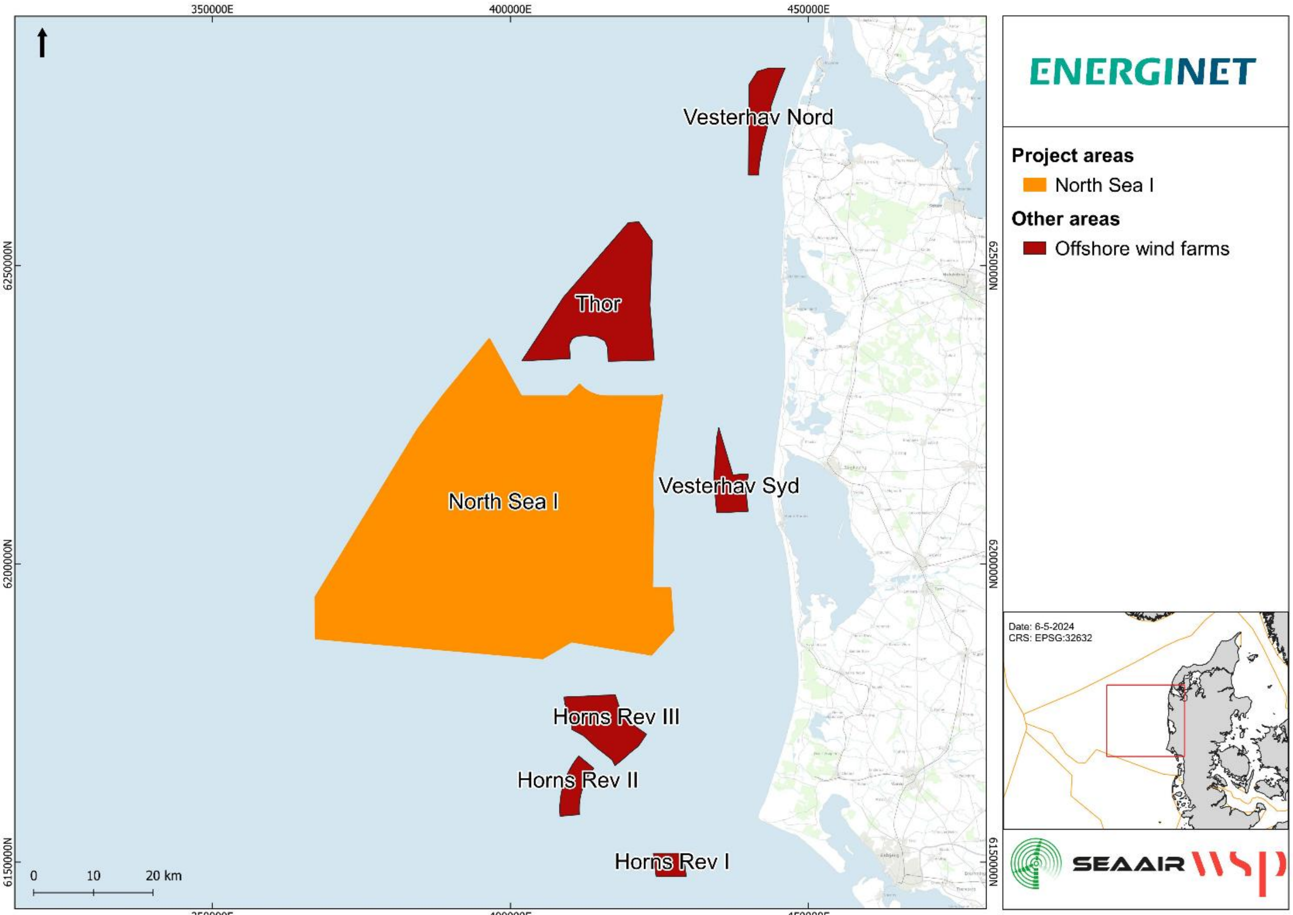

Figure 1 Overview of the North Sea I area and neighbouring offshore wind farms (existing, under construction and approved).

The coastal radars in Denmark are owned and operated by the Danish Defence.

The potential impact of the future offshore wind farms on the performance of the coastal radars are dealt with in a separate assessment report on the Danish Defence' radar systems. This report will not be publicly available.

As the coastal radars also are used to monitor civilian shipping traffic, they are mentioned in this report, but a detailed assessment or analysis is not conducted. Negative impacts on the coastal radars will be unacceptable for the Danish Defence, and the civilian shipping can therefore be assured that the quality of the surveillance monitoring by the coastal radars will not be allowed to be impaired by the establishment of offshore wind turbines in the area.

The offshore wind farms will not be planned and completed in detail until concessionaires have been selected. Therefore, this report assesses worst-case scenarios, i.e. the solutions that are considered most critical for maintaining the current performance of existing civile Radar and Radio systems.

The report is relevant for owners and users of radar and radio systems. It is intended as an overview of systems identified in the area, as well as for users of the technical services that may potentially be affected, either as direct or indirect users, in or around the area.

The NSI area is divided into two areas (NSI.1 and NSI.2). This technical background report only covers the North Sea I – area 1 (NSI.1) (Figure 2).

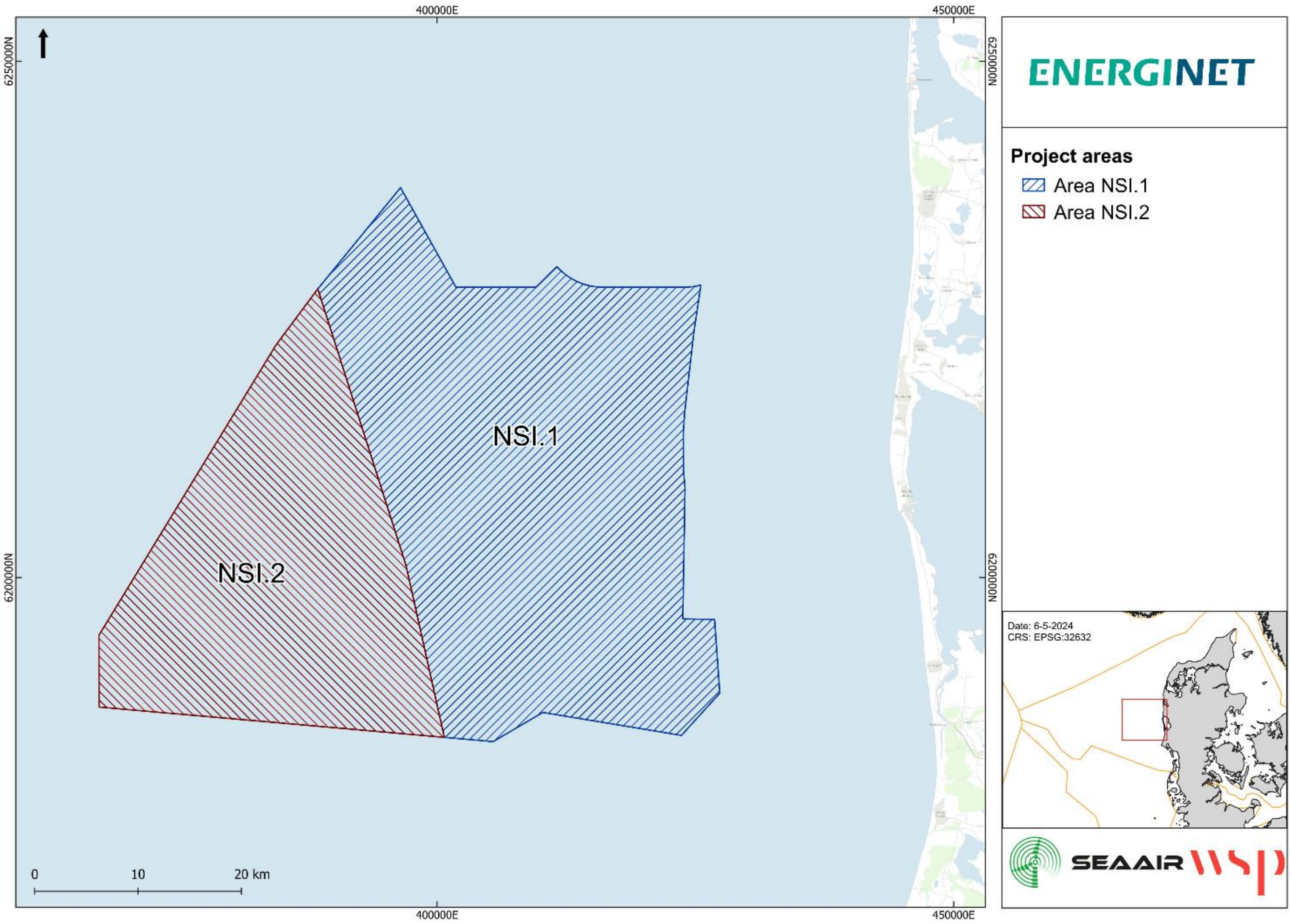

Figure 2 The map shows the division North Sea I area 1 (blue) & area 2 (grey).

For this technical background report for radar and radio systems, it is not relevant to categorize potential impacts into the usually divided three phases: construction, operation, and decommissioning. Disturbances could be induced starting with the construction phase, but the operational phase is most significant due to the rotating rotor blades.

2.2 INTRODUCTION TO BASIC PRINCIPLES OF RADIO WAVES

Radio waves are electromagnetic waves that propagate at the speed of light. When a transmitting device applies an electrical signal to an antenna, an alternating current is generated in the antenna. The electric current changes its direction with the transmitting frequency. The alternating electric current will generate an electromagnetic field around the conductive part of the antenna. This electromagnetic field will propagate in all directions at the speed of light.

Electromagnetic waves can be reflected or absorbed by physical structures and objects that the electromagnetic waves pass through and/or hit in their direction of propagation.

Wind turbines are typically made of metal, carbon fibre and fibreglass. Metal and carbon fibre are conductive and will therefore reflect a majority of the electromagnetic waves further out into space in a direction other than the intended transmission direction, and some of the signal will be returned in the opposite direction of the transmission direction of the reflective surface (backscatter) towards the source of the signal. Fibreglass is typically an electrically insulating material, but moisture, including salt coating from sea mists, is sufficient to make the surface conductive and thus reflective to electromagnetic waves.

2.2.1 RADIO WAVE PROPAGATION PROPERTIES

Electromagnetic waves do not propagate uniformly, as radio waves can follow the curvature of the Earth to a greater or lesser degree. Furthermore, in certain frequency bands, they can be reflected by the electrically charged (ionizing) layer in the upper atmosphere, which is formed by the interaction of the solar wind with the Earth's atmosphere and magnetic field. The solar wind is a continual stream of protons and electrons from the sun's outermost atmosphere' affecting the Earth's atmosphere and magnetic field.

2.2.2 RADIO WAVE ATTENUATION

Radio and radar signals are strongly attenuated during their propagation and are especially attenuated or even blocked by physical structures, buildings, and/or objects.

2.2.3 CUMULATIVE EFFECTS

The cumulative effect represents the total of both positive and negative impacts on a specific radar/radio system. In this evaluation, the focus is primarily on the negative impacts. This cumulative impact assessment relies on experiential knowledge rather than precise calculations or detailed analysis.

While a single offshore wind farm might not significantly affect a given radar system, assuming the radar's signal and data processor can effectively manage and eliminate unwanted or false echoes. The addition of new or existing wind turbine projects in the same direction or sector could introduce substantial disturbances. As these additional disturbances might overburden the radar's signal and data processor, impeding its functionality due to the increased processing demands from multiple sources of interference or changes in environmental conditions.

For radio communication, the signal will be attenuated as the wind turbines partly shade the signal and partly physically blur the signal content due to reflections between the wind turbines.

2.3 APPLICATION OF RADIO SYSTEMS

This report utilizes the international classification and designation for different types of radio systems and are used as categorisation i.e. the following sections describes these types and the usage.

2.3.1 RADIO BROADCAST

Broadcasting typically aims for signals to be received in all directions around the transmitting antenna and is typically used for TV and radio broadcasting, including news, music, and similar broadcasts. Broadcast is transmitted from public broadcast service units and private local radio and/or TV stations.

2.3.2 RADIO COMMUNICATION

Radio communication can take place between two or more parties, either stationary or mobile radio transmitters/receivers. A radio communication system consists of at least one transmitter and one receiver.

Radio communication is used for information transfer and is used for radiotelephony, mobile telephony, data transmission, wireless local area networks and Internet connections, and several other purposes.

In relation to the NSI area, this could be communication between land, aircraft, ship, offshore installation, or any combination of these four forms of communication.

Communication can also be used for radio chains/link connections, typically establishing direct connections between onshore and offshore installations or between offshore installations. Radio chains are mainly used to transfer data between two geographical points or locations.

2.3.3 RADIO NAVIGATION

Radio navigation is mainly conducted using GNSS (Global Navigation Satellite System), which is a collective term for the satellite-based navigation services of several nations. For aeronautical navigation in particular, two older technologies are still in use: NDB and VOR systems (Non-Directional Beacon) and (VHF Omnidirectional Range).

NDB ground systems emit a fixed radio signal on an omnidirectional antenna. Aircrafts are equipped with an Airborne Direction Finder (ADF) system, allows an aircraft to fly to the transmitter's position even if it is mobile (shipborne). These systems are being phased out in the EU for airports but will continue to be used in maritime operations involving helicopter approaches to landing decks, both on ships and offshore platforms.

The VOR system utilizes a ground-based transmitting station. The VOR station broadcasts radio signals in all directions, but the broadcasts/signals are encoded according to specific propagation directions, allowing aircraft to use the signal to fly a pilot chosen course toward the VOR station.

2.3.4 RADIO LOCATION

DIRECTION FINDING

Radio location in the form of radio direction finders is used along the west coast of Jutland and operate on the international maritime distress and calling frequencies. Direction finding stations can provide direction/bearing to the transmitted signal (transmitter), while cross bearing from minimum two stations can locate the position on the sea surface.

RADAR

Radio location, in the form of radar, is typically used to determine the position of an object, ship, aircraft, or other maritime object.

Unlike radio scattering (broadcasting), radar systems want to concentrate the radio waves in a narrow propagation direction that can be controlled by a rotating antenna or fixed antenna array.

Since the propagation speed of radio waves is approximately constant, the distance can be calculated as a function of the time between sending and receiving the radio signal (pulse to echo), the bearing to the echo being the direction of the antenna at the time of echo detection.

MULTILATERATION

Multilateration (MLAT) uses a common time reference in multiple radio receivers spread across an area. Aircrafts emit radio signals with a unique identity. Based on the time difference, the distance difference from the aircraft to the receiver can be determined and subsequently, the spatial position of the aircraft can be calculated by receiving the signal at minimum four or more receiving stations.

MLAT is the generic term for the functionality and is used in local areas such as airports. When a larger geographical area needs to be covered, the same generic technique is used, but the systems are generally referred to as Wide Area Multilateration (WAM). The difference is how the time stamping of the received signals from the aircraft is organized.

3 METHODOLOGY

The existing radar and radio systems were mapped by reviewing the frequency register, publicly available information, and literature and additionally by contacting relevant owners of systems, Danish agencies, and the Danish Defence.

In the introduction in section 2, the classification and designation for different types of radio systems are described. In section 5, the existing systems in the area relevant to the NSI area is identified and subsequently the potential impact on the existing systems is assessed and described in section 6. The findings in section 6 are listed in a table overview of potential impact in section 10, inclusive a description of mitigation measures relevant to the performed level of assessment.

The starting point for the mapping of systems in this document is the Danish Agency for Data Supply and Infrastructure (SFDI) published frequency register. The source register is in the form of a CSV file with approx. 27,000 registrations and these were sorted on a geographical basis. Irrelevant registrations of geographical locations and not impacted equipment in Denmark are excluded and have been sorted out from the source file.

The remaining relevant area contains all records WEST of 009º E, as well as records located between 55º N and 56º 45' N. After sorting and filtering, approximately 1,600 records are available for further processing. Private closed networks and point-to-point radio links that transmit data between points on land are discarded, as they are assessed not to be influenced by potential OWF (A1, A2 and A3) within NSI.1. The remaining 551 elements (registrations) are individually sorted, analysed, and categorized.

In addition, consultation has been carried out with identified stakeholders, who constitute:

The Danish Defence (TDD, 2023), Danish Maritime Authority (DMA, 2023), NAVIAIR (NAVIAIR, 2023), Lyngby Radio (Radio, 2023), Nationale Maritime Operations Center NMOC & Join Rescue and Coordination Center JRCC (JRCC, 2023), Fog consulting (FC, 2023), Ørsted (Ørsted, 2023), Cibicom (CIBICOM, 2023) and Vattenfall (Vattenfall, 2023).

4 TECHNICAL PROJECT PARAMETERS

4.1 NORTH SEA I, AREA 1

Figure 3 illustates the relative location of the three wind farm areas (A1, A2 and A3) within NSI.1, off the west coast of Jutland.

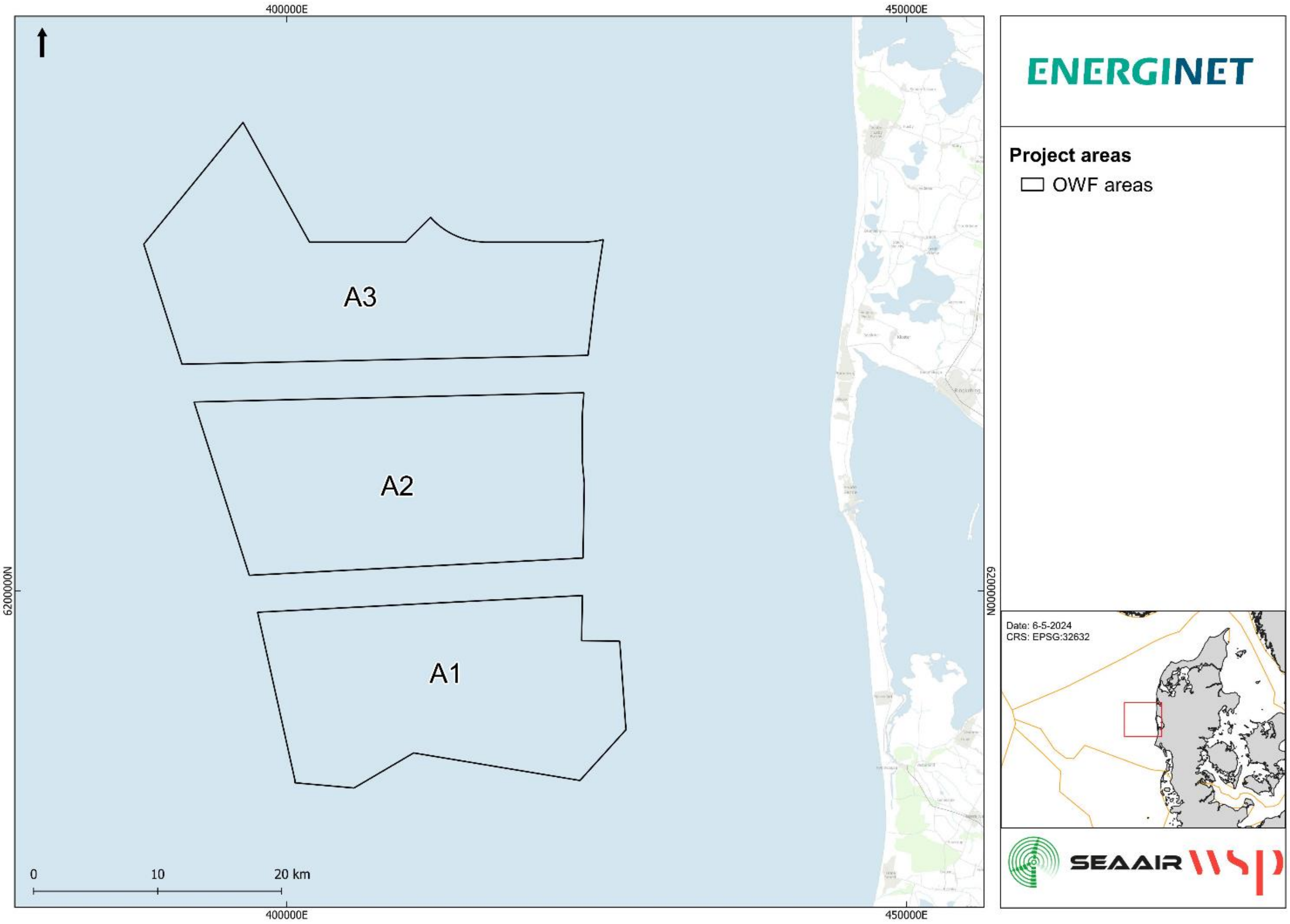

Figure 3 The three windfarm areas (A1, A2 and A3 within North Sea I, area 1).

4.2 WINDFARM AREA A1, A2 AND A3

The NSI.1 (Figure 2) is divided into three windfarm areas (Figure 3). The table below lists the area covered by each sub-area and the shortest distance to the west coast.

Table 2 Area overview North Sea I, area 1.

North Sea I	Area [km]²	Shortest distance to the coast [km]
North Sea I, Area 1	1344	20
OWF A1	366	20
OWF A2	401	20
OWF A3	401	20

4.3 TENTATIVE LAYOUTS

Energinet has published proposals for a total of four (4) possible layout scenarios, with 15 MW and 27 MW turbines, respectively. For each wind turbine size, a layout is proposed which constitutes a so-called overplanting layout, with more than three times the number of wind turbines in the area covered. Figure 4 to Figure 7 shows the intended layouts for the four scenarios.

The final wind turbine layout for the offshore wind farms will be detailed once the Concessionaires have been selected.

4.3.1 TYPES OF WIND TURBINES

The planned wind turbine layouts are based on sizes and types of wind turbines (WTG) of 15 and 27 MW, respectively. The height dimensions for the two types are shown in Table 3.

Table 3 WTG dimensions.

Wind turbine type	15MW	27MW
Lift height [m]	146.5	180
Rotor diameter [m]	233	300
MSL to tip height [m]	263	330
MSL to lowest point of wing tip [m]	30	30

In order to optimise the utilisation of the available wind, dynamic physical conditions require a certain minimum distance between the individual offshore wind turbines. Typically, the distance is specified in a number of rotor diameters.

4.3.2 WIND TURBINE SPACING

The wind turbines are separated by a minimum distance for optimal wind energy production turnover. When overplanting in the area, this distance is reduced. The distance is calculated in number of rotor diameters.

Table 4 Distances between WTG in rotor diameter (RD) per scenario.

Scenario id	WTG units	Min. distance in RD	Max. distance in RD
Scenario 1; 15MW	201	7.1	11.6
Scenario 1; 27MW	111	8.0	17.4
Scenario 2 Overplanting 15MW	699	3.6	6.6
Scenario 2 Overplanting 27MW	390	4.0	7.8

In the overview above (Table 4), the four offshore wind turbine configurations are summarised with minimum and maximum distances between the turbines.

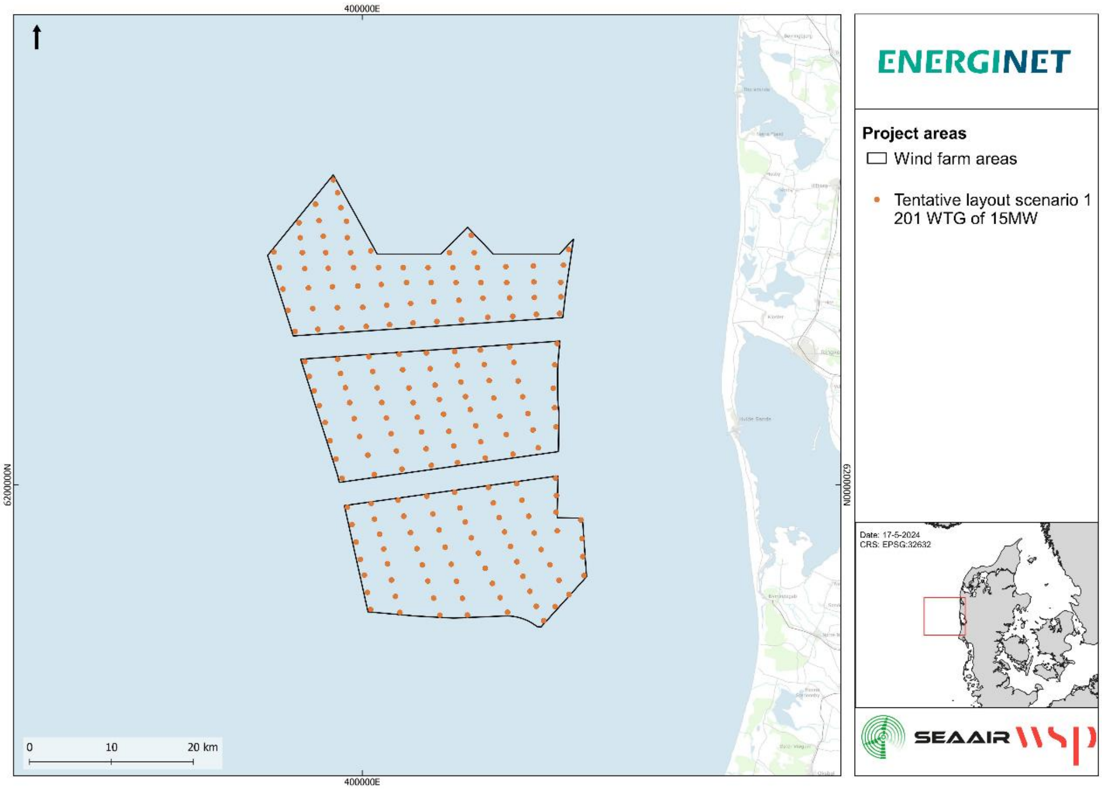

Figure 4 Layout for Scenario 1 with 201 WTG of 15MW, as prepared for the visualisation example for the strategic environmental assessment of the project.

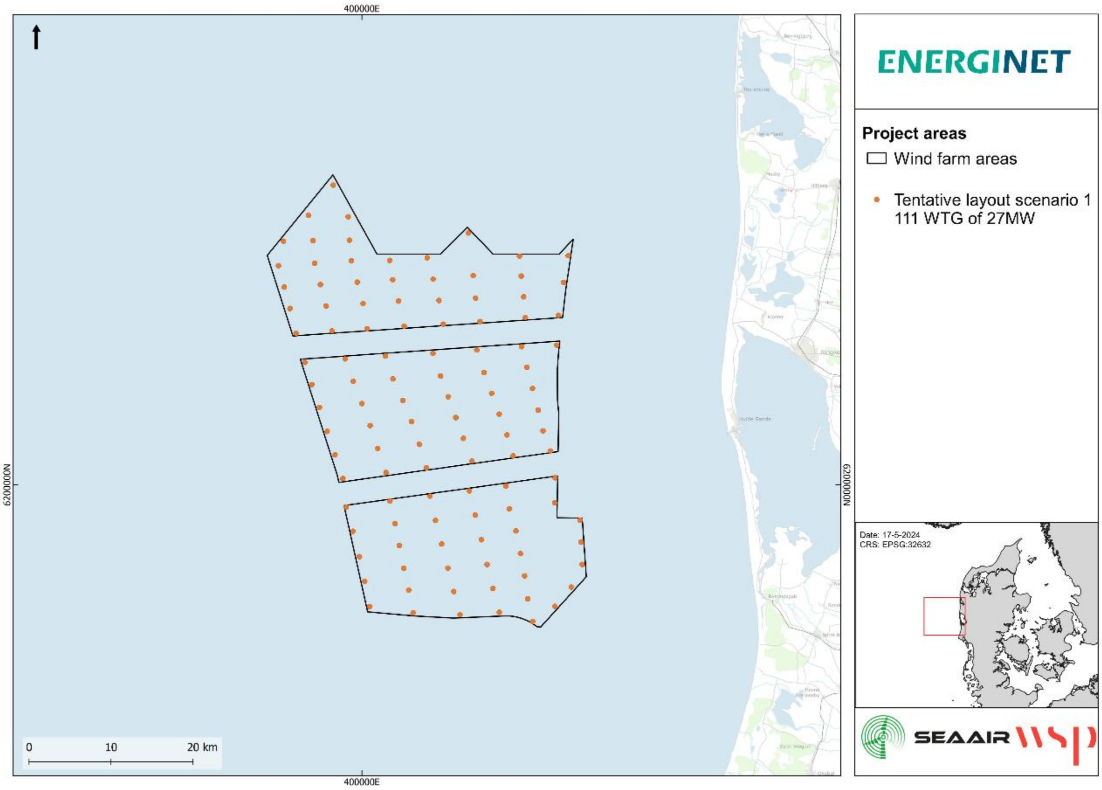

Figure 5 Layout for scenario 1 with 111 WTG of 27MW, as prepared for the visualisation example for the strategic environmental assessment of the project.

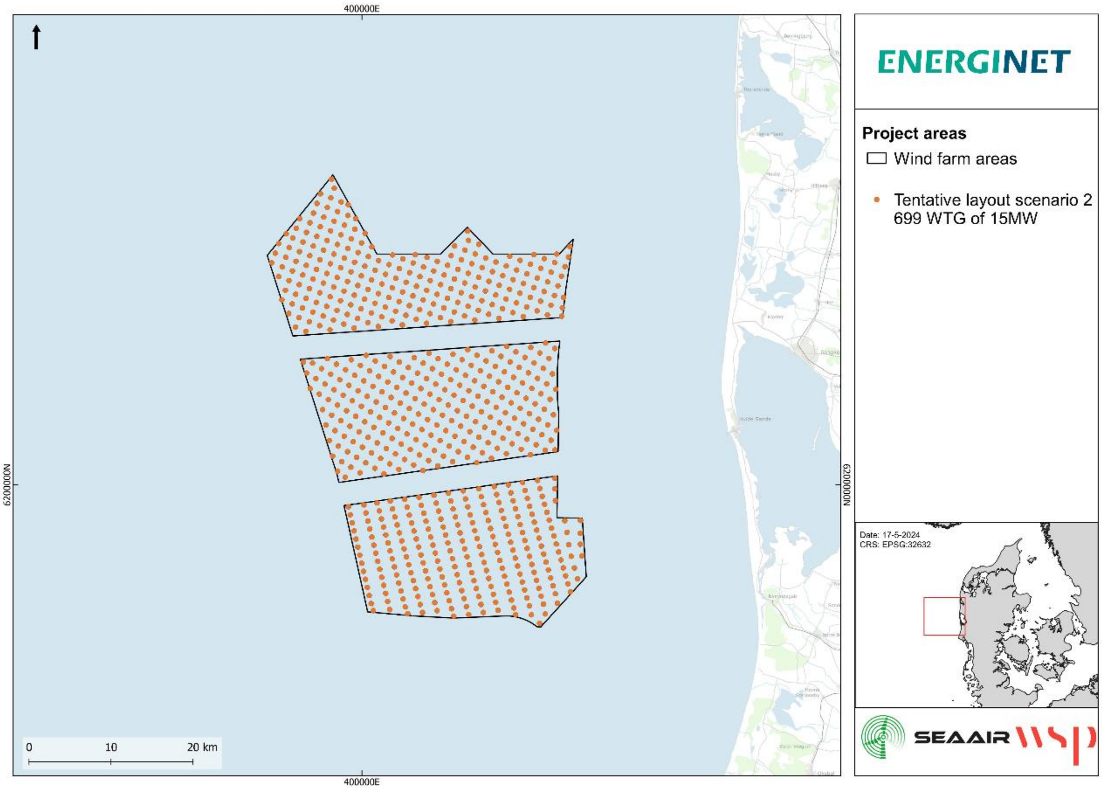

Figure 6 Layout for Scenario 2 with 699 WTG of 15MW (overplanting), as prepared for the visualisation example for the strategic environmental assessment of the project.

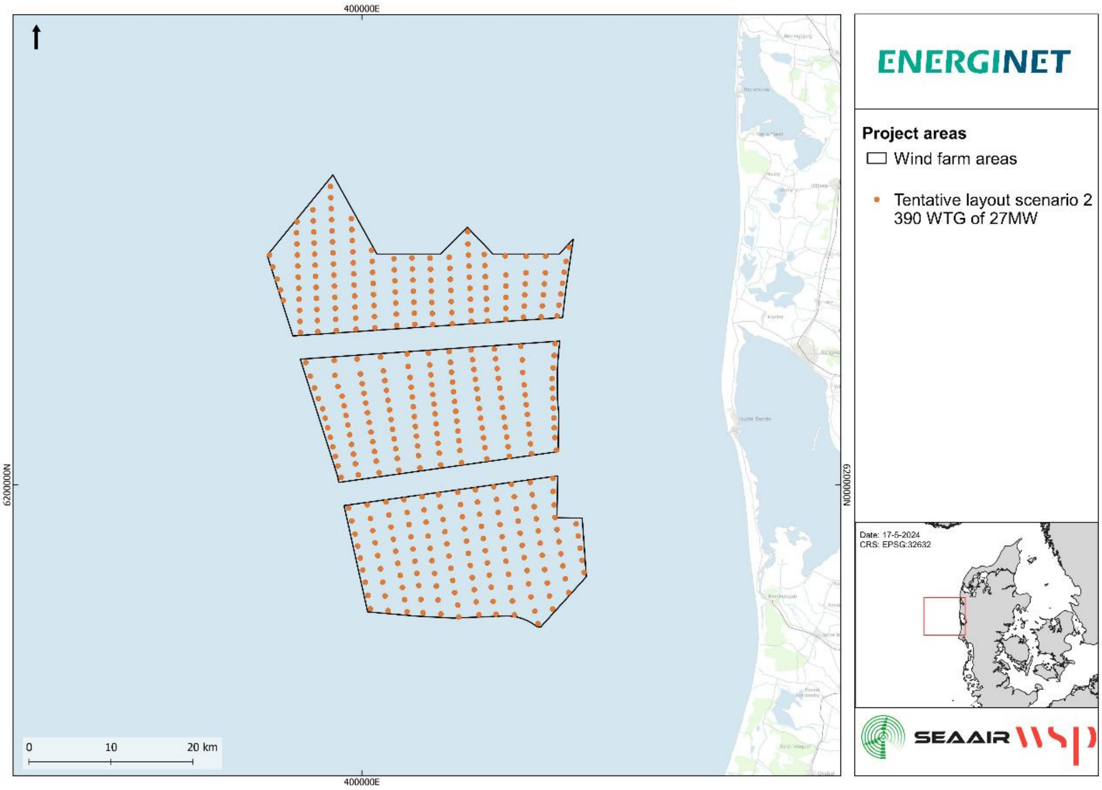

Figure 7 Layout for Scenario 2 with 390 WTG of 27MW (overplanting), as prepared for the visualisation example for the strategic environmental assessment of the project.

The above four scenarios represent possible configurations of offshore wind turbines in the NSI.1 (Figure 4 to Figure 7).

4.4 OFFSHORE SUBSTATIONS

In the information material from Energinet, there is no information on the location of offshore substations, but it is anticipated that there will be minimum of one offshore substation in each of the three sub-areas.

5 EXISTING SYSTEMS

This section identifies and lists the specific existing systems that are in use in the area of interest to this assessment in relation to the NSI.1.

The categorisation is with reference to the international classification and designation for different types of radio systems described in section 2.

5.1 RADIO BROADCAST

Radio broadcasting can be divided into national broadcasts from DR's (Denmark's Radio) large transmitters and local broadcasts from smaller transmitters, typically anchored in market town environments. The national radio broadcast service is also responsible for disseminating emergency messages to citizens.

5.2 RADIOCOMMUNICATION

5.2.1 PUBLIC MOBILE SERVICES 3G/4G/5G

These services relate to land-based communication, which in addition to the intended coverage on land are providing coverage in near coastal areas.

5.2.2 PRIVATE MOBILE RADIO

Private mobile radio (PMR) services are typically anchored in public or private organisations with internal communication needs. The frequency register describes the position of the fixed installation and the transmitting power.

5.2.3 EMERGENCY RADIO SYSTEM – SINE

The SINE radio system is a closed emergency response network that interconnects communication elements of the emergency response, both for civilian and military units. The individual radio systems can communicate via networked base stations and directly from unit to unit.

Maritime units and helicopters in emergency response use SINE at sea, within range of the base station or directly between units when the base station is out of range.

TETRA[2] is an international standard for a radio network. This standard is the basis for the national SINE network. Other operators can use comparable networks and are installed on oil platforms and offshore wind farms in the North Sea.

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[2] TETRA Terrestrial Trunked Radio

5.2.4 MARITIME PUBLIC SERVICES

Radio communication at sea is divided[3] into four (4) zones A1, A2, A3 and A4. Zone A1 is the area that can be covered by VHF[4] coastal radio stations on land, A2 can be covered by MF[5] radio stations, A3 is covered by geostationary satellites, while A4 at the Earth's poles is covered by HF[6] radio stations.

In Denmark, the coastal radio service for the North Sea I area is provided by Lyngby Radio[7] (LYRA) by VHF radio stations located along the west coast of Jutland from Blåvands Huk near Varde, from Bovbjerg near Lemvig and at Hanstholm.

In areas off the coast where the coastal radio on VHF no longer reaches, ships can contact land via MF. LYRA has transmitting and receiving facilities located at Blåvands Huk and at Bovbjerg near Lemvig.

On both VHF and MF, emergency and safety frequencies are monitored, so that an emergency call can always be picked up and monitored.

Along the west coast of Jutland, coastal rescue stations have been established. These stations often have radio direction-finding systems so that locally originating signals and bearings can be measured and cross bearings from multiple stations can be utilized to locate the position of the vessel/person in distress.

5.2.5 AUTOMATIC IDENTIFICATION SYSTEM

Automatic Identification System (AIS) is a mandatory system in larger fishing vessels, cargo ships and passenger ships. AIS is becoming more and more widespread among recreational vessels as a safety and information tool for all AIS-equipped vessels.

AIS broadcasts the vessel's name, position, speed, and other data that is important for navigational safety. The system is dependent on the availability of GMDSS signals.

Each vessel can receive information about and from vessels that are within VHF radio range of each other. Data is also received at stations along the coast, providing a global network for positioning ship traffic.

5.2.6 AERONAUTICAL COMMUNICATION

Voice communication between aircraft and air traffic services is mainly carried out in the VHF band. In the North Sea, users include high-flying airliners and low-flying helicopter traffic to and from offshore platforms and offshore wind farms in the area.

NAVIAIR has transmitting and receiving stations and facilities on the west coast of Jutland situated at Børsmose near Varde and Bovbjerg near Lemvig, as well as on two offshore platforms in the North Sea, the Gorm and Siri platform. Aircraft can communicate in flight with either a land-based or an offshore situated ground station.

Local traffic in the southern part of the Danish North Sea is served by the Tyra area[8]. Tyra is currently served from a centre located at Esbjerg Airport. The service is primarily provided through submarine cables (fibre) and alternatively via geostationary satellite connections.

The Danish Defence uses VHF and UHF frequency bands for voice communication over the North Sea I area.

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[3] GMDSS Global Maritime Distress Service System (GMDSS) describes the division of sea areas
[4] VHF maritime frequencies in the range 150 to 170 MHz
[5] MF maritime frequencies in the range of 1.5 to 3 MHz
[6] HF maritime and aviation frequencies in the range 3 to 28 MHZ
[7] Lyngby Radio is a state enterprise under the Danish Defence. LYRA is operated from Karup in Central Jutland
[8] TYRA TIZ/TIA

Ship-to-shore and ship-to-aircraft communication can be carried out on both frequency bands, whereas military communication predominantly utilises the UHF band, while in ship-to-shore and ship-to-aircraft the VHF band is used for communication between civilian and military units.

Communication over the North Sea is established with forwarded transmitter/receiver stations along the coast at Blåvand, Ringkøbing and Bovbjerg.

5.2.7 RADIO LINKS

Radio links consist of point-to-point links for the purpose of transmitting information in both directions in the form of voice and/or data and often as a combination of both. The individual stations (links) of radio chains use highly directional antennas, often in the form of antennas with parabolic reflectors.

The aim is to eliminate and avoid interference in the transmission by a free line of sight between the stations. Interference can occur if objects are present in the direct line of sight between the two antennas or so close to the direct line of sight (fresnell zone) between the stations that the object is illuminated by the antennas and the reflected contribution causes interference. Interference can be constructive and destructive. As a result, the transmitted radio signal can be altered so much that it becomes completely or partially unusable and the radio link cannot transmit information between the 2 points.

The relevant radio links for the NSI area are Land-based radio links, offshore-based radio links and satellite earth stations described below.

LAND-BASED RADIO LINKS

It is mainly telecom companies that have radio chain flat permits (flade tilladelser) between radio masts on land. There are no transmissions from the coast over the North Sea.

OFFSHORE-BASED RADIO LINKS

There are point-to-point radio links internally between offshore platforms and offshore wind farms.

SATELLITE EARTH STATIONS

Data communication between land and offshore installations in the North Sea is primarily via submarine cables (fibre) and secondarily via geostationary satellites. Communication with the satellite usually requires its own transceiver and antenna station or a connection to a provider of these services.

5.3 RADIO NAVIGATION

5.3.1 NAVAIDS

For air traffic purposes, radio signals transmitted from the ground by Navigational Aids (NAVAIDS) are used. The transmitted signals are used either for area navigation or for landing purposes. NAVAIDS is comprised of four systems NDB, VOR, DME and ILS.

NDB SYSTEM

Non Directional Beacon (NDB) is a simple navigation system where the ground station is located on land, on an offshore installation or onboard a ship. The NDB emits a signal that can be homed in on by the aircraft or vessel. The NDB transmission are received by an onboard radio direction-finding system that can display the relative bearing to the NDB transmitter.

Today, NDBs are available as landing aids at the airports in Esbjerg, Stauning, on several[9] offshore installations with helidecks and onboard more ships with helidecks.

VOR SYSTEM

For ground-based navigation, the VHF Omni Range (VOR) system is still used, although it is expected to be partially phased out over the coming years and replaced by GNSS[10] systems. The ground station emits a radio signal that is structured to emit 360 radials. One radial per compass degree.

An aircraft can select a radial and receive its position relative to that chosen radial.

Military aircraft can also use a purely military navigation system called TACAN, which is a military equivalent of VOR and DME combined. The nearest TACAN installations are located at the Jutland Air Force Stations.

DME SYSTEM

Distance Measuring Equipment (DME) enables an aircraft to measure the distance to a known DME ground station. This station responds to the aircraft's request call, allowing the aircraft to calculate the distance to the ground station.

The aircraft can call multiple DME ground stations simultaneously. In conjunction with a database of ground station positions, the onboard equipment can calculate the 3-dimensional spatial position of the aircraft.

ILS SYSTEM

Instrument Landing System (ILS) is a system of radio transmitters and antennas that provides an aircraft on approach to an airport with a horizontal directional signal, a vertical directional signal and distance markings in relation to the runway being approached.

Esbjerg Airport transmits ILS signals in both east and west direction. Stauning Airport transmits the ILS signals to the east only.

5.3.2 MARITIME NAVIGATION

The maritime traffic mainly uses GNSS for navigation. However, radar can also be used for navigation, although radar is not nearly as accurate as GNSS. In addition, ground-based navigation and dead reckoning are additionally used.

5.3.3 SPACE-BASED NAVIGATION

Global Navigation Satellite System GNSS systems are used throughout society for many purposes, both for positioning but also for precise time stamping.

There are different GNSS systems (e.g. GPS, Galileo and GLONASS) operated by different nations, and most receivers can receive and process GNSS signals from different systems simultaneously.

[9] Dan F, Gorm C, Halfdan A, Harald, Siri, Skjold, Syd Arne and Tyra

[10] Global Navigation Satellite System is a term for all nations' satellite-based navigation and timing systems.

A GNSS receiver utilises orbiting satellites for primary positioning, while correction signals such as EGNOS[11] are transmitted from a geostationary satellite.

5.4 RADIO LOCATION

5.4.1 RADAR FOR AIR SURVEILLANCE

Airspace surveillance is carried out by both the Danish Defence and the Civil Air Traffic Control Service (NAVIAIR). Both organisations use both Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR) radar systems. The Danish Defence provides and distribute radar coverage data to the national Air Navigation Service Provider (ANSP) NAVIAIR.

The radar sensors used by NAVIAIR are typically fixed installations, while the Danish Defence has fixed installations and a number of mobile units at its disposal. These mobile units are not included in the considerations as their expected deployment positions are not publicly available.

It should be noted that the terminology of primary and secondary designation of the two radar systems is of historical origin and does not reflect whether it is the primary system or the secondary system that is used by the organisations for the detection.

PRIMARY SURVEILLANCE RADAR

A primary radar system is a - non-cooperative - system where the radar station on the ground emits radio signals in the form of pulses through the radar antenna that creates a very narrow directional beam or propagation with a propagation angle in azimuth typically below 2º.

When the radio signal encounters an object such as an aircraft or wind turbine, the signal will be reflected/scattered in all directions, a small fraction of the transmitted signal strength will be reflected back to the radar station's antenna and received by the radar. Based on the time between sending the radar pulse and the return of the echo (reflection), the speed of light and the direction of the antenna, the position of the aircraft can be determined.

Since the system does not require cooperative equipment on board the aircraft, a primary radar can detect an aircraft if it has a non-absorbent and a reflective surface.

SECONDARY SURVEILLANCE RADAR

A secondary radar acts as a call/response system. The system is a cooperative system. The radar station emits a number of radio pulses where the time delay between pulses determines the information requested (interrogation). A radio receiver in the aircraft picks up these radio signals. The coherence of the received signals is decoded, and the aircraft emits a tuned set of pulses (reply) containing the requested information.

This function happens in a special onboard device called a transponder. The time between receiving an interrogation in the transponder and sending a reply is constant(fixed). On this basis, the radar station (interrogator) can calculate distance and direction based on the time difference between send and receive and the direction of the antenna.

The secondary radar system requires an active radio receiver and transmitter with associated logic (transponder) to determine the position of an aircraft. The aircraft must therefore co-operate in the radar station's position

[11] European Geostationary Navigation Overlay Service, a GNSS correction signal to improve navigation over the European continent.

determination. This is normally a requirement for civilian aircraft but is not the case for military aircraft of foreign powers flying over the open sea and clear of a country's territorial boundary.

In order for the functionality of the secondary radar system to be fulfilled, the aircraft must actively want to be detected.

5.4.2 ADS-B[12] & MULTILATERATION

All commercial and several recreational aircraft use secondary radar mode S.

Mode S is used for several technical and operational purposes in flight. One of these is the broadcast of the aircraft identification[13], as well as the technical address of the aircraft[14]. This allows all Mode S transmissions from the aircraft to be uniquely attributed to the aircraft.

ADS-B is an extension where mode S also transmits the aircraft's technical data, position data and other navigation data, from which course and speed etc. can be derived.

5.4.3 RADAR FOR COASTAL SURVEILLANCE

The Danish Defence has built several coastal radar stations along Denmark's coasts and straits to monitor coastal shipping traffic. The individual radar sensors provide data to central control rooms from which the Danish Defence monitors ship traffic and activities of other operational interest.

The systems are publicly referred to as Kystradar (KYRA) and Vessel Traffic Services (VTS). Selected coastal radar stations are equipped with an additional radar system used for low altitude air surveillance.

5.4.4 RADAR FOR METEOROLOGICAL SURVEILLANCE

Metrological use of radar covers two different disciplines. The Danish Meteorological Institute (DMI) uses a network of five radar stations to measure cloud formations and precipitation in relation to forecast services.

The radars are located in North Jutland at Sindal, on Rømø, in East Jutland at Virring, on Stevns and at Rytterknægten on Bornholm (see Figure 8).

These radars are specifically tuned to best measure the water content of the atmosphere, and the amount and type of precipitation. The measurement is relatively slow, as a scan of the entire atmosphere within the weather radar's coverage area must be measured in minutes.

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[12] ADS-B Automatic DependenSurveillance - Broadcast

[13] Identification is either airline route number or aircraft registration, e.g. Danish aircraft OY-xxx

[14] A 24 bit binary code that is unique, comparable to a MAC address

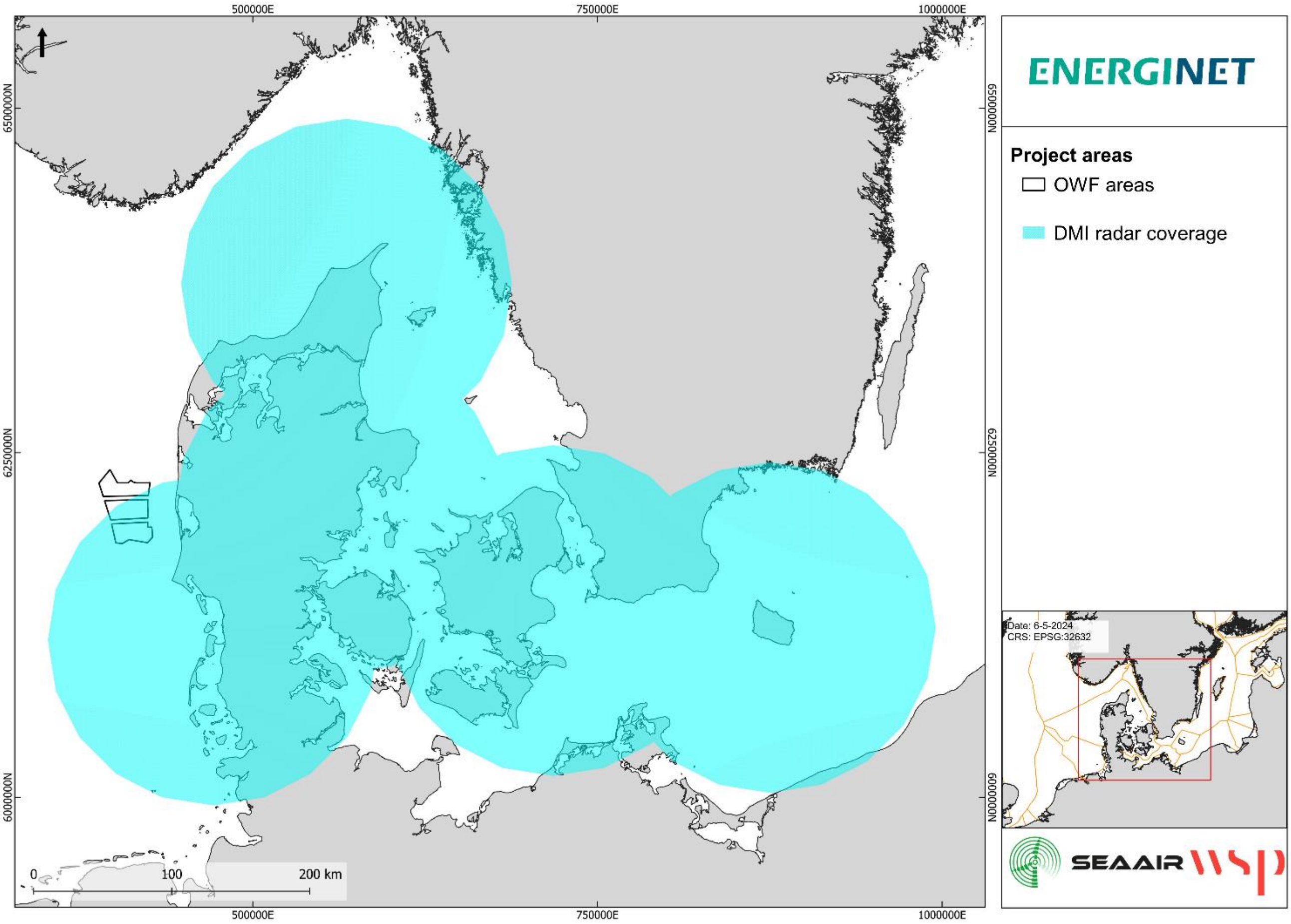

Figure 8 DMI radar coverage.

In relation to flight safety and in provision of Air Navigation Service ATC primary radars are often equipped with a specific weather channel that can detect precipitation at the same time as aircraft are detected. The update rate here is reduced to seconds.

Aircraft inherently want to avoid flying through cloud formations with heavy precipitation, but while DMI's weather radars are optimised to give the meteorologist the best chance of predicting weather developments, they are not optimal for an air traffic controller to assess the current weather picture.

Wave radars used to measure wave properties are installed on platforms in the North Sea and operated by Vattenfall. These types of installations are not affected by OWF.

In addition, there are radars that are a part of Ocean Monitoring System projects, including for the south-eastern part of the North Sea, operated in Germany from Büsum and the island of Sylt. Both HF and X-band radars are used.

5.4.5 RADIO DIRECTION FINDER

Radio direction-finding equipment measures the direction of the incoming electromagnetic wave. Antennas for radio direction finders are designed in such a way that, along with the communication, they deliver information about the direction to the transmitting station or source.

Radio direction-finding systems can be affected if there are foreign objects in the vicinity of the antennas that can cause reflections and can or will result in angular errors in the direction finding and thus indicating an incorrect direction of the incoming radio wave.

The further away a wind turbine is, the smaller the impact and angular error is for the direction finder equipment.

6 ASSESSMENT OF IMPACT

This section evaluates and describes the potential negative impacts on the systems identified in section 5. This section is the extract and evaluation of the registered relevant systems listed in the frequency register.

6.1 RADIO BROADCAST

There are state and regional Radio and TV transmissions from Varde and Videbæk transmitter positions, but NSI will not affect reception on land. CIBICOM, which operates the masts and systems, has assessed that the influence of offshore wind farms in NSI does not raise concerns for their services (CIBICOM, 2023).

Several local radio stations are located in the cities along the west coast. Their reception at sea may be affected by NSI due to their significantly lower transmit power. No further assessments are recommended.

6.2 RADIO COMMUNICATION

6.2.1 PUBLIC MOBILE SERVICES 3G/4G/5G

Given that NSI is at least 20 kilometres from the coast, public services on land are not affected. Telecom operators cannot be expected to cover this far out from the coast with mobile coverage (MCC, 2023).

6.2.2 PRIVATE MOBILE RADIO

LAND-BASED COMMUNICATION

In the coastal area of the west coast of Jutland, many base stations are serving mobile communications from small football clubs to large industrial corporations These directly serve onshore tasks and no companies have been identified with visible activities in the area where NSI will be established.

These installations overall serve onshore needs and will not be affected by building OWF's within NSI.1.

OFFSHORE BASED COMMUNICATION

There are installations on offshore facilities, but here the coverage area is the local facility and its nearby surroundings, a coastal/shore-to-offshore communication need is not identified.

It is assessed that these installations serve local needs at sea and will not be affected by building OWF's within NSI.1.

There is communication from the coast to/from Horns Rev, and a similar communication is expected to be established between Vesterhav Syd and Vesterhav Nord, but as these facilities are not located between the coast and NSI.1, they will not be affected by building OWF's within NSI.1.

6.2.3 EMERGENCY RADIO SYSTEM – SINE

SINE in the form of the TETRA standard is used on land as an emergency response system and as TETRA closed networks on offshore installations in the North Sea. It is not expected to be affected by building OWF's within NSI.1.

6.2.4 MARITIME PUBLIC SERVICES

Through Lyngby Radio, the Danish Defence has established MF and VHF transceiver systems along the west coast, these systems are part of the Global Marine Distress and Safety System (GMDSS). This global international safety system divides sea areas into four categories: A1-, A2-, A3- and A4 areas. The categorisation of the areas is mainly determined by the range of the maritime service and which radio frequencies are used for transmissions.

Area A4 excludes the other Sea Areas A1, A2 & A3 and only A4 covers the polar regions. The A4 area covers 71-degrees North Latitude and above respectively 71-degrees South Latitude.

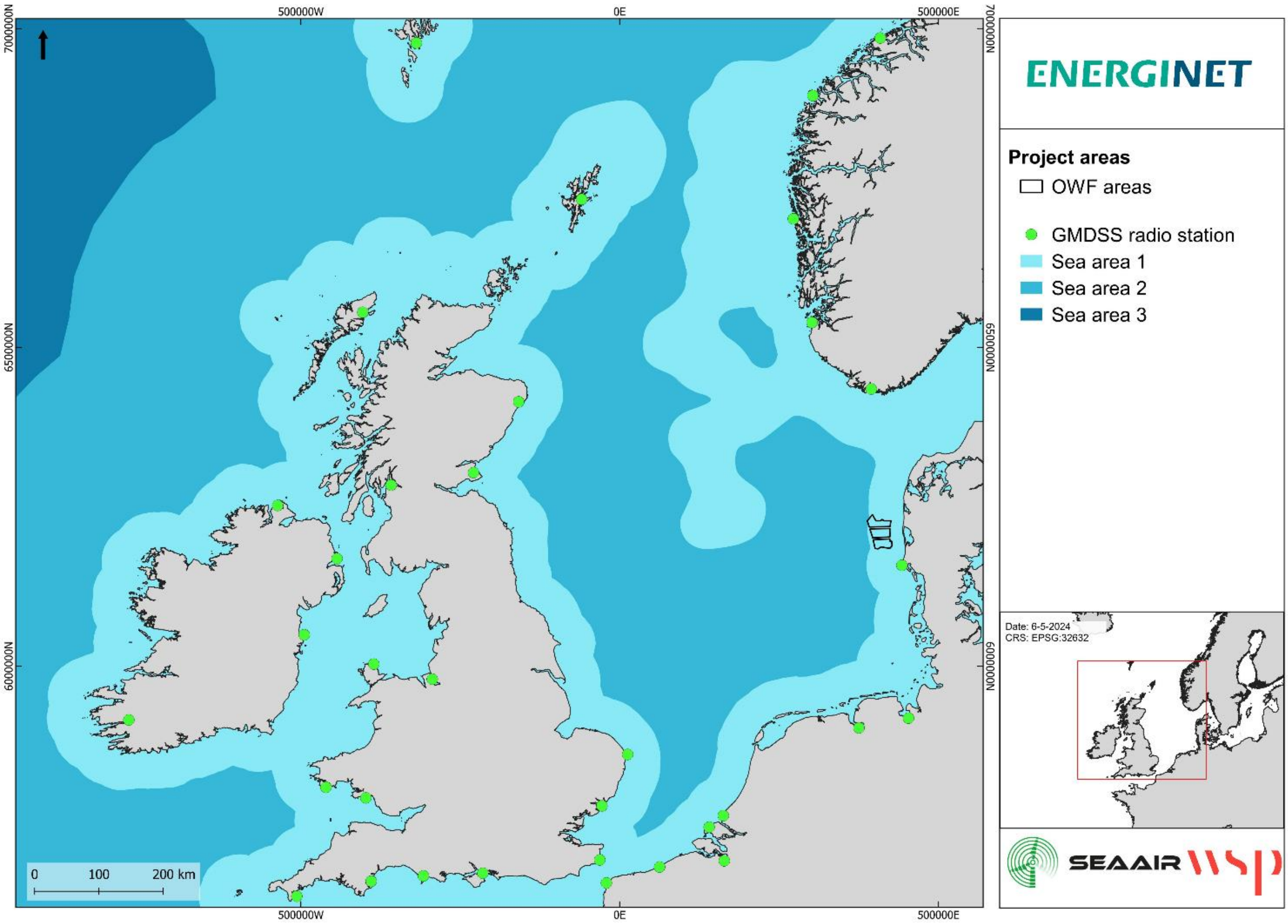

Figure 9 Illustrates the GMDSS Sea areas (A1, A2, A3 and A4) and the OWF's within NSI.1.

For the North Sea, areas A1 and A2 are relevant. Area A1 covers out to approx. 20-30 NM from the coast. This is operated by VHF radio, while A2 covers out to max. 250[15] NM in the North Sea and is operated by MF radio. A3 is outside areas A1 and A2 and communication is via coverage from the INMARSAT system (Figure 9).

The challenge here is that the NSI.1 extends further than VHF radios can reach. Typically, the antenna height of the vessel is the decisive factor for the line of sight and thus for establishing communication. Therefore, radio communication can be obtained via MF if no other communication methods are available. Communication to area A4 around the poles is operated with HF radio systems in the frequency band 3-30 MHz.

Maritime MF communication typically uses frequencies from 1.5 MHz to 2.8 MHz. The propagation typically follows the curvature of the earth. Further, investigation on how this communication will be affected by offshore wind farms in the NSI area could be a need of the service operator. The wavelength of these signals is between 200 to 100 meters, so there may be attenuation and reflections that only can be clarified through further investigation or analysis. The

[15] Further out in the North Sea it is sea area A2 and with additional coverage by MF.

Danish Defence has expressed concern about potential interference impact on radio systems used by the Danish Defence (TDD, 2023).

6.2.5 AUTOMATIC IDENTIFICATION SYSTEM

The AIS system operates on VHF frequencies. The ships transmit their own position based on GNSS data, so the accuracy of the position data is not considered to be affected. Similarly, ship-to-ship reception is not affected outside the wind turbine areas.

However, reception on land transmitted from parts of the North Sea may be affected through signal strength reduction and fading through the NSI area. Further investigation or assessment is recommended.

A separate Background report is prepared concerning the Maritime Traffic and Navigation Safety.

6.2.6 AERONAUTICAL COMMUNICATION

An immediate assessment is that communication from base station Børsmose will be significantly affected by the planned offshore wind farms in the NSI area. The need for the establishment of a new transmitting and receiving station at sea or other similar mitigating measures should be investigated.

A similar assessment is that communication from Bovbjerg will be affected by the NSI wind turbines. In collaboration with NAVIAIR, the need for further analyses should be clarified. The establishment of a new transmitting and receiving station in relation to the possible impact challenges for the Børsmose base station may constitute a necessary mitigation measure.

When communicating to and from ships and low-flying aircraft, it is expected that there may be negative impacts in the form of fading on communication[16] to and from units, west of and in the NSI.1, when the OWFs are build.

6.2.7 RADIO LINKS

LAND-BASED RADIO LINKS

There are many local radio link connections on land, but all are considered not to be influenced/impacted by building OWFs within the NSI.1.

OFFSHORE-BASED RADIO LINKS

The frequency register indicates multiple radio links (point-to-point) between offshore platforms. Over time, a widespread communication network has been established via fibre cables on the seabed, and occasionally interconnection with radio links from platform to platform. There are not identified connections between offshore platforms and land through radio links. Additional connections from land to offshore platforms exist in the form of satellite links.

Satellite links are unlikely to be disturbed by wind turbines, as long as the turbine blades do not penetrate the first Fresnel zone between the two point-to-point stations.

[16] In a previous analysis where a single onshore wind turbine was planned to be located approximately 2000 metres from a Ground-Air radio station, simulations showed significant fading in the received radio signal.

SATELLITE EARTH STATIONS

It is assessed that Land-based satellite earth stations are not affected by building OWFs within NSI.1.

6.3 RADIO NAVIGATION

6.3.1 NAVAIDS

The systems and equipment described in the three following sections are all NAVAIDS which are ground-based navigation equipment. NSI.1 is located outside all Danish NAVAIDS recommended respect distances[17] see Figure 10.

NDB SYSTEM

NDBs are installed at Esbjerg and Stauning Airports, as well as on many offshore installations and ships with helipads. The NSI will probably result in a bearing with a minimal error, but as the NDB is used to find the offshore platform or ship, the signal strength will increase when approaching the NDB and the error is minimised or eliminated close to the NDB station.

For airports, according to the current national plan[18], NDB equipment must be phased out by 2030.

VOR SYSTEM

The VHF Omni Range navigation systems VOR stations located at Blåvands Huk and at Ramme west of Lemvig, have been taken out of operational service. The facilities are currently closed, but the protective surfaces/respective distances are specified in the Danish Planning and Rural District Agency's map material.

The nearest operational VOR station is located on Als and is not to be affected by building OWF’s within NSI.1, due to distance.

DME SYSTEM

Distance Measuring Equipment (DME) is used by larger aircraft for area navigation. The aircraft's DME equipment transmits pulses at a given frequency, these pulses are received at a DME ground station and copied out again at a different frequency with a constant delay. The aircraft can then calculate the distance to the ground station based on the permanent delay.

This allows the aircraft to measure the distance to a sufficient number of ground stations simultaneously and the 3rd dimensional position is calculated and used for navigation.

Earth stations are located on Helgoland, Esbjerg, Stauning, Ramme, Sindal and in the UK sector of the North Sea.

DME/DME navigation is one of several systems, an aircraft can use simultaneously with other systems and therefore NSI is not considered to have an immediate impact on aeronautical navigation options, when overflying the NSI area.

The Danish Defence uses a mix of military and civilian systems for navigation. Thus, the Danish Defence challenges are similar to civilian users when it comes to the use of civilian systems.

[17] ICAO EUR DOC 015

[18] Danish Transport Authority, Danish Defence and NAVIAIR, Airspace Strategy 2020+, revision 03-05-2020

Military aircraft can also use a purely military navigation system called TACAN, which is a military equivalent of VOR and DME combined. The nearest TACAN installations are located at the Air Force Stations in Jutland and are thus so far from the NSI.1, thus building OWF's within the NSI.1 area does not affect the use of the systems.

ILS SYSTEM

The ILS system must deliver the required field strength out to 25 NM from the runway threshold. For Esbjerg, runway 08 is relevant. However, the runway is orientated so that the directional signal passes south of NSI.1and is thus not affected.

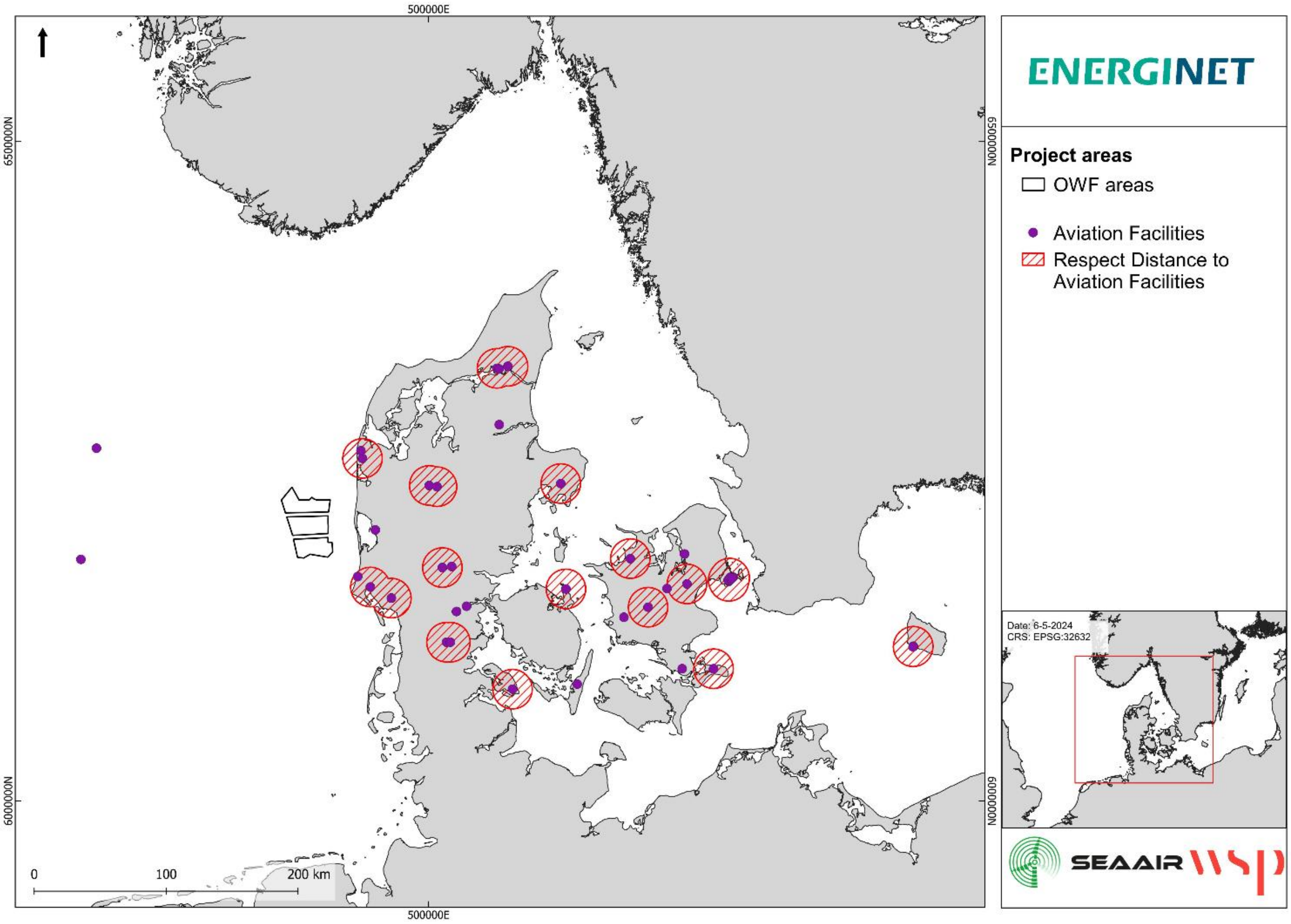

Figure 10 Illustation of the respect Distance to Aviation Facilities[19] NAVAIDS and three OWFs (A1, A2 and A3) within the NSI.1.

6.3.2 MARITIME NAVIGATION

Maritime navigation is mainly related to GNSS systems, which are not expected to pose challenges to regular civilian ship traffic outside the pre-investigation area of NSI.1.

[19] Kort.plandata.dk

There is, in publicly accessible information, not concluded awareness of reporting or statements describing any navigation challenges within existing offshore wind farms in Danish waters - due to the influence from the presence of OWF.

6.3.3 SPACE-BASED NAVIGATION

GNSS systems base calculations on transmission runtime of signals from known satellite positions. The largest position errors are due to distance variation[20] through the atmosphere.

When using correction signals from EGNOS, navigation and position fix accuracy should be available for navigation outside the NSI.1 area and is assessed also to be operational within the NSI.1 area.

6.4 RADIO LOCATION

6.4.1 RADAR FOR AIR SURVEILLANCE

NAVIAIR has its own radar systems at Esbjerg Airport, Billund Airport and Aarhus Airport. In addition, radar signal utilised from a southern Norwegian radar is used, as well as the Danish Defence's radars at Aalborg and Skrydstrup Air Base[21]. Additional radar installations on Zealand are irrelevant in relation to building the three windfarm areas within NSI.1.

PRIMARY SURVEILLANCE RADAR

The Billund radar station is located in high terrain, but far enough to the east that it is not assessed to be affected by the three OWF areas within NSI.1.

The physical size of an object, its shape, and the spatial angle from which it is illuminated, have a huge impact on the resulting echo usability for the radar system. A wind turbine has such large dimensions, that the reflection of the radar signal on the wind turbine/-s has a total signal strength of the signal that, as an example, unintentionally is scattered towards an aircraft, and then subsequently reflected back to the radar antenna. This changes the direction and distance an aircraft is measured to have in the radar and is referred to as 'multipath'. The consequence of multipath is a false echo.

Multipath is not a challenge for the Billund radar, as it is situated too far east in relation to the three OWF area within NSI.1.

The Danish Defence and NAVIAIR use radar installations at the 3 Jutland military air force stations Aalborg, Karup and Skrydstrup for air traffic control. These stations are located relatively low and so far away from the North Sea that they are not expected to be affected.

For airspace surveillance of military interest, long-range radar systems are used. Three radar stations are located in Jutland. These radars are not expected to be affected.

Two (2) Obstruction Light Control (OLC) radar systems are located at the cities of Klinkby and Søndervig respectively. The two radars are installed as part of the construction of the 2 offshore wind farms Vesterhav Syd and Vesterhav Nord and are used to control obstruction lights for each of the 2 offshore wind farms (Vattenfall, 2023). The radars are optimised to detect aircraft inside and in the vicinity of the wind farms. The final wind turbine positions for NSI must

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[20] GNSS position data has several sources of error, but the most significant is variation in the propagation and deflection of radio signals in the upper layers of the atmosphere. Less significant errors are caused by reflections and blockages from local objects such as wind turbines, etc.
[21] AIP DK ENR 1.6.1.2 Radar Services and Procedures

likely be configured in the radar software on the OLC radar at Søndervig. Klinkby OLC radar is not affected, as instrumented range for the radars is assumed to be 26 km.

SECONDARY SURVEILLANCE RADAR

In southern Norway, the radar station EVJE is located. The radar is located so far north, that it is not affected by the OWF's within the NSI.1.

However, the OWFs within NSI.1may affect the Esbjerg SSR radar located at Esbjerg Airport, as it serves the traffic passing through in the North Sea. There are other radars that are part of or supplying to the overall air traffic picture, but Esbjerg is important for low-flying helicopter traffic and traffic to and from the UK.

It is expected that an in-depth analysis of the influence of OWFs within the NSI.1 on Esbjerg MSSR Radar will be necessary to perform. It is recommended that NAVIAIR is contacted for clarification of supporting measures.

6.4.2 ADS-B & MULTILATERATION

ADS-B is used for multilateration. NAVIAIR has a number of antennas located along the west coast of Jutland to pick up Mode S and ADS-B signals.

It is assessed that receiving, especially low-flying helicopters, en-route to the offshore platforms in the North Sea is problematic due to the size of NSI.1.

It is recommended to enter a dialogue with NAVIAIR about any additional analysis needs.

6.4.3 RADAR FOR COASTAL SURVEILLANCE

The Danish Defence operates a network (KYRA) of coastal radars for monitoring ship traffic. In relation to the NSI project, there are radars at Thyborøn and Blåvands Huk. In addition, a gap filler radar has been installed at Vesterhav Nord OWF (TDD, 2023) (Figure 11).

VTS are found in the Öresund, the Great Belt and at Skagen, and are thus irrelevant for OWFs in the NSI.1.

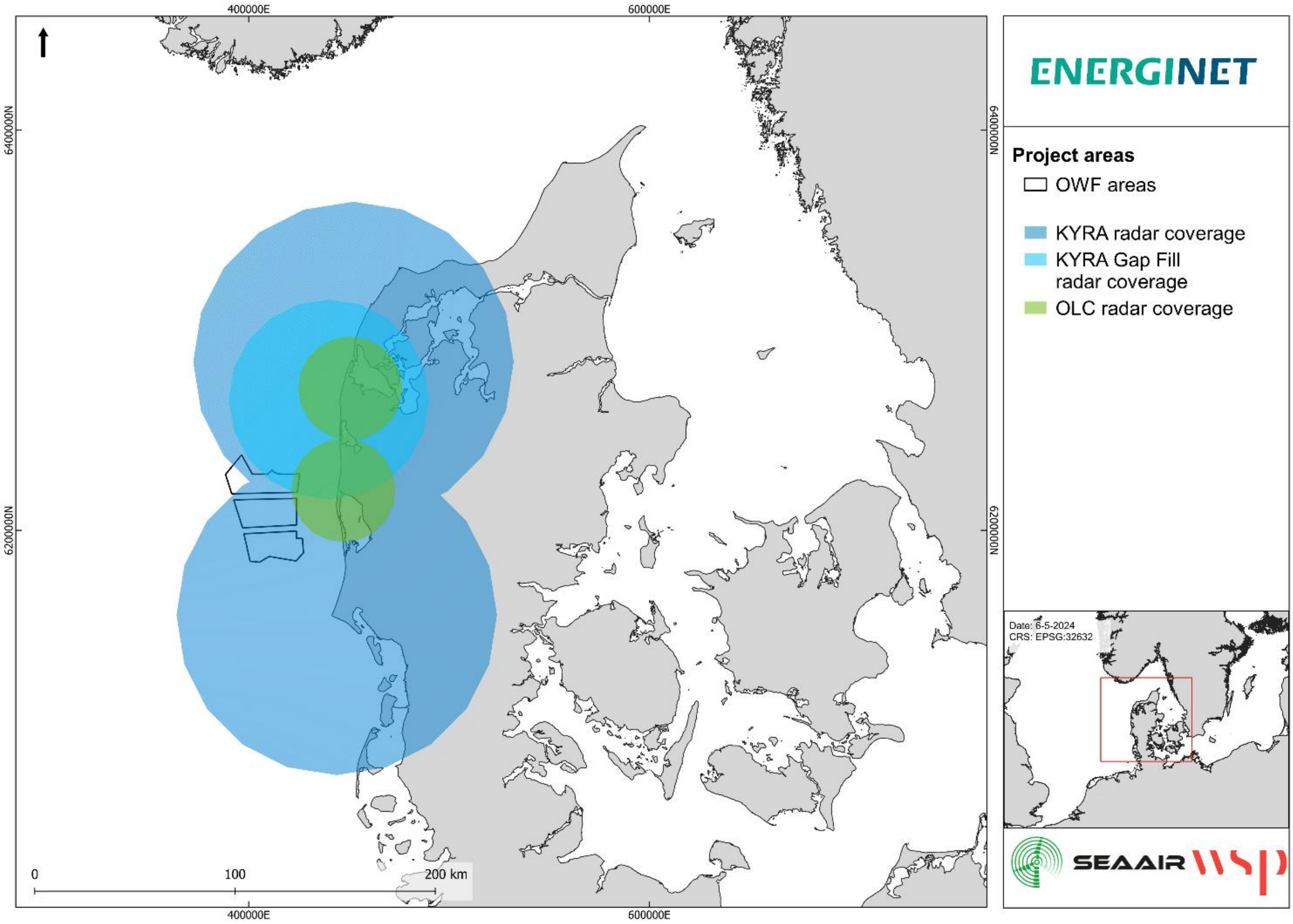

Figure 11 KYRA radar coverage + OLC radar coverage North Sea North and South.

The Danish Defence coastal radars at Thyborøn and Blåvands Huk will be affected by North Sea I. Further technical and operational analysis and mitigation measures are to be expected, including possible offshore radar positions to close and mitigate shadow fields in the NSI area (Gap Filler Radar).

The already existing Gap Filler Radar situated at Vesterhav Nord OWF cannot compensate for NSI impacts.

6.4.4 RADAR FOR METEOROLOGICAL SURVEILLANCE

The Danish Meteorological Institute (DMI) has five radars in Denmark for recording precipitation. The radars have an instrumented range of 120 km and a maximum range of approximately up to 240 km. Radiation and scanning ranges are usually above horizontal for weather radars.

Relevant here is the weather radar on Rømø. A combination of distance and antenna height indicates that the weather radar will be affected by the planned offshore wind farms in the NSI area. Experience shows that the Rømø weather radar can detect the current wind farms at Horns Rev, which already has a negative impact on the radar's performance.

Horns Rev 3 is stated to have a wind turbine height of approx. 190 metres. Therefore, it cannot be ruled out that OWFs within NSI.1 with taller wind turbines, will affect the weather radar on Rømø, which is why further analysis of the influence is recommended.

6.4.5 RADIO DIRECTION FINDER

In Esbjerg, Hvide Sande, Thorsminde and Thyborøn there are maritime VHF base stations for the Coastal Rescue Service's rescue stations for search and rescue operations (SAR). In addition, the rescue stations have radio direction finders that are used on VHF channel 16, which is the safety and emergency channel.

OWF's within NSI.1 will affect the ability of the direction finders to provide accurate bearings for vessels travelling through NSI.1 and west of the field. The accuracy of these direction finders and the precision of a vessel's position when cross-tracking, may be affected to an operationally unacceptable level. Further, analyses and investigations are recommended.

6.5 TRANSBOUNDARY IMPACT ASSESSMENT

Radar and radio systems located in neighbouring Norway and Germany have been studied. Known radar stations and radio stations have been assessed for potential negative impact. No radars whose locations are publicly available were found to be affected to such an extent that further analysis of potential impact is deemed necessary. This is because the distance is so far, that the identified systems are not within Line of Sight.

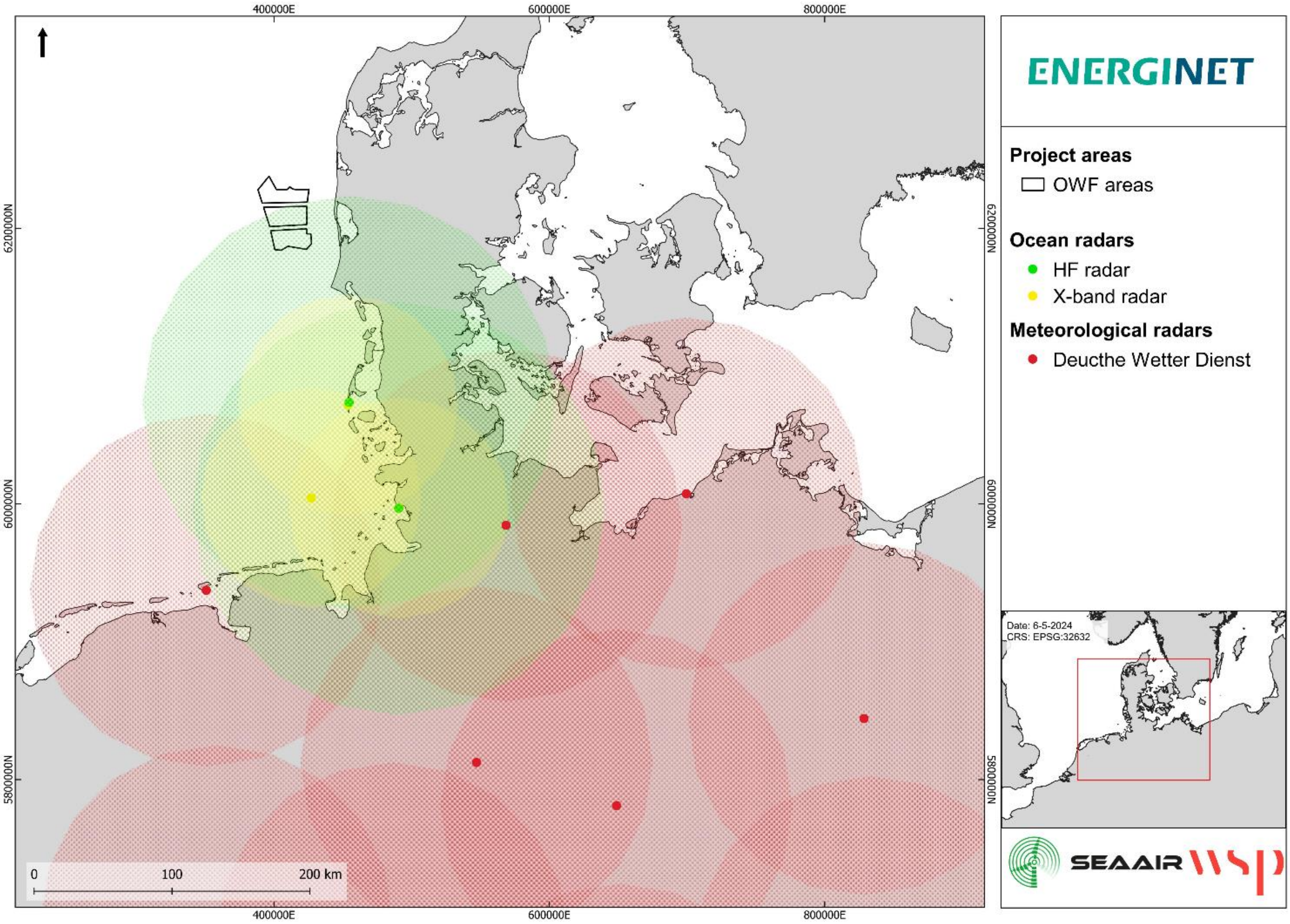

Figure 12 Illustration of German ocean and meteorological radars and the OWFs within the NSI.1.

The two German weather radars at Boostedt and Emden are located further south, and OWFs within the NSI.1 are not within instrumented range, instrumented range is the radar's configured maximum distance for detecting and displaying echoes.

The Danish Energy Agency has conducted a consultation regarding scoping for the environmental assessment of the NSI plan in the period 6 March - 31 November 2023 (Høring, 2023)[22].

During the same period, stakeholders such as neighbouring Norway and Germany will be consulted on the transboundary environmental impacts of the plan (ESPOO consultation) in accordance with the ESPOO Convention.

The consultation was initiated to support the possible establishment of offshore wind farms before the end of 2030 in accordance with the Climate Agreement. In a previously conducted ESPPO consultation regarding Vesterhav Syd, there was no response or feedback from neighbouring countries to the request (NIRAS, 2015) [23].

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[22] Consultation on the environmental assessment of the North Sea Plan 1 https://hoeringsportalen.dk/Hearing/Details/67261

[23] https://ens.dk/sites/ens.dk/files/Vindenergi/vesterhav_syd_saeby_bornholm_owf_reply_to_espoo_response_2nd_hearing_2016.pdf

7 CUMULATIVE IMPACT

Due to climate challenges, the designation of areas for offshore wind farms has intensified and large areas are being planned for the establishment of offshore wind farms. In particular, this means that national maritime and airspace radar surveillance is challenged, and it is anticipated to have an impact on the required level of detection and surveillance. In particular, national military interests and surveillance requirements often cannot be maintained at the necessary high operational level.

For wind farms of a size equal to what is planned for the NSI.1, it would be due diligence in risk planning to incorporate expected increased requirements for analyses from the state and also requirements for the establishment of mitigation measures that can compensate for expected potential impacts. It may be necessary to install mitigation measures on land or in the offshore wind farm. Further, consultation with affected functional areas is required for further clarification.

According to the Marine Spatial Plan for Denmark (Danmarks Havplan, 2023), areas west of the NSI have been designated for renewable energy and energy islands. These designated areas are at such a distance from North Sea I, that they are not assessed to induce further negative impacts in the mapping area of this report (NSI.1).

OWFs within the NSI.1 will have the largest potential impact of the existing offshore wind farms in the area. The Vesterhav Nord, Vesterhav Syd, Thor and Horns Rev wind farms will constitute an overall cumulative impact.

It is expected that further in-depth analyses will determine the mitigation measures needed in order to minimise or compensate for the impacts introduced by the establishment of OWFs within NSI.1 to an acceptable level.

There is intense helicopter traffic to service offshore platforms and wind turbines. Flying out towards platforms typically takes place below cloud cover, while returning to land can be done above cloud cover. Thus, flying takes place at altitudes of 500 FT to 3,000 FT. This should be kept in mind when further assessing the recommended additional analyses.

8 MITIGATION MEASURES

It is recognised and widely accepted that high-rise buildings, chimneys, and wind turbines can interfere with radio and radar signals.

Mitigation measures must, by their very nature, be determined after further analyses and investigations. However, it is already foreseeable that there may be a need for "strategic" positions in the offshore wind farms that can be equipped with radar for maritime surface surveillance and/or airspace surveillance and possibly for forward situated radio transceiver stations.

It is recommended to consider "strategic" positions in relation to NSI.1 early in the project phase.

The details regarding mitigation measures in relation to the Danish Defence's radar facilities are to be determined based on a thorough analysis which is conducted in parallel to this technical background report. The final requirements are coordinated between the future concessionaire and the relevant authorities in Denmark.

Based on detailed technical analyses, the scope and type of mitigation measure(s) can be assessed and recommended. There is an escalation in the complexity of the type of mitigation measure depending on the analysed impact. The following are only examples and cannot be considered as clear-cut solutions that can be applied to all OWF projects. Mitigation measures can range from technical solutions, physical relocation, software solutions, configuration/modification of the system and finally to the installation of additional/supplementing systems for mitigation.

The Danish Agency for Data and Infrastructure SFDI recommends that if, during the design of a wind turbine or other tall buildings, it is assessed that there is a risk of interference to a radio link connection, a dialogue should be started with the owner of the radio link in question (the licence holder). This will clarify whether or not there is a risk of an interference impact or problem (SFDI, 2023).

The owner will be able to better assess the risk of an interference problem based on their specific knowledge and experience with the systems. It is assumed that this recommendation applies not only to radio links but also to other systems that provide critical services such as emergency communications and radar coverage.

It is recommended that the clarification is made well in advance of the start of design and construction work to avoid costly changes or delays at a later stage in the project process.

9 IDENTIFICATION OF DATA GAPS & INSUFFIENCIES

The full consequences of the impacts on the systems and the need for mitigation measures cannot be assessed or determined on the current basis of project information. In most cases, it will require further analysis of the system identified as potentially impacted. Analyses will only be accurate once the number and positions of offshore wind turbines in the NSI area have been determined.

It can be noted that especially positions and frequencies for registered systems in the frequency register (Frekvensregisteret, 2023) are not always provided or, in case of doubt, cannot be verified. The declaration and registration of foreign systems are subject to greater uncertainty than the source data of national systems in Denmark.

In parallel with this technical background report, a separate study of potential impacts and possible mitigation measures in relation to military radars is being conducted. The study is initiated by Energinet and includes analyses of military radars according to Eurocontrol guidelines (Guidelines-EUROCONTROL, 2014) or the Danish Defence specifications. The analysis reports are typically classified and are available to the Danish Defence only. These more detailed technical analyses are a prerequisite for determining and selecting adequate and compensatory mitigation measures.

10 CONCLUSION

The NSI.1 is located west of the existing offshore wind farms Vesterhav South, Southwest of Vesterhav North, South of Thor (under construction) and North of Horns Reef 1, 2 and 3.
Further west and northwest of NSI.1, are a number of oil and gas fields in the North Sea. The distance to these offshore installations extends beyond 175 km from origo of NSI.1.

10.1 SUMMARY

An overview of the assessments of potential impacts and mitigation measures is provided in Table 6 below derived from the assessments in section 6 and section 8 and the classification of impacts in Table 5.

10.2 CLASSIFICATION OF IMPACT

Categorisation and significance of the stated criteria in Table 5 overview of potential impact on Radar and/or radio systems

Table 5 Overview impact categories

Category of impact	Description
No impact	No potential impact on existing conditions.
Negligible impact	Impact in the form of e.g. dampening of non-critical service
Minor impact	Potential impact may occur that may have a minor or near negligible effect on system performance or user use. The impact may be temporary in nature.
Moderate impact	Potential impact is assessed as likely to have a moderate or significant impact on functionality and performance. Possibly and typically of a permanent nature.
Significant impact	Potential impact is highly likely and permanent in nature and requires at least a detailed analysis to assess the impact.

10.3 OVERVIEW OF POTENTIAL IMPACT

Table 6 Overview of considered potential impacts in this technical report.

System type	Description of impact	Impact category	Mitigation measure	Commentary
RADIO BROADCASTING	Radio and TV broadcasts on Land	Negligible impact	None	Non-critical services
RADIO COMMUNICATION				
Public mobile services 3G/4G/5G		No impact	None	-
Private mobile services		No impact	None	-
The SINE emergency response system		No impact	None	-
Maritime public services	Possibly reduced coverage of Coastal radio stations and VHF rescue stations in the NE edge of the wind farm and minor impact on radio coverage in the southern part of the wind farm area	Minor impact	Possibly. TX/RX relay station in OWF	Alternative form of communication is available. Need for further analysis is to be assessed by the system owner
Automatic Identification System	AIS communication from ship traffic may be damped or muted in the offshore wind farm area	Negligible impact	None	Non-critical service
Aeronautical communication	Air-Ground-Air VHF communication from base station Børsmose and Bovbjerg	Moderate impact	Possible establishment of TX/RX station in OWF	Critical service. NAVIAIR should be consulted regarding analysis needs
Radio Links				
Land-based radio links		No impact	None	-
Offshore-based radio links		No impact	None	-
Satellite earth stations		No impact	None	-
RADIO NAVIGATION				
NAVAIDS				
NDB systems	Ground-based NDB	No impact	None	-

	For ship-borne NDB within OWF, minor bearing errors may occur	Negligible impact	None	-
VOR systems		No impact	None	-
DME systems		No impact	None	-
ILS systems		No impact	None	-
Maritime navigation		No impact	None	-
Space-based navigation		No impact	None	-
RADIO LOCATION				
Radar for airspace surveillance		No impact	None	-
Primary radar system	Civil ATC TMA PSR radar Danish Defence Air Defence radar installations OLC radar	No impact No impact No impact	None None None	Billund TMA within rLOS - OLC radar within rLOS
Secondary radar system	CIVLE ATC SSR radar ALL, BLL & KAR Civil ATC SSR radar ESB	No impact Moderate impact	None Not clarified	-ESB SSR evaluated af a critical service. NAVIAIR should be consulted regarding analysis needs
ADS-B & multilateration	No problems are expected	No impact		It is recommended to consult NAVIAIR if they opposed suspect possible negative effects
Radar for maritime surveillance	Coastal radar Thyborøn and Blåvands Huk Gap Filler radar North Sea North OWF	Moderate impact Minor to Moderate impact	To be clarified Gap-fill radar requirements expected	Technical analysis initiated by Energinet Depends on the instrumented range
Radar for meteorological monitoring	DMI meteorological radar Rømø	Minor impact		DMI should be consulted regarding analysis needs
Radio Direction finder equipment	Coastal rescue stations' VHF direction finders, bearing accuracy can be affected	Minor impact	Possible establishment of supporting VHF direction finders on OWF	Used in SAR operations. Operational risk is unknown, Danish Defence should be consulted

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