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Hejre to South Arne Development Project

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Environmental Impact Assessment – Hejre tie-back to South Arne

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1. Non-technical summary

INEOS E&P A/S plans to develop the Hejre field in the central part of the Danish North Sea. As part of the authority approval of the development plans an EIA (assessment of impacts on the environment) has been made. The EIA is an environmental assessment that aims to describe the project, it's impacts on the surrounding environment and the measures taken to prevent and reduce the impacts. This non-technical summary summarizes the main points of the EIA. The full environmental assessment is documented in the subsequent chapters of this report.

The Hejre field is located in licence 5/98 in the central part of the Danish North Sea, approximately 300 km from the Danish west coast and close to the Norwegian shelf border. See location of Hejre on the map below (Figure 1-1). The oil and gas in the Hejre reservoir lie in a geological layer consisting of sandstone at approx. five kilometres depth. Due to the depth, the field is a so-called HPHT field, i.e. a field where oil and gas are high temperature and high pressure. This is different from other Danish oil and gas fields, but HPHT fields are well known in other parts of the North Sea.

Development of the Hejre field started in 2011 with the submission of the original development plan and EIA for drilling of up to 12 wells, and a stand-alone platform with living quarters and processing and export of oil and gas. The platform foundation, the so-called jacket, was installed in 2014 and drilling of five wells took place in the period from 2014 to 2016. Oil was confirmed in three of the wells.

The original project was stopped in 2016 when the then owners of the Hejre field DONG E&P and Bayerngas cancelled the contract with the supplier consortium for the platform production module. Since INEOS E&P A/S took ownership of DONG E&P late 2017, various solutions for re-development of the Hejre field have been investigated.

The re-development concept presented in this report, the Hejre tie-back to South Arne, comprises a solution where a new minimum topsides module is added to the existing Hejre jacket and where well fluids are routed via a new pipeline to the South Arne platform for processing and further export. The concept will thus to a large extent build on already existing elements (i.e. the Hejre jacket, the 3 Hejre HPHT wells and the South Arne installations). An option to drill an additional HPHT well into the Lunde reservoir is included.

The present EIA report assesses the environmental impacts of all elements and activities relating to the re-development project. As the Hejre tie-back to South Arne re-development project extends beyond the activities assessed in the original Hejre EIA from 2011 it is considered a change to a project covered by point 29 a in Annex 1 of Act no. 4 of 03/01/2023 on environmental assessment of plans, programmes and specific projects (EIA):

- 29) Any change or extension of projects listed in this Annex, provided that such change or extension itself meets the threshold values, if any, set out in this Annex.

The report also covers a screening of the project's potential impacts on Natura 2000 sites and on Annex IV species) according to the Offshore Impact Assessment Order (Order No. 1050 of 27/06/2022) and an assessment of impacts on the environmental targets according to the Marine Strategy Act (Act no. 1161 of 25/11/2019).

1.1 The project

The evaluation of the re-development concepts has been based on studies of project economics, technical feasibility as well as working environment, safety and environment, sustainable development and business conditions. The selected Hejre tie-back to South Arne re-development concept comprises of an unmanned topsides at Hejre that will be remotely controlled from South Arne. A new 30 km insulated multiphase pipeline will be installed between Here and South Arne, where well fluids from Hejre will be processed.

The Hejre oil will be produced to the South Arne Gravity Based Structure (GBS) storage tank where it will be temporarily stored before being exported by shuttle tanker via the existing South Arne oil offloading system. The gas will be exported through the existing South Arne to Nybro pipeline. To ensure that the export gas from South Arne can comply with the specifications required by the Nybro Gas Facility, the heavy gas components, the so-called Natural Gas Liquids (NGLs), from Hejre will be injected into the South Arne reservoir and will remain there.

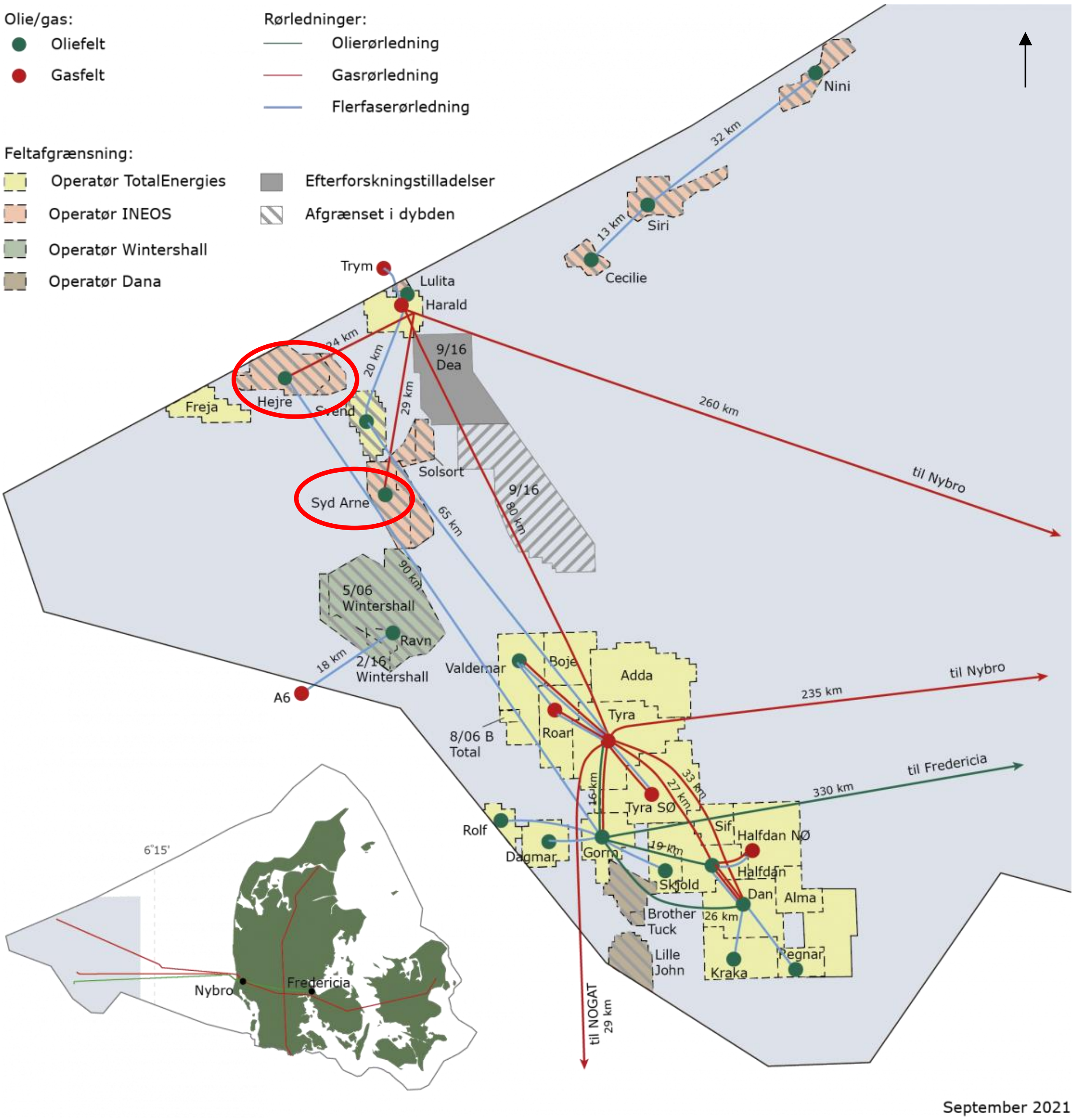


Figure 1-1 Location of the Hejre Field, South Arne and infrastructure in the Danish sector of the North Sea.

The Hejre tie-back to South Arne project includes the following activities required for the re-development, operation and decommissioning of the Hejre field until end-of-life:

- Construction and installation of a new unmanned topsides and a new fortified riser (vertical connection between the multiphase pipeline on the seabed and piping on the platform topsides) at Hejre. This also includes minor modifications to the existing Hejre jacket to remove the temporary items left over from the original installation in 2014 and hook-up between the Hejre pre-drilling well-head module installed in 2014 and the new topside.

- The 3 existing Hejre HPHT wells will be opened to the reservoir and made ready for production (so-called perforation and clean-up). One of the wells that will not be used for production (HA-5) will be repaired to ensure that it remains closed off. Drilling of an additional well from the Hejre platform into the Lunde reservoir is included as an option. This part of the work will be carried out by a drilling rig.

- Minor modifications will take place at the South Arne Wellhead Platform East (WHPE) to make the platform ready to receive the well fluids from Hejre. This includes installation of new equipment, such as pumps, and also a new caisson with riser and power cable. A caisson is a large vertical piece of pipe that protects the equipment inside from external impacts.

- Minor modifications will take place at the South Arne Main platform, including removal of obsolete process equipment and installation of new equipment, e.g. pumps

- Laying and commissioning of a new 30 km 10” or 12” multiphase pipeline and a fibre optics power cable between Hejre and South Arne. Prior to installation a seismic survey along the pipeline route will be carried out.

- Production of oil and gas from the Hejre and potentially Lunde wells, processing of the well fluids at South Arne, and operation and maintenance of the multiphase pipeline and power cable, Hejre platform and wells for 20 years.

- Decommissioning, i.e. plugging and abandonment of the Hejre and Lunde wells, flushing and dismantling the Hejre platform and jacket, emptying the Hejre-South Arne pipeline and preparing for *in situ* disposal below seabed if permitted by the Authorities.

Offshore pipeline installation work is expected to start in Q2 2026, and pipeline hook-up, installation of the new Hejre topsides, modifications at South Arne and perforation and clean-up of the Hejre wells is expected to take place in Q2 and Q3 2027. First oil is expected in Q4 2027.

The timing for the potential drilling of the Lunde well is also not shown in the schedule but will take place after work on the existing Hejre wells is completed – either directly after or in a later campaign.

1.2 Alternative Hejre field re-development concepts considered

Since 2016, following early termination of the original Hejre development project, five other main alternatives for the re-development of the Hejre field have been considered but screened out for technical and/or economic reasons.

- **Process, Utility and Quarter Topside.** New stand-alone process, utility and living quarter at Hejre for processing of Hejre fluids and using of existing Hejre jacket, pre-drilling unit and export routes. This included the possibility of a co-development of the nearby Solsort discovery.

- **Mobile Production Unit.** Converted jack-up drilling rig with process module located at the Hejre field for processing of the Hejre fluids using of existing Hejre jacket, pre-drilling unit and export routes.

- **Valhall Tie-Back.** Tie-back to Valhall (Norway) through a new multiphase pipeline from Hejre to Valhall. New Bridge Linked Platform (BLP) at Valhall for processing of Hejre fluids. Use of existing Hejre jacket and pre-drilling wellhead module.

- **Harald Tie-Back.** Tie-back to Harald through a new multiphase pipeline from Hejre to Harald. Umbilical for supply of power, chemicals etc. from Harald to Hejre. New module at Harald for processing of Hejre fluids. Use of existing Hejre jacket and pre-drilling wellhead module.

- **Siri Tie-Back.** Tie-back to Siri through existing Hejre gas export pipeline to the South Arne Harald WYE at which a new 43 km pipeline would be established to Siri. A new gas export pipeline from Siri to tie in at Tyra East. New manned topside at Hejre with living quarter. Modifications at the Siri platform. Use of existing Hejre jacket and pre-drilling wellhead module.

1.3 Existing environment

1.3.1 Physical and biological environment

This section is a very brief summary of Chapter 6 *Description of the existing environment*. Please refer to this chapter for a more detailed description including references etc.

Environmental setting

The Hejre and South Arne fields are situated in an area with relatively low plankton production. Due to the relatively low biological production, the area is not an important nursery area for fish larvae and juvenile fish (although fish spawning takes place in the area) and the abundance of seabirds is low.

Water quality

The water quality is comparable to other areas in the central North Sea, which are defined as "problem areas" based on a combination of input of contaminants from sources on both land and sea, in addition to input from atmospheric deposition.

Seabed

The seabed sediment around Hejre and South Arne consists of fine sand with a very low content of organic material.

A baseline survey conducted at Hejre field in 2013 prior to drilling, showed that the concentrations of all investigated contaminants (PAH, THC, NPD and heavy metals) were low and generally well below the assessment criteria for sediment contamination provided by OSPAR. There was no difference between the concentrations of contaminants in samples from Hejre and from a reference station located 15 km north of Hejre.

An assessment of contaminants in the sediment around the South Arne platform was conducted in 2021. Concentrations of contaminants (PAHs and heavy metals) were generally low and below the HELCOM/Danish Targets. In general, there is no correlation between concentrations of contaminants and distance to the Syd Arne platform. The exception is Barium for which the average concentration was higher than the potential toxic concentrations (TEL) and concentrations decreased with the distance from the platform. Barium is associated with drilling activities. However, a calculation of the EnS-index (an environmental status index based on descriptors in the Marine Strategy Framework Directive) indicated a "good environmental status".

Benthic infauna

The benthic infauna that lives in and on the surface of the seabed at Hejre and South Arne is generally characterized by bivalves, polychaetes and echinoderms. At South Arne the species diversity seemed to be lower around the platform compared to a reference station, and there seemed to be an increase in species biodiversity with increased distance from the platform. This corresponds well with previous findings, that potential impacts on the benthic infauna tends to local.

Fish and fisheries

Herring, sprat and mackerel are the dominating pelagic species at Hejre and South Arne. The dominating demersal species are whiting, haddock, dab, long rough dab, plaice and grey gurnard, however, cod, lemon sole and sandeel are also relatively common.

Most of the commercially exploited North Sea stocks of the typical fish species encountered in the area around Hejre and South Arne are in good condition and are fished at a sustainable level. However, the cod stock in the North Sea is in a poor condition. Spawning stock biomass is below the sustainable level and the fishing mortality is too high. Cod, plaice, dab, long rough dab, lemon sole, mackerel and whiting spawn in the Hejre and South Arne area.

Seabirds

Due to the relatively low biological production, the waters around Hejre and South Arne are not important for sea birds. During winter some seabirds may be encountered in the area, not because the area is of importance for these species, but because they are distributed over the entire North Sea during winter. The predominant species are fulmar and kittiwake. Additionally, gannet, razorbill and common guillemot occur in low densities. These species are mainly associated with cliffs and offshore islands, and they only occur in the open sea outside the breeding season. They occur in larger densities in other areas of the North Sea with more favourable feeding opportunities than the Central North Sea.

Marine mammals

Grey seals and harbour seals may occasionally be sighted around Hejre and South Arne, although the area is not a core area for these species. Harbour porpoise is the most common cetacean in the North Sea followed by white-beaked dolphin, and minke whale. All cetaceans are listed in Annex IV of the EU-Habitats Directive and is therefore strictly protected. The harbour porpoise is regularly occurring in the waters around Hejre and South Arne.

Protected areas

Hejre and South Arne are situated far from Danish designated Natura 2000 areas. However, ca. 49 km south is a German designated Natura 2000 area: DE 1003-301 Doggerbank. As an extension of this area is the Dutch NL 2008-001 Doggerbank and the UK0030352 Dogger Bank in the UK sector. The basis for the designations of these areas are Harbour porpoise, Grey seal and Harbour seal.

Valuable and vulnerable areas (Særlig Verdifulle Områder (SVO-areas)) is the management framework for marine protected areas in Norway. The closest SVO to Hejre and South Arne is the Sandeel field South. The Sandeel field South is designated as SVO to protect valuable spawning areas for sandeel. The SVO is located ca. 44 km from Hejre. The area is also designated to protect the two seabird species, common guillemot and northern fulmar. Northwest of the Sandeel field South is the Mackerel field SVO, designated as important spawning area for mackerel.

Eight protected areas under the Marine Strategy Framework Directive have been designated in the North Sea. The closest area H is located in the far western part of the Danish EEZ, that is immediately west of Hejre and South Arne. The second closest area G is located to the north-east of Hejre and South Arne. None of the project activities are located within the protected areas.

1.3.2 Human environment

Commercial activities in the western part of the Danish sector of the North Sea include:

- Oil and gas extraction
- Shipping
- Fishery and
- Cultural heritage

There is ongoing oil and gas activities in the central North Sea. The closest existing oil and gas facilities in operation to Hejre and South Arne are the Total operated fields Svend and Harald.

Hejre and South Arne are situated outside shipping routes of merchant vessels.

Hejre and South Arne are also situated in an area with low fishery intensity compared to other areas in the North Sea. Although the fishing intensity is relatively low the area is nonetheless of some significance for the Danish fishery for sandeel. The waters around Hejre and South Arne are without significance for the fishery of other countries.

The only cultural heritage that potentially could exist around and between Hejre and South Arne is ship and plane wrecks. The Palace and Culture Agency has not registered wrecks in the project area.

1.4 Assessment of impacts and environmental risks

1.4.1 Impacts that have been assessed

Below is an overview of operations and conditions that potentially may affect organisms and other environmental features that have been assessed in the EIA. The potential impacts are presented for construction (Figure 1-2), operation (Figure 1-3) and decommissioning (Figure 1-4).

Each of the three project phases involve activities with the potential of impacting the environment. These activities are identified in the first row. Each of these specific activities may impact the environment in different ways, which have been identified in the second row. It is these activities that have been assessed in this EIA.

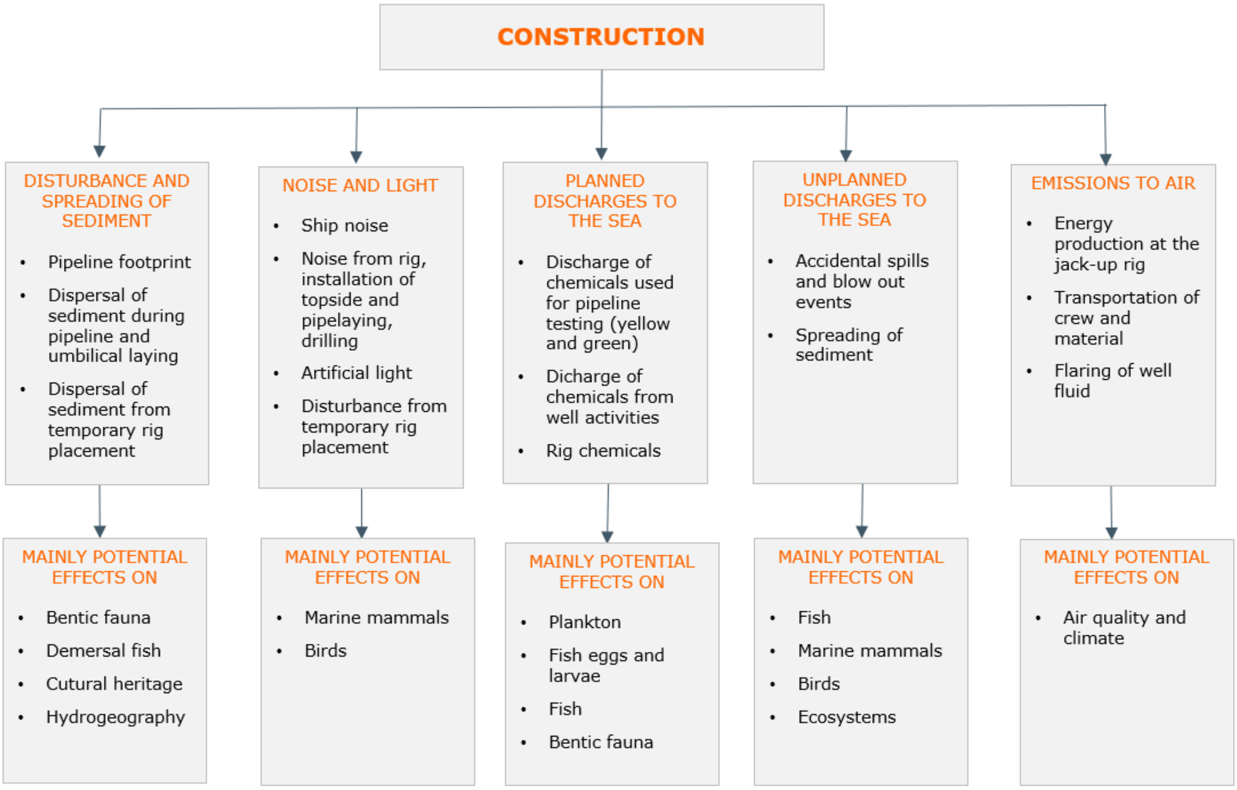


Figure 1-2 Overview of aspects and impacts during the construction phase assessed in the EIA.

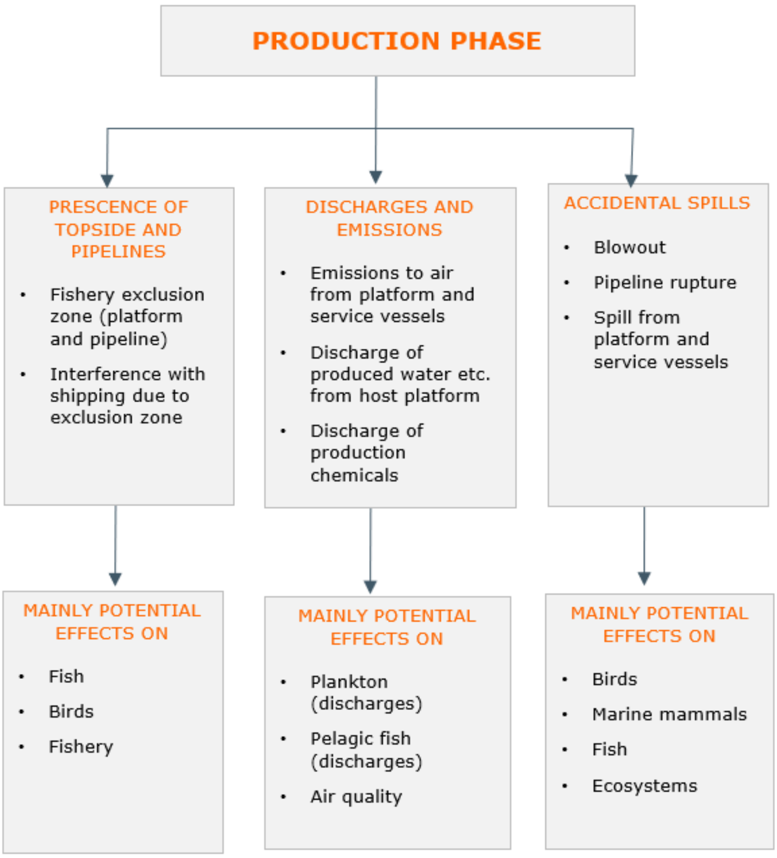


Figure 1-3 Overview of aspects and impacts during the production phase assessed in the EIA.

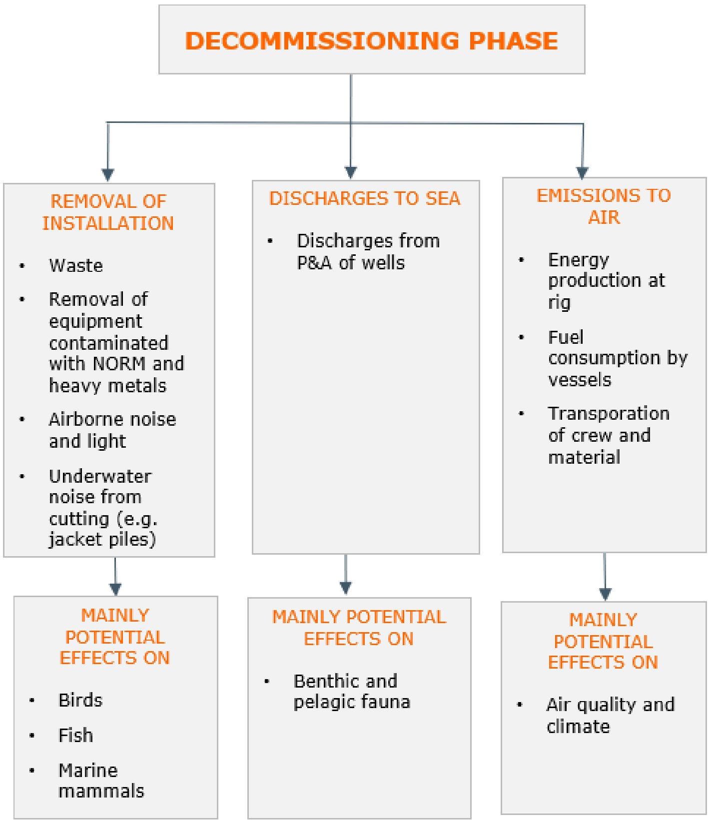


Figure 1-4 Overview of potential impacts during the decommissioning phase assessed in the EIA.

1.4.2 Severity and risk of impacts

Environmental severity and risks of different project activities and incidences has been assessed. Environmental risk is defined as the combination of the severity of and impact of an activity/incidence and the probability that the impact will occur.

The severity of an impact has been defined by combining criteria for:

- The nature of the impact (Positive or negative)
- Extension of the impact (Local, regional, national or international)
- Duration of the impact (Short-term, medium-term or long-term/ reversible vs. irreversible)
- Magnitude of the impact (Small, medium or large).

By combining these criteria in a predefined manner, the following severity categories have been used: Positive impact, no impact, minor impact, moderate impact or major impact.

The probability that an impact will occur has been defined as very low, low, probable, highly probable or definite.

1.4.3 Impacts during construction phase

Drilling, construction and pipelay

Perforation and clean-up of the three existing Hejre wells (HA-1A, HA-2 and HA-4) and repair of an existing well barrier in the HA-5 well will be required. The majority of mud and chemicals used for perforation and clean-up will be used in a closed system and skipped and shipped to shore with the exception of utility chemicals. Modelling shows that effects are within a maximum of 1,500 m from the point of discharge. Furthermore, the discharges are short term batch discharges and thus the impact can be expected to be low.

Drilling of Lunde well will result in discharge of mud, cuttings and chemicals. In the upper part of the well water-based mud (WBM) will be used and mud and cuttings will be discharged to sea. In the lower part of the well oil-based mud (OBM) will be used. OBM mud and cuttings will be shipped to shore for disposal. Modelling shows that effects for a limited amounts of chemicals are within a maximum distance of 500 m from the discharge point except for the BOP control fluid which shows effect in a distance of minimum 5,000 m. However, the discharges are short term and thus the impact can be expected to be negligible to low.

It is expected that the drilling of the Lunde well with water-based mud at the Hejre Field and resulting discharge will only have local, that is within a radius of no more than 200 m, and limited, if any, effects on benthic fauna. If impacts are observed, it is expected that recovery of impacted fauna will take place within 0.5-2 years after the drilling ends, and probably nearer the 0.5 years than the 2 years.

During the construction phase there will be emissions to air in relation to installation activities. Emission related activities primarily include power production on the jack-up rig itself and transportation of crew and material by ship and helicopter. Also, a total of up to 4,800,000 Sm^3 gas from the four wells will be flared during clean-up. The total emissions from the construction activities include around 50,650 tons CO_2, 583 tons NOx and 42 tons SOx. The clean-up flaring comprises approx. 35% of the total CO_2 emissions from the construction activities. The environmental risks related to air emissions is assessed to be negligible as the impact will be minor, it will take place offshore where background levels can be expected to be low, and the activities will occur during a limited period.

During the construction phase machinery, propellers and thrusters of ships will generate underwater noise. The potential impacts have been investigated in terms of the expected generated noise and sound exposure levels harmful to marine life. The impact of noise producing activities will be temporary and local. It is not expected that the project activities at Hejre and South Arne will exceed the sound exposure levels that are harmful to cetaceans and seals. Based on this, it is assessed that underwater noise will have negligible impacts on marine life such as cetaceans and fish.

The potential drilling of Lunde well will add to the noise levels from the construction phase. Data from field studies on impacts on seals of underwater noise during drilling are not available but based on a comparison of measured underwater noise levels from different drilling rigs it is assessed that drilling noise will not affect marine mammals beyond a distance of 100 m from the rig if at all.

Above-water noise generated during the construction phase has the potential to temporarily disturb seabirds locally. However, as this potential impact is expected for a limited number of birds, it is expected that this will in no way impact seabird population.

The rig and vessels used for drilling and construction will increase the artificial light and noise emissions compared to the production phase. It is expected that these activities will take place 24 hours a day and that the work sites will be illuminated during the dark hours. Artificial light may affect seabirds and migrating land birds both positively and negatively. Light may improve foraging during night for seabirds, but there may also be an increased risk of bird collision, since they may be attracted by the light. The risk of bird collision due to light attraction is considered to be minor and the negative impact on bird population due to light is considered to be negligible.

All waste from Hejre and South Arne will be transported to Esbjerg by vessel. The waste will be sorted and sent to approved waste treatment plants. The environmental risk is assessed to be negligible.

The substructure (legs) of the rig to be used for the well perforation and clean-up activities will be temporary located in the water column. The legs are an open lattice structure and are considered too small to have any impact on the hydrography of the North Sea. In addition to that the rig will only be placed in the location temporarily.

Laying and commissioning of pipeline

Prior to the actual laying of the pipeline and power cable, a pre-installation survey and a possible final survey of the expected route will be conducted, including seismic surveys. This will have the potential to impact marine life such as fish and cetaceans. The potential impacts have been investigated in terms of the expected generated noise and sound exposure levels harmful to marine life. The noise generation is expected to be for a relatively short-term period in a local area. In addition, noise levels are not expected to cause harm to cetaceans and seals. Based on this, potential impacts are assessed to be negligible.

The laying of the pipeline and power cable will disturb the seabed via the process of trenching or jetting and cause temporary turbidity in the water, possibly affecting the benthic and pelagic organisms. Such impact will be insignificant and will not affect the spawning stocks or recruitment of species spawning in the area such as cod. Since the area is not a core spawning area for the vulnerable sandeel, the environmental risk of an impact on spawning stock and recruitment of sandeel is assessed to be negligible.

The laying of the pipeline and power cable may potentially bury or damage any ship or plane wrecks along the route. However, the Palace and Culture Agency has no registered findings of wrecks in the vicinity of the project area and the environmental risk is assessed to be negligible. A route survey will be carried out as part of the planning of the exact location of the pipeline.

The trench will naturally backfill within a short period of time. Shortly after the backfilling, benthic fauna will recolonize the affected areas. The impact is therefore considered negligible.

The pipeline will be pressure tested using seawater that has been added a combined solution of corrosion inhibitor, biocide, oxygen scavenger and a fluorescent tracer chemical. Since the discharges take place over a very short period (24 hours), it is assessed that the toxic effects on any eggs or larvae of fish that may be spawning in the area and other plankton organisms will be local, marginal and without measurable impacts on the stocks.

1.4.4 Impacts during production phase

Hejre will be supplied with power from the host South Arne, and thus no power generation will take place at Hejre. At South Arne the power is generated by two 24 MW gas turbines. Also, no flaring will occur at Hejre and the emissions related to flaring at South Arne are expected to remain at the existing level. No emissions will occur at Hejre, apart from emissions related to transport by ship and helicopter in relation to facility maintenance, and the impact of air emissions from flaring and power production at South Arne (CO_2, NO_X and SO_X) is therefore assessed to be low (CO_2) or negligible (NO_X and SO_X).

All waste from Hejre and South Arne will be transported to Esbjerg by vessel. The waste will be sorted and sent to approved waste treatment plants. In case equipment is contaminated with Naturally Occurring Radioactive Material (NORM), it will be sent onshore for cleaning and the NORM waste will be stored at an approved site. The environmental risk is assessed to be negligible.

Potential produced water from the Hejre and Lunde wells will be discharged from the South Arne platform or re-injected into the South Arne reservoir after treatment with the primary objective of keeping the content of oil in the produced water below the OSPAR requirement of 30 mg/l. The current level of discharges of produced water from South Arne are not expected to change after tie-in of Hejre.

Regular maintenance of the Hejre facility and wells will occur over the 20 years lifetime of the facility. Maintenance involves discharge of facility and well service chemicals. The discharge will occur over a period of a few hours per event and with a maximum effect range of 5000 meters.

1.4.5 Impacts during decommissioning phase

The expected lifetime of the Hejre installation is approximately 20 years. The decommissioning of the platform, wells and pipelines/cables is related with a number of potential impacts such as emissions to air from rig activities, discharges from plugging and abandonment (P&A) of wells and possible disturbance by light and of the seabed due to removal of structures.

Emissions to air from decommissioning activities are related to fuel consumption by the jack-up rig, special vessels such as heavy lift vessels and transportation of crew and material by helicopter and boats. The emissions from the decommissioning activities of the Hejre tie-back to South Arne are 53,710 tons CO_2, 906 tons NOx and 69 tons SOx. The environmental risk from emissions is assessed to be negligible.

P&A activities of the Hejre wells will result in discharge of mud and chemicals. WBM, cement, slop chemicals, wash train chemicals and rig chemicals will be discharged. OBM will be used, and mud will be shipped to shore. Modelling shows that effects for a limited amounts of chemicals are within a distance 250 m and up to 5000 m from the discharge point for a few of the wash train chemicals. However, the discharges are short term and thus the impact can be expected to be negligible to low.

The new multiphase pipeline is expected to be emptied and left *in situ*. The emptied and cleaned out pipeline and subsea structures will remain buried below seabed level and will slowly degrade, and the impacts from this during the decommissioning phase will be negligible.

1.4.6 Impacts of accidental spills

Blow-out and pipeline rupture are extremely rare events. However, in case of blowout or pipeline rupture the environmental impacts may be severe. Experience from previous blowouts and oil spills at sea have shown that it is mainly birds, marine mammals, fish and coastal ecosystems that may be affected by large oil spills.

The assessment of the environmental impacts of accidental blowout is based on modelling results representing a worst-case scenario in which no mitigating oil spill response measures are taken.

it is assessed that the environmental risks related to accidental spills during construction and operation of Hejre is Low to Negligible.

The environmental risk of a blowout is generally assessed to be low. This is mainly due to the risk of a blowout being extremely low since double barrier safety systems and mitigative measures are in place on the platform. Drilling activities will be carried out in accordance with best available practice to reduce risk of blowouts. In case of a blowout, the INEOS oil spill contingency plan will be activated, and oil spill combat will be carried out, which will reduce the spreading of oil and mitigate impacts of any spill.

1.4.7 Summary of environmental impacts

The tables below summarise the assessed environmental severities and risks of planned activities during construction phase (Table 1-1), production phase (Table 1-2) and decommissioning (Table 1-3).

Table 1-4 shows the severities and risks during accidental spills.

Table 1-1 Environmental severity and risk of planned activities during the construction phase.

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of discharges to sea			
Discharge of chemicals from rig activities / drill-ing	Insignificant impact	Probable	Negligible
Discharge of pipeline testing chemicals	Insignificant impact	Probable	Negligible
Impacts of air emissions			
Air emissions (NO_X, SO_X)	Minor impact	Low	Negligible
Air emissions (CO_2-eq)	Minor impact	Highly probable	Low
Impacts of underwater noise			
Pre-installation survey – underwater noise	Insignificant impact	Probable	Negligible
Noise from rig	Insignificant impact	Probable	Negligible
Noise from support vessels	Insignificant impact	Probable	Negligible
Noise from drilling activities	Minor impact	Highly probable	Negligible
Impacts of artificial light			
Night foraging opportunities for seabirds	-	Probable	Positive effect
Bird collision due to light attraction	Minor impact	Low	Negligible
Impacts of waste			
Generation of waste	Minor impact	Low	Negligible
Impacts on seabed			
Laying of pipelines – dispersion of sediments	Insignificant impact	Highly probable	Negligible
Drilling of Lunde well	Minor Impact	Highly probable	Negligible
Impacts on cultural heritage			
Damage of wrecks	Minor impact	Very low	Negligible
Impact on hydrography			
Impacts on seabed	Insignificant impact	Low	Negligible
Impacts on water column	Insignificant impact	Low	Negligible
Impacts on benthic fauna	Insignificant impact	Low	Negligible

Table 1-2 Environmental severity and risk of planned activities during the production phase.

Impact	Severity of impact	Probability of impact	Environmental risk
Impacts of discharges to sea (at South Arne)			
Impacts of PW discharges on pelagic organisms	Minor impact	Low	Negligible

Impact	Severity of impact	Probability of impact	Environmental risk
Impacts of air emissions (at South Arne)			
Air emissions (NO_X, SO_X)	Minor impact	Low	Negligible
Air emissions (CO_2-eq)	Minor impact	Highly probable	Low

Table 1-3 Environmental severity and risk of impacts of planned activities during decommissioning.

Impact	Severity of impact	Probability of impact	Environmental risk
Impacts of air emissions			
Air emissions (NO_X, SO_X)	Minor impact	Low	Negligible
Air emissions (CO_2-eq)	Minor impact	Low	Negligible
Impacts of waste			
Generation of waste	Minor impact	Low	Negligible
Impacts from discharge to sea			
Discharge of chemicals from rig activities and P&A activities	Insignificant impact	Highly probable	Low

Table 1-4 Environmental severity and risk of impacts of accidental spills.

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of accidental spills*			
Oil release during blow-out	Major impact	Very low	Low
Gas release during blow-out	Moderate impact	Very low	Negligible
Rupture of pipeline	Minor impact	Low	Negligible

1.5 Socio-economic impacts

The following socio-economic issues have been assessed:

- Changes in fish catches and tourism due to prohibited zones
- Changes in fishing industry and tourism due to accidental oil spill and gas escape
- Changes in employment and tax revenue.

The impact from the project is considered to be negligible or positive. The overall potential loss of fish catches due to the restriction zones around the two pipelines is estimated to 100 tonnes and 156,700 DKK yearly. Compared to the total fish catches in the Nord Sea the decline in fish catches due to the Hejre tie-back to South Arne development project is relatively small.

It is unlikely that a potential oil spill or gas escape will affect the commercial fishery or the tourism sector due to the low probability of the accident to occur.

The overall impact on employment from activities at the Hejre tie-back to South Arne re-development is assessed to be negative, as the platform will be unmanned.

The overall impact on tax revenue from the Hejre tie-back to South Arne re-development is assessed to be positive, but less than the level for Hejre Legacy as the oil and gas resources estimated for the Hejre Legacy were 40 percent larger than what is estimated today based on the knowledge gained during drilling of the wells in 2014-2016.

1.6 Cumulative effects

Potential cumulative effects from the re-development of Hejre fall in three categories. Impacts from construction and operation of the tie-back project may interact with:

- Impacts from other oil and gas activities,
- Impacts from neighbouring platforms and existing operations
- Impacts from other activities such as wind farms, cable and pipeline installation and fishery and shipping in the region.

Potential cumulative effects from the Hejre platform (own production) will have a low likelihood to occur during the construction phase, with emission to air and discharges from the platform as closest platform is more than 20 km from Hejre.

At the South Arne platform, discharges of produced water are not likely to have potential cumulative effects as the distance to other platforms with similar discharges are too far to influence each other and the discharges from South Arne are very limited due to high produced water reinjection.

There is no knowledge of any planned simultaneous activities by INEOS E&P A/S or operators nearby. Cumulative impacts from other activities are not expected.

1.7 Cross border impacts

Mainly local effects from the project are expected during normal operation but in relation to accidental situations as blow outs and spills transboundary effects can occur.

Cross border impacts have furthermore been described in detail in a specific ESPOO document.

1.8 Natura 2000 areas

The EU Habitats Directive (Council Directive 92/43/EEC of 21 May 1992) specifies natural habitats and wild fauna and flora for which the member states must ensure protection. The species and nature habitats to be protected are specified in the Annexes of the directive. Annex IV lists species of animal and plants in need of particularly strict protection. Of the marine mammals encountered in the North Sea, all species of cetaceans are listed in Annex IV. However, only harbour porpoise, white-beaked dolphin and minke whale are encountered regularly in the Danish part of the North Sea, and only the harbour porpoise is regularly spotted in the development area for the Hejre tie-back to South Arne.

Hejre and South Arne are situated far from Danish designated Natura 2000 areas. However, around 49 km south of the field is a German designated Natura 2000 area: DE 1003-301 Doggerbank. Part of the basis for the designation of this area is the harbour porpoise.

Since the nearest Natura 2000 area is 49 km away and since there is not documented negative impact on cetaceans (Annex IV species) from the operations included within this EIA, impacts on Natura 2000 sites or Annex IV species are not expected.

1.9 Marine Strategy Framework Directive

Good Environmental Status in the marine environment is described by 11 descriptors defined in the Marine Strategy Framework Directive (MSFD). MSFD is implemented in Danish marine strategy act, which is setting the framework for the management of the marine areas in Denmark.

A summary of the potential impacts on the 11 descriptors is provided in the table below (Table 1-5).

Eight areas in the North Sea have been designated as marine protected areas according to the Marine Strategy Framework Directive. The closest is area G to the west of the project area, and the second closest is area H east of the project area. This project has no activities within these protected areas.

Table 1-5 Potential impacts on the 11 descriptors given by the Marine Strategy Framework Directive is summarised below. The environmental risk of preventing or delaying good environmental status is assessed.

Descriptor	Assessment of potential impact
D1 **Biodiversity**	Potential impact on species and habitats includes impacts from airborne and underwater noise, light, spreading of sediment, physical disturbance of seabed, planned discharge, accidental spill of oil and chemical and risk of blowout. The potential impacts are assessed either to be negligible or no impact The impact on the environmental targets for descriptor 1, *biodiversity*, will not prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D2 **Non-indigenous species**	International vessels can introduce non-indigenous species though marine fouling and discharge of ballast water. The risk of introduction of new non-indigenous species is considered low. Due to the low risk of a major impact on the environmental targets for descriptor 2, *non-indigenous species*, it is assessed that the project will not prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D3 **Commercially exploited fish stocks**	Commercially exploited fish stock can potentially be affected by physical disturbance, spreading of sediment, underwater noise, planned discharge of chemicals and unplanned oil spill (blowout). It is assessed that the potential risk of affecting fish stocks is negligible. The potential impacts on the environmental targets for descriptor 3, *commercially exploited fish stocks*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D4 **Marine food webs**	Marine food webs can potentially be affected by physical disturbance of the seabed, spreading of sediment, underwater noise, artificial light, planned discharge of chemicals and unplanned oil spill (blowout). The potential impacts on the environmental targets for descriptor 4, *Marine food web*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D5 Eutrophication	There will be no impact on descriptor 5, *eutrophication* and it is assessed that the project will not prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.

Descriptor	Assessment of potential impact
D6 **Sea floor integrity**	The seafloor integrity will be temporarily affected during pipelay due to physical disturbance of the seabed and by the rig activities for well drilling, perforation and clean-up activities. The pipelines will be buried >1 m below the seabed and the integrity of the seabed is expected to recover few years after pipelay. It is assessed that the potential risk of affecting the sea floor integrity is negligible. The potential impacts on the environmental targets for descriptor 6, *sea floor integrity*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D7 **Alteration of hydrographical conditions**	The hydrography may be impacted by the presence of the rig for well perforation and clean-up activities. The project will not alter hydrographical conditions. The potential impacts on the environmental targets for descriptor 7, *alteration of hydrographical conditions*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D8 Contaminants (concentrations and species health)	Discharge of produced water in addition to drilling and production chemicals will not exceed threshold values set in the Marine Strategy II. It is assessed that the potential risk of affecting the contaminants is negligible. Acute pollution events include accidental spill and blow-out. These are extremely rare events. The risk of accidental spill and blow-out is furthermore prevented through a number of mitigating measures. The potential impacts on the environmental targets for descriptor 8, *contaminants*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D9 **Contaminants in fish and other seafood for human consumption.**	Measurable contaminants in fish and other seafood will only occur as a result of major oil spill. It is assessed that the potential risk of affecting the contaminants in fish and other seafood for human consumption is negligible. The potential impacts on the environmental targets for descriptor 9, *contaminants in fish and other seafood for human consumption*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D10 Marine litter	Littering will be prohibited on the platform and all waste are collected, sorted and send to shore. It is assessed that the potential risk of affecting the marine litter is negligible. The potential impacts on the environmental targets for descriptor 10, *marine litter*, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D11 **Underwater noise**	During construction it is expected that the majority of noise generated will be low frequency noise although impulse noise will be emitted during the pre-installation survey of the pipeline. In addition, underwater noise will be generated by the potential drilling of the Lunde well. The project activities at Hejre and South Arne is not expected to exceed the sound exposure levels that are harmful to cetaceans and seals. Noise levels will not exceed the thresholds for PTS set in the Marine Strategy II. It is assessed that the potential risk of affecting the underwater noise is negligible. The potential impacts on the environmental targets for descriptor 11, underwater noise, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.

1.10 Monitoring programme

A monitoring programme in line with regulatory requirements is already in place for the South Arne including continuous monitoring in relation to discharges to sea and emissions to air. A similar monitoring programme for Hejre will be set up and agreed with relevant authorities based on requirements in legislation and permits.

For South Arne a risk-based approach for produced water management in alignment with OSPAR and Danish authority guidelines is already in place. The modelling of the environmental risk of discharges will be updated to include the Hejre tie-in latest 6 months after the discharge of produced water begins. The modelling of environmental risk will be updated at least every 5 years according to the guidelines.

A seabed monitoring programme covering the Danish part of the North Sea takes place every three years. This has traditionally included seabed sampling for monitoring the environmental status of the seabed around the oil and gas installations.

1.11 Project design and impact mitigation

1.11.1 Environmental management

In general, a range of parameters are applied through INEOS's environmental management system including proper working procedures to minimize the environmental impact from operation, using BAT and BEP (best available technology and best environmental practice) in the process of selecting the technical solutions. It is considered a general INEOS practice to have proper contingency plans in place with established working procedures to minimize the effects of incidents or to effectively collect spills, should an incident happen. INEOS also systematically register and analyse incidents and near-miss events to prevent unintended environmental impacts in the future.

1.11.2 Project adaptations

Other, more specific measures will be considered for the individual installations as summarised below:

- Operational excellence: Minimizing the environmental impact by focusing on stable production, reduction of slugging and limiting the number of unplanned shutdowns.
- Evaluation and implementation of initiatives at Hejre to reduce emissions to air and thereby the climate impact as much as possible:
    - Installation of electrical driven crane instead of diesel driven crane if feasible.
    - Reducing emissions to air as part of the energy efficiency management system. Potential savings in energy consumption and emissions to air evaluated on a yearly basis.
- Limiting the impact on marine mammals in relation to underwater noise from pipelay and decommissioning activities by evaluating noise impact from equipment to be used and by use of passive acoustic monitoring equipment and marine mammal observers during noise-generating activities.
- Limiting the risk of introducing non-indigenous species from vessels by exchange of ballast water in open waters, by implementing a ballast water treatment system or by regular removal of marine fouling from the vessels sides prior to departure. See section 19.7 for further information.

1.11.3 Mitigation measures

All potential impacts are assessed to be either 'insignificant' or 'low, and no possibilities for effectively reducing the impacts further have been identified.

For activities generating underwater noise, the project will adhere to "Standard terms for preliminary investigations at sea" from the Danish Energy Agency (2018).

2. Introduction

INEOS E&P A/S is investigating the possibility to re-develop and subsequently operate the Hejre field in the Danish Sector of the North Sea. The Hejre field was previously operated by DONG E&P A/S. The intended re-development entails a development solution with a Hejre tie-back to South Arne using the existing Hejre facilities.

The partners in the Hejre licence (5/98) are:

- INEOS E&P A/S (operator) 60 %
- INEOS E&P (Norge) Petroleum DK AS 25 %
- INEOS E&P (Petroleum Denmark) ApS 15 %

INEOS E&P A/S has commissioned COWI to carry out an environmental impact assessment (EIA) for the re-development, operation and decommissioning of the Hejre field. The present report documents the EIA process, findings and conclusions. The EIA has been carried out in compliance with the Danish EIA regulation (Consolidation Act No. 4 of 03/01/2023).

The report also covers a screening of the project's potential impacts on Natura 2000 sites and on Annex IV species) according to the Offshore Impact Assessment Order (Order No. 1050 of 27/06/2022) and an assessment of impacts on the environmental targets according to the Marine Strategy Act (Act no. 1161 of 25/11/2019).

The original Hejre concept ('Hejre Legacy') was approved by the Danish Energy Agency (DEA) after the completion of an EIA process (DONG E&P A/S 2011). The platform steel jacket and pre-drilling wellhead deck was installed in 2014. The topside fabrication contract was however terminated in 2016 due to technical difficulties and significant delays. Drilling continued as per original scope and was completed in 2016. A total of 5 HPHT wells were drilled of which 3 are suitable for being part of the Hejre field re-development. The 3 wells are ready for production following production liner perforation and well clean-up.

As the Hejre field re-development via tie-back to South Arne extends outside the previously approved project scope, an updated EIA report is required according to Act No. 4 of 03/01/2023 on environmental assessment of plans, programs and specific projects (EIA). The re-development project is covered by Annex 1, point 29) *Any change or extension of projects listed in this Annex, provided that such change or extension itself meets the threshold values, if any, set out in this Annex*.

The present EIA report thus assesses the environmental impacts of all elements and activities relating to the full re-development project. As the re-development project to a large extent will build on already existing elements (e.g. the Hejre jacket, the 3 Hejre HPHT wells and the South Arne installations) these will be described briefly where relevant to ensure general understanding of the concept and its potential environmental impacts.

2.1 The Hejre field

The Hejre field is located within licences 5/98 and 1/06 in the Danish sector of the North Sea, approximately 300 km offshore from the Danish west coast, ref. Figure 2-1. The licenses cover an area of approximately 114 km² in total.

The field is a High-Pressure High-Temperature (HPHT) oil field with associated gas and comprises of several large segments bounded by faults. Within the main Hejre field, three of the main segments have been penetrated by exploration/appraisal and development wells, and the resources are considered proven. To date, 7 wells (including discovery well, Hejre-1 and appraisal well, Hejre-2) and 2 side-tracks (HA-1A and HA-3A) have been drilled.

The Hejre jacket is located at the position 6.234.174,9 mN, 559.510,8 mE (reference UTM zone 31 on ED50 Datum) at approximately 68 m water depth.

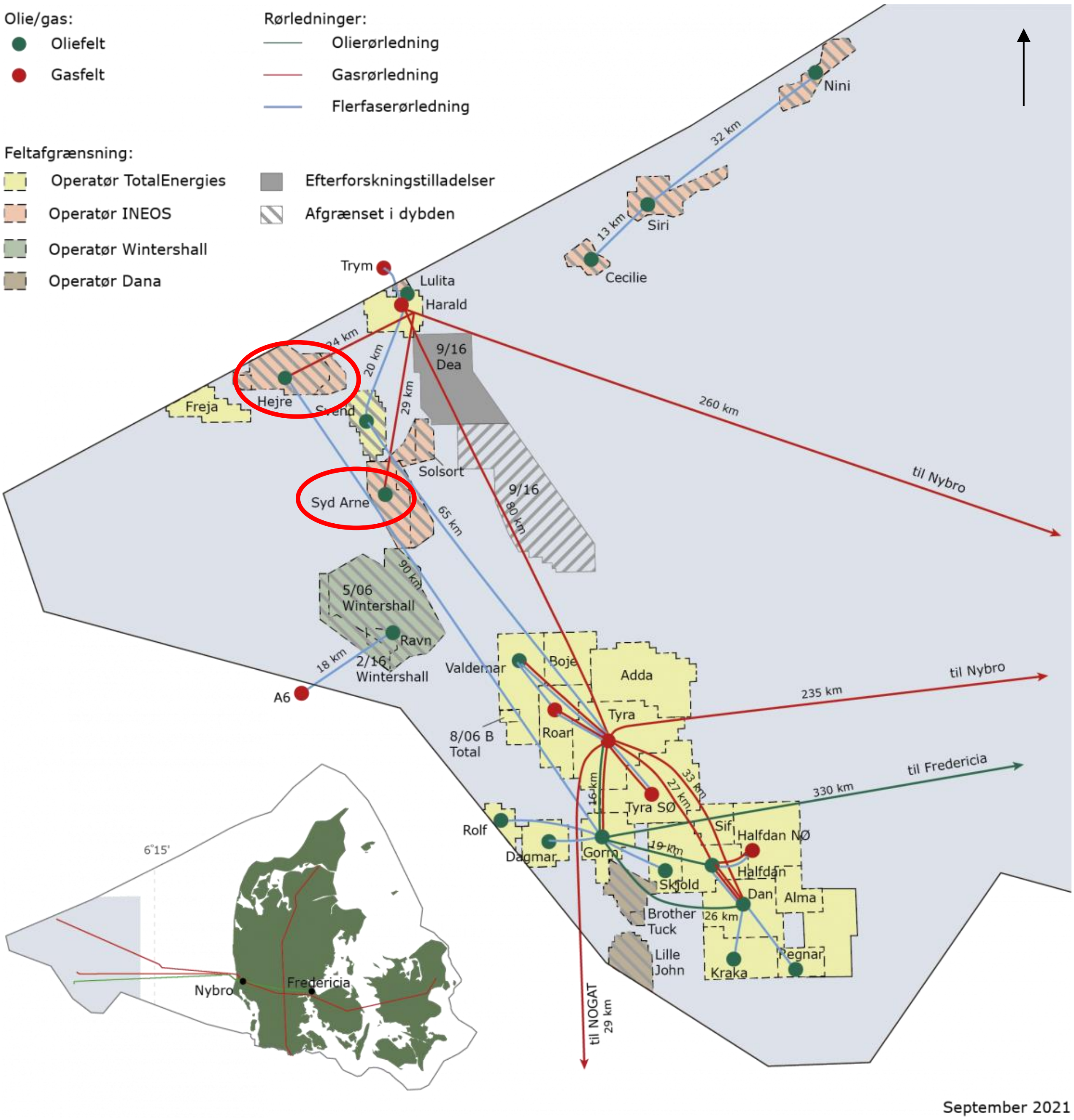


Figure 2-1 Location of the Hejre field, South Arne and surrounding infrastructure in the Danish sector of the North Sea.

2.2 Original Hejre development concept

The Hejre Legacy development concept was based upon a stand-alone, integrated, live oil production plat-form with 5 HPHT production wells drilled consecutively with the possibility of drilling up to 12 wells in total.

Hejre Legacy also included two new pipelines: a 90 km oil export pipeline from Hejre to Gorm E and a 24 km gas export pipeline from Hejre to the South Arne Harald WYE connection on the South Arne to Nybro pipeline. From Gorm E the oil would be exported through existing infrastructure to the oil terminal in Fredericia. The original project is shown in Figure 2-2 below:

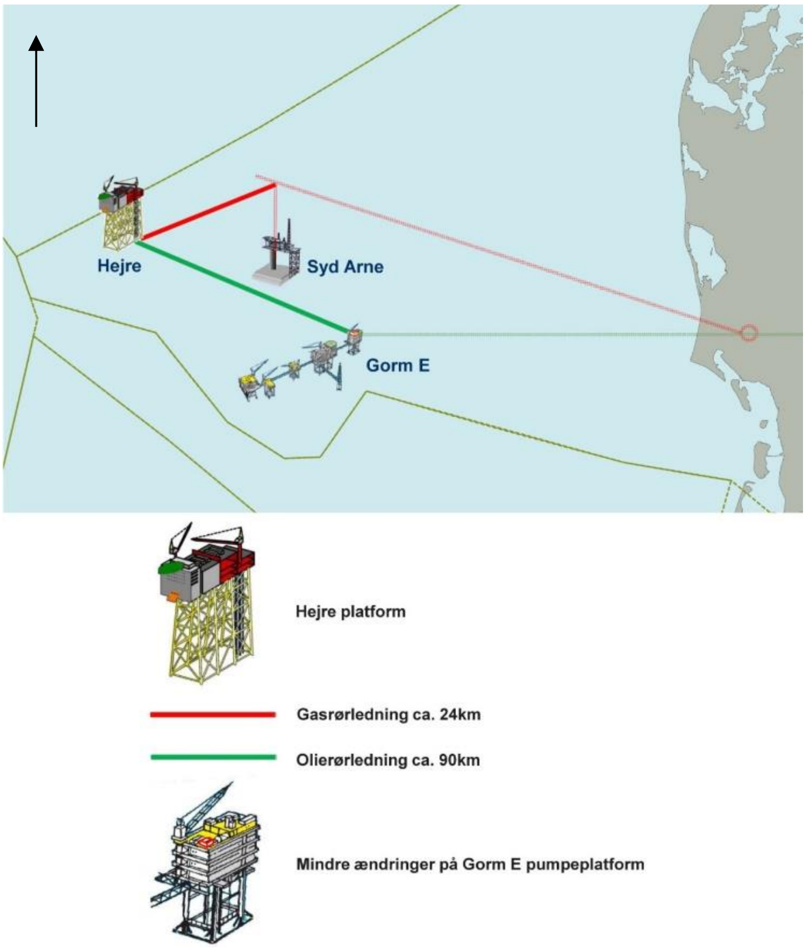


Figure 2-2 Overview of the original Hejre concept presented in the Hejre EIA, DONG E&P A/S 2011. Not to scale.

The platform steel jacket and the pre-drilling wellhead deck (PDWD) was installed in 2014. Drilling was completed in 2016 and at present 3 HPHT wells are ready for production, following perforation and clean-up.

The in-place weight of the Hejre jacket after installation was 8,114 tons and for the PDWD the gross in-place weight was 809 tons. In addition, 16 piles were installed, 4 at each corner leg, to secure the jacket to the seabed. The 16 piles had a total weight of 3,265 tons

2.2.1 Project phases

2.2.1.1 Jacket and PDWD EPC Phase. February 2012 to June 2014

On 27 February 2012 Technip France signed the EPC contract to Engineer, Procure and Construct (EPC) the Hejre Platform. Jacket and PDWD Fabrication denoted as first steel cut started 03 April 2013 and finished 17 May 2014 where DONG Energy took delivery of the jacket and PDWD. The jacket and PDWD has been constructed by Heerema Fabrication Group (HFG) in Vlissingen yard in Holland.

The jacket and PDWD was installed by Heerema Marine Contractors (HMC) in May/June 2014.

Key dates are summarized in Table 2-1 below.

Step	Start Date	End Date	By
Fabrication	03/04/2013	17/05/2014	By HFG in Vlissingen Yard
Load-Out	21/04/2014	22/04/2014	By Mammoet on skid ways
Transportation	20/05/2014	22/05/2014	By HMC on H-627 launch barge
Launch	23/05/2014	23/05/2014	By HMC on H-627 launch barge
Upending and Set-Down	24/05/2014	24/05/2014	By HMC with Hermod SSCV
Pile installation	24/05/2014	02/06/2014	By HMC with Hermod SSCV
Pre drilling deck installed	02/06/2014	04/06/2014	By HMC with Hermod SSCV

Table 2-1 Jacket Fabrication, Transportation and Installation Dates

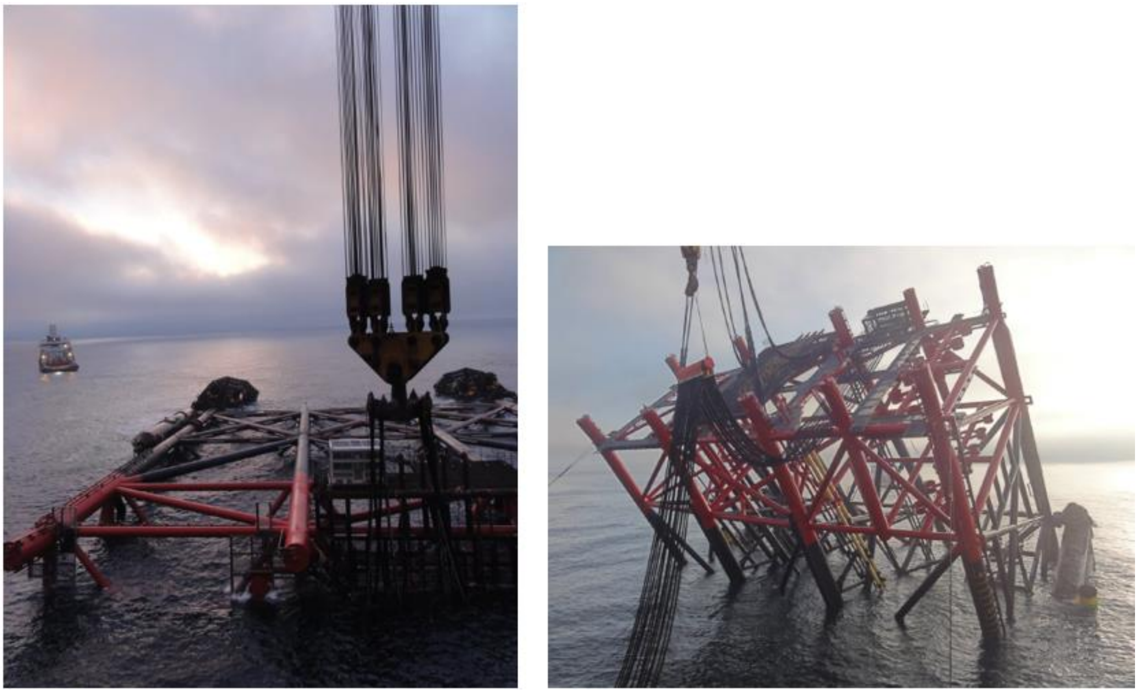


Figure 2-3 Jacket upending and set down

After Jacket upending and set down, the piles were installed by driving the piles (Figure 2-4) into the ground using a hammer (Figure 2-4). The pile driving was commenced at low energy to for any marine mammals to move away from the noise source.

Figure 2-4 Pile (left) and hammer for pile driving (right)

2.2.1.2 Hejre well drilling phase. June 2014 to September 2016.

Drilling of wells by Mærsk Resolve commenced immediately after jacket installation and took place until September 2016 where 5 wells (HA1 to HA5) had been completed.

Figure 2-5 Hejre field well drilling by Mærsk Resolve, summer 2015

Within this period the Mærsk Resolve drilling rig supplied the necessary power, data communication, life-saving equipment, accommodation etc. for drilling and the necessary manning.

2.2.2 Impact from existing Hejre installations

As there has not been any production from the Hejre field, not has any installation, construction, modification or drilling activities taken place since completion of the drilling in 2016, there are no emissions, waste generation or discharges related to the Hejre field as is today.

Only remaining impact from the installation of the Hejre jacket is the physical footprint of the Hejre jacket on the seabed (roughly 40x60 meters), but there are no current disturbance of the seabed taking place.

2.3 Hejre tie-back to South Arne concept

The Hejre tie-back to South Arne development concept comprises a new Hejre topsides capable of sending multiphase flow to the existing South Arne Main platform (host), where processing of the multiphase will take place. The structure and the layout of the new Hejre topsides are designed to fit the existing jacket structure and pre-drilling module.

The concept is based on using existing infrastructure and to use available capacity at South Arne. The production from Hejre will be exported to South Arne using a new 30 km multiphase pipeline (wet insulated or pipe-in-pipe) from Hejre to South Arne.

After processing at South Arne, the oil and gas will be exported using the existing infrastructure on the South Arne platform. The stable oil will be temporarily stored in the platform's Gravity Based Structure (GBS) from where it will be offloaded by shuttle oil tankers and transported to shore. The gas will be exported through the existing export pipeline from South Arne to Nybro.

Figure 2-6 below shows an overview of the concept.

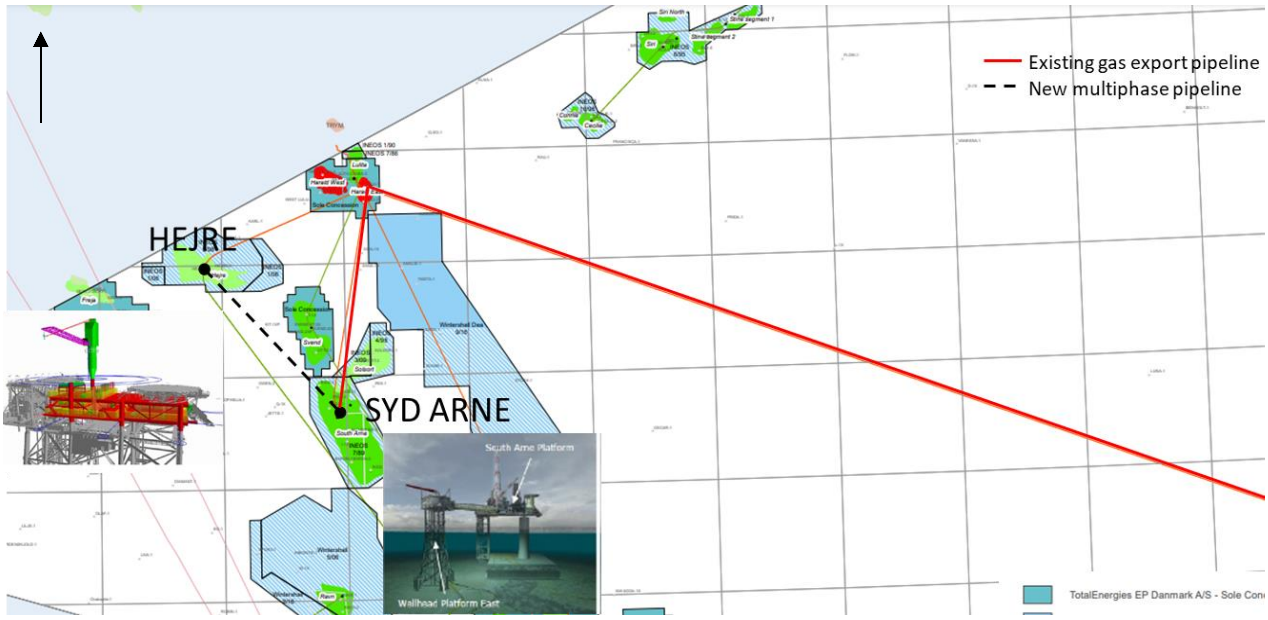


Figure 2-6 Overview of the concept for the Hejre tie-back to South Arne development project.

2.4 Scope of EIA

This EIA provides a technical description of the project, a presentation of the environmental impacts from the construction, production and decommissioning phases, planned environmental monitoring and if relevant mitigating measures.

This EIA includes an environmental impact assessment of the re-development of the Hejre field including an assessment of the necessary modifications at South Arne, processing and export of oil and gas from South Arne, as well as the decommissioning of the Hejre field.

In short, the EIA covers the following processes:

- Construction, operation, maintenance and decommissioning of a Hejre remotely controlled unmanned topside incl. riser.

- Installation, operation, maintenance and decommissioning of interfield multiphase pipeline and power cable with fibre optic from Hejre to the South Arne.
- Perforation and clean-up of 3 production wells at the Hejre field. Barrier repair of well HA-5.
- Drilling of a new well; Lunde (optional)
- Modifications of the South Arne Well Head Platform East (SA WHPE) including new tie-in module with a sludge catcher, multiphase pig receiver and new riser.
- Tie-in scope at the South Arne main platform including new NGL injection booster pumps.
- Decommissioning

All potential impacts resulting from the tie-back activities are assessed in regard to the criteria's given in Chapter 7. Impacts from activities or components of the Hejre Legacy project that are not part of the Hejre tie-back to South Arne project are not relevant to this EIA and are not described further.

To ease the understanding of the changes between the new tie-back concept described in the present Hejre EIA compared to the stand-alone concept described in the Hejre Legacy EIA from 2011, an overview has been prepared in Table 2-2.

Table 2-2 An overview of the Hejre Legacy concept compared with the new Hejre tie-back to South Arne concept.

Hejre Legacy Concept	**Hejre tie-back to South Arne Concept**
Drilling of 5 production wells including completion. Production test included. The possibility to drill up to 12 wells included.	Perforation and clean-up of 3 wells. Barrier repair of well HA-5. Drilling of Lunde well (optional).
Installation of jacket.	No installation of jacket. Jacket already installed as part of Hejre Legacy. Modification of the jacket to remove the temporary items left over from the original installation in 2014.
Installation of topside including: Living quarter for max POB of 70 Well head area Process area (see details below) Helideck Flare Two cranes – diesel driven Emergency fire water system Expected weight 15.000 ton	Installation of topside including: Unmanned remotely controlled New riser Helideck Shelter One crane – electrically driven Emergency fire water system Expected weight 2.100 ton
Pipelines: New oil export pipeline from Hejre to Gorm E New gas export pipeline from Hejre to South Arne Harald WYE on the South Arne to Nybro gas pipeline	Pipelines: New 30 km multiphase pipeline from Hejre to South Arne Use of existing gas pipeline from South Arne to Nybro. Power cable from South Arne to Hejre
Modifications at Gorm E: New riser Recycling cooler Pig receiver Fiscal metering Modifications to existing piping and manifold	Modifications at South Arne: New tie-in module at the South Arne WHPE including slug catcher, multiphase pig receiver and new riser. NGL injection booster pumps at South Arne main platform.
Average manning expected: POB 29	Average manning expected: Unmanned. At South Arne crew transportation in relation to maintenance expected as a part of normal operations.
Daily production: Oil: 35.000 BOPD Sales gas: 76 MMscfd Produced water max: 10.000 BPD	Daily production (uncapped by host capacity): Oil: Maximum 35.000 BOPD Sales gas: 57 MMscfd Produced water max: 2.000 BPD

Processing at Hejre: Processing of oil, gas and water Cleaning and discharge of produced water. Utilizing possibility to export produced water to shore. Power production: 3 dual fuel turbines with output of 5.5 MW each (only two operating at same time) Pressure relief by flare system	No processing at Hejre
Maintenance of 5 wells	Maintenance of 4 wells (3 Hejre and 1 Lunde)
Decommissioning	Decommissioning

2.5 Time schedule

The proposed time schedule for the Hejre field re-development up until EXECUTE (Construction) is illustrated below in Figure 2-7. The subsequent Operations phase (approx. 20 years) and the future Decommissioning phases are not shown in the schedule.

Offshore pipeline installation work is expected to start in Q2 2026, and pipeline hook-up, installation of the new Hejre topsides, modifications at South Arne and perforation and clean-up of the Hejre wells is expected to take place in Q2 and Q3 2027. First oil is expected in Q4 2027.

The timing for the potential drilling of the Lunde well is also not shown in the schedule but will take place after work on the existing Hejre wells is completed – either directly after or in a later campaign.

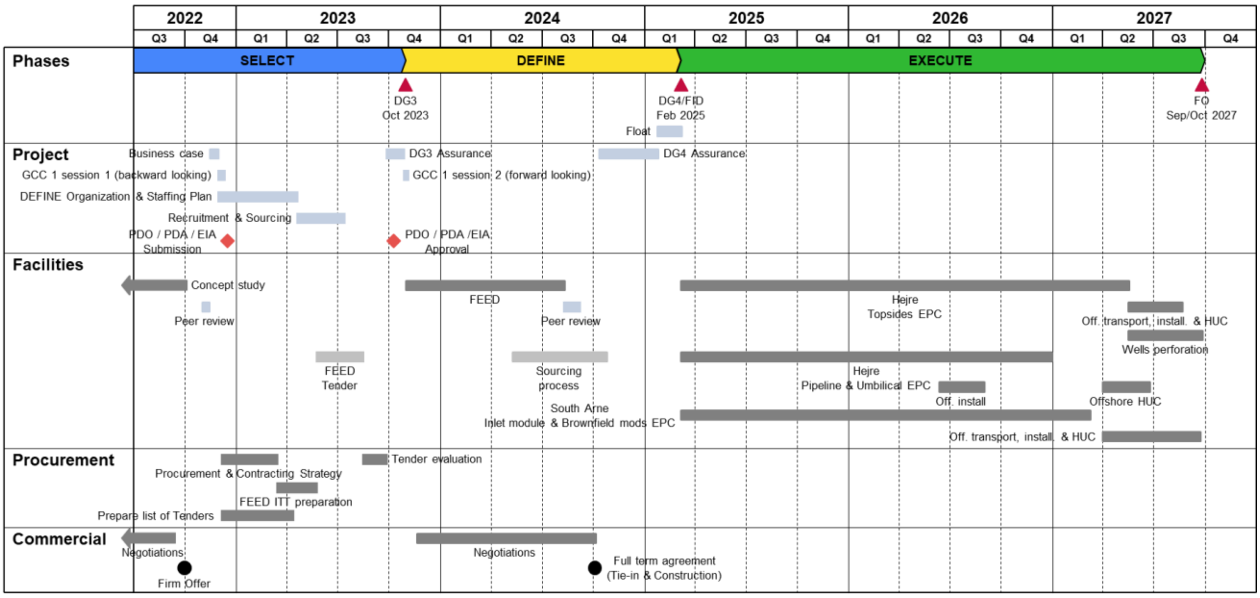


Figure 2-7 High-level time schedule for the Hejre field re-development.

2.6 Abbreviations

The following abbreviations are used in the document:

Abbreviation	Explanation
BAT	Best Available Technique
BBL	Barrel
BEP	Best Environmental Practice
BLP	Bridge Linked Platform
BOP	Blow-Out Preventer
BOPD	Barrels of Oil Per Day
BPD	Barrels Per Day
BRL	Background Reference Level
CH_4	Methane
CO_2	Carbon diOxide
DCE	Danish Centre for Environment and Energy
DEA	Danish Energy Agency
DEPA	Danish Environmental Protection Agency
DSV	Diving Support Vessel
DUC	Danish Underground Consortium
DW	Dry Weight
EC	European Council
EIA	Environmental Impact Assessment
EnS-Index	A quantification of environmental status based on descriptors in the Marine Strategy Framework Directive
ES	Environmental Status
ERL	Effect Range Low
ETS	Emission Trading System
EU	European Union
FPSO	Floating Production Storage and Offloading
GBS	Gravity Based Structure (the oil storage tank at South Arne)
GES	Good Environmental Status
GOR	Gas Oil Ratio
HELCOM	Helsinki Commission
HLV	Heavy Lift Vessel
HOCNF	Harmonised Offshore Chemical Notification Form
HPHT	High-Pressure High-Temperature
HUC	Hook-Up and Commissioning
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Seas
IMO	International Maritime Organization
JNCC	Joint Nature Conservation Committee
MMSCFD	Million Standard Cubic Feet per Day
MPU	Mobile Production Unit
MSFD	Marine Strategy Framework Directive
mT	Metric Tonnes
NGL	Natural Gas Liquids

NH^{4+}	Ammonia
nmVOC	Non-Methane Volatile Organic Compounds
NORM	Naturally Occurring Radioactive Materials
NOx	Nitrogen Oxides
NPD	Naphthalene, C1-Naphtalene, C2-Naphtalene, C3-Naphtalene, C1-Phenantrene, C2-Phenantrene, C3-Phenantrene, Dibenzothiophene, C1-Dibenzotiophene, C2-Dibenzotiophene, C3-Dibenzotiophene
OCP	Organo Chlorine Pesticides
OSCAR	Oil Spill Contingency and Response
OSPAR	OSlo PARis convention
OSRL	Oil Spill Response Limited
P&A	Plugging and abandonment (the process for decommissioning of wells)
PAH	Polycyclic Aromatic Hydrocarbons
PBDE	Poly Brominated Diphenyl Ethers
PCB	Poly Chlorinated Biphenyls
PEC	Predicted Environmental Concentration
PLONOR	Pose Little Or NO Risk
PNEC	Predicted No-Effect Concentration
POB	Persons On Board
PPB	Parts Per Billion
PPM	Parts Per Million
PTS	Permanent Threshold Shift
PUQ	Process, Utility and (living) Quarter
RBA	Risk Based Approach (method of assessment of discharges of produced water according to OSPAR)
ROV	Remotely Operated underwater Vehicle
SA	South Arne
SAC	Special Areas of Conservation (under the EU Habitats Directive)
SAL	Single Anchor Loading
SCANS	Small Cetacean Abundance in the North Sea
SEL	Sound Exposure Levels
SINTEF	Stiftelsen for INdustriell og TEknisk Forskning
SO_x	Sulphur Oxides
SPA	Special Protection Area (under the EU Birds Directive)
SPL	Sound Pressure Level
TA	Temporary Abandonment
TD	Total Depth
TEL	Target Effect Level - a low range for potential toxicological effect
THC	Total Hydrocarbons
TL	Transmission Losses
TTS	Temporary Threshold Shift
VOC	Volatile Organic Compounds
WHP	Well Head Platform
WHPE	(South Arne) Well Head Platform East
WHPN	(South Arne) Well Head Platform North

3. National and international legislation

3.1 Environmental impact assessment

An EIA is required in order to obtain an approval for offshore exploration and production of oil and gas and certain industrial plants. This requirement is set forth in Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment. The directive is implemented in Danish legislation through the:

- Subsoil act (Consolidation act no. 1533 of 16/12/2019)
- EIA act (Consolidation act no. 4 of 03/01/2023)
- Offshore impact assessment order (Executive order no. 1050 of 27/06/2022)

The present EIA is compliant with the above-mentioned legislation.

The public hearing process for offshore projects is as follows:

The project owners' application, the environmental impact assessment report will be available on the website of the Danish Energy Agency (DEA), and the public will have the opportunity to comment on the EIA through an eight-week public hearing phase. After the hearing period the DEA will decide if a permit for the project will be granted.

Decisions regarding the project and the EIA will be published on the DEA website, and any party with relevant and individual interests in the decision may file a written complaint on environmental issues to the Energy Board of Appeal within four weeks of the publication.

3.2 Protection of the marine environment

3.2.1 Discharges to sea

The Marine Environment Act (Consolidation act no. 1165 of 25/11/2019) regulates discharges and emissions from platforms.

The associated regulation on discharges to the sea of compounds and materials from certain marine facilities (Executive order no. 394 of 17/7/1984) defines the information needed to obtain a permission for discharges.

The discharge permit regulates discharge of oil and chemicals to the sea and, among others, define requirements on:

- Maximum oil concentration in discharged produced water
- Limitations for total amount of oil to be discharged
- Monitoring programme for oil concentration in discharge water
- Continuous control of total oil discharge
- Classification of offshore chemicals

- Use and discharge of offshore chemicals depending on classification (explained below).
- Regular reporting on discharge of oil and chemicals

3.2.2 Classification of offshore chemicals

Chemicals are classified according to the DEPA colour coding system, which follows the OSPAR classification (substitution, ranking and PLONOR) and relates to the environmental hazard of offshore chemicals. The codes are:

- **Black** chemicals are the most critical and not acceptable to be used offshore.
- **Red** chemicals are environmentally hazardous to such an extent that they should generally be avoided and be substituted where possible. Substances that are inorganic and highly toxic (EC/LC < 1 mg/l) and/or have a very low biodegradation (< 20% in 28 days) are classified as red. Substances that meet more than one of three criteria of low biodegradation (< 60% in 28 days), high bioaccumulation (log Pow ≥ 3 and MW < 700) or toxicity (EC_{50}/LC_{50} < 10 mg/l) are also classified as red.
- **Yellow** chemicals exhibit some degree of environmental hazard, which in case of significant discharges can give rise to concern. Substances that meet one of three criteria of low biodegradation (< 60% in 28 days), high bioaccumulation (log Pow ≥ 3 and MW < 700) or toxicity (EC_{50}/LC_{50} < 10 mg/l) are classified as yellow.
- **Green** chemicals are considered not to be of environmental concern (so-called PLONOR-substances that "Pose Little Or NO Risk" to the environment) and also includes organic substances with EC_{50}/LC_{50} > 1 mg/l, acids and bases categorized as green chemicals.

3.2.3 Regulation of non-indigenous species

Regulation to prevent introduction of non-indigenous species through ballast water regulated through Executive order no. 733 of 19/05/2022 about handling of ballast water and sediments from ship ballast tanks. In addition, introduction of non-indigenous species through ballast water is regulated through the following international conventions and declarations:

- IMO's Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (known as the London Convention 1972) including the 1996 Protocol which became effective in 2006.

3.2.4 Emissions

Air emissions from platforms, drilling rigs and ships are regulated in the in the regulation on prevention of air pollution from ships (Notification no. 9840 of 12/04/2007) and by The Marine Environment Act (Consolidation act no. 1165 of 25/11/2019).

In addition, air emissions from platforms are regulated in the regulation on certain air polluting emissions from combustion installations on offshore platforms (Executive order no. 1449 of 20/12/2012) and in the regulation on prevention of air pollution from ships (Notification no. 9840 of 12/04/2007).

Order of solid and liquid content of sulphur in fuels (Order no 228 of 06/02/2022) regulates the amount of sulphur allowed in ship fuel and thus indirectly impact the emission from ships.

3.3 Offshore safety

In order to prevent and mitigate pollution from spills to the sea, contingency plans must be established for offshore platforms that carry out exploration, production and transport of oil hydrocarbons in accordance with the Marine Environment Act (Consolidation act no. 1165 of 25/11/2019 § 34a). The mandatory content of such plans is stipulated in the related executive order on emergency preparedness in the event of pollution of the sea from oil and gas plants, pipelines and other platforms (Executive order no. 909 of 10/07/2015).

In addition, the Offshore Safety Act (Statutory Order no. 125 of 06/02/2018 §45) requires the preparation of contingency plans to prevent and counteract the consequences of major accidents, including major environmental incidents, at the before mentioned facilities.

3.4 Waste

3.4.1 Waste segregation and handling

Waste from the Hejre tie-back to South Arne development will be handled in compliance with the Danish Environmental Protection Act (Consolidation Act no. 879 of 26 June 2010) and the relevant Statutory Order on waste no. 2512 of 10/12/2021. Furthermore, the municipality of Esbjerg has a local regulation regarding industrial waste[1] which set out rules for the general handling of waste.

3.4.2 Naturally Occurring Radioactive Material (NORM)

Offshore oil production in the North Sea is associated with contamination of certain parts of the processing equipment by low-level radioactivity substances, known as NORM (Naturally Occurring Radioactive Material).

NORM naturally occurs in the reservoirs in the North Sea; hence NORM may occur in drill cores and cuttings in drilling mud. The radioactive elements occur in chemical compounds in the produced water (formation water) either dissolved in the water or as small particles in the multiphase flow from the wells. NORM also occurs in systems where formation water and sea water are mixed. The radioactive particles or NORM can be accumulated and concentrated in separators (sludge) or deposited as scale in pipes and process equipment due to changes in pressure and temperature. NORM can also occur in the production liner of the wells.

The use (handling, storage, discharge, and disposal etc.) of radioactive substances such as NORM is regulated through The Radiation Protection Act (Consolidation Act no. 23 23/01/18 on Ionizing Radiation and Radiation Protection) and its underlying orders:

- Executive Order no. 669 of 1 July 2019 on ionizing Radiation and Radiation Protection.
- Executive Order no. 670 of 1 July 2019 on Use of Radioactive Substances.

The above legislation also regulates the use of sealed radioactive sources.

3.5 Natura 2000 areas and protected species

Natura 2000 is a network of nature protection areas established under the EU Habitats Directive and the Birds Directive. The network consists of Special Areas of Conservation (SACs) designated by the member states under the Habitats Directive 92/43/EEC of the Council of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. The network also consists of Special Protection Areas (SPAs) desig-

[1] https://www.esbjerg.dk/erhverv/affald-energi-og-miljoe/affald/farligt-affald/regulativ-for-erhvervsaffald

nated under the Birds Directive 2009/147/EC of the European Parliament and by the Council of 30 November 2009 on the conservation of wild birds. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats.

The directives are implemented in Danish legislation through the:

- Environmental Goal Act: Consolidation act no. 119 of 26/01/2017
- Subsoil Act: Consolidation act no. 1533 of 16/12/2019
- EIA Act: Consolidation act no. 4 of 03/01/2023
- Habitat Act: Executive order no. 2091 of 12/11/2021
- Offshore impact assessment order: Executive order no. 1050 of 27/06/2022.

Prior to any decision on projects with potential impact on a Natura 2000 area or a protected species (Annex IV), documentation must be presented that the activity will not lead to negative effects on the favourable conservation status of species or habitats that are part of the selection basis or affect the integrity of the area or species negatively.

3.6 Espoo Convention

Convention on Environmental Impact Assessment in a Cross-border Context, the Espoo Convention from 1991, sets out obligations of parties to assess the environmental impact of certain activities at an early stage of the planning. The convention also lays down a general obligation on the Member states to notify and consult each other on all major projects that are likely to have a significant adverse environmental impact across boundaries.

The Danish Environmental Protection Agency is the Danish Point of Contact for notifications regarding to the Espoo Convention and thus also takes care of the notifications and consultation of other countries according to the Espoo convention for projects where the DEA is the competent authority.

3.7 OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic or OSPAR Convention is the main legislative instrument regulating international cooperation regarding the marine environment in the North Sea. The Convention regulates international cooperation in the North-East Atlantic and sets European standards for the offshore oil and gas industry, marine biodiversity and baseline monitoring of environmental conditions. The focus of the convention is on BAT, BEP and clean technologies.

The OSPAR Convention has implemented several strategies on environmental issues such as hazardous substances, biodiversity and radioactive compounds. The strategies include prohibition of the discharge of oil-based mud (OBM), and how drill cuttings are managed in the construction phase. In addition, hazardous substances are regulated after principles of substitution, where less hazardous substances or preferably non-hazardous substances substitute these substances if possible. The Convention requires a HOCNF (Harmonised Offshore Chemical Notification Format) and a pre-screening of substances in relation to their toxicity, persistence and biodegradability. Compounds that cannot be substituted must be ranked if not listed on the PLONOR (Pose Little Or No Risk) list, which contains the substances with no or little environmental effect.

The OSPAR Commission recommends an elimination of discharges of produced water, so that by 2020 the discharge of produced water will not result in unwanted effects in the marine environment. Discharged produced water should not contain more than 30 mg dissolved oil per litre calculated as a monthly average. The Commission has established a risk-based approach (RBA) to assess the discharge of produced water. The RBA recommendation 2012/5 and the associated RBA guideline 2012-07 were adopted in 2012, and all contracting parties finalised their implementation plans in 2013 which is followed by full implementation in 2020.

OSPAR agreement 2017-02 recommends procedures for monitoring of environmental impacts of discharges from offshore installations including monitoring of sediment and water column characteristics. The monitoring programmes should comprise both baseline surveys prior to any petroleum development and follow-up surveys during exploration, production and decommissioning.

In OSPAR decision 98/3 on the disposal of disused offshore installations, OSPAR sets up the rules for leaving disused installations offshore. A disused offshore installation is defined as an offshore installation that no longer serves the purpose it was originally placed in the area for, or not serving another legitim purpose. Offshore pipelines are not covered by the decision.

The general rule is that offshore installations are not allowed to be left in a maritime area. Derogation from decision 98/3 may be considered for parts of an installation if certain conditions are met.

3.8 Energy and climate

3.8.1 CO_2 emissions

To reduce industrial greenhouse gas emission and to combat climate change, the EU has set up an emission trading system (EU ETS) for emission allowances of greenhouse gas. The system is set forth in Directive 2003/87/EC of the European Parliament and by the Council of 13 October 2003 on establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. The system is implemented in Danish legislation through the CO_2 Quotas Act (Consolidation act no. 1353 of 02/09/2020).

The EU Commission lays down rules for the monitoring and reporting of greenhouse gas emissions and activity data pursuant to EU Directive 2003/87/EC in the trading period that commenced on 1 January 2021 (EU Commission implementing regulation (EU) 2018/2066 of 19 December 2018).

3.8.2 Climate partnership

The Danish Government has decided that Danish emission of CO_2 shall be reduced with 70% in 2030 compared to the emissions in 1990. This takes place through the Climate act (Consolidation act no. 2580 of 13/12/2021).

The Government invited Danish companies to participate in Climate Partnership to develop ideas to meet the goal for 2030 through the Confederation of Danish Industry (DI).

The oil and gas industry gave input to the Partnership agreement within the areas of:

- Energy efficiency
- Electrification of the installations using common power infrastructure in the North Sea for example from wind power plants
- Carbon Capture and Storage (CCS)

- Hydrogen production, transportation and storage.

The final climate partnership agreement has been finalized in March 2020 and published by the Danish Council on Climate Change in the report "Known paths and new tracks to 70 percent reduction".

Some of the initiatives were initiated in the first Danish oil and gas energy efficiency action plan 2008-2011 agreed between the Minister of Energy and Climate and the Danish Operators in April 2009, which was followed by a second action plan for 2012-2014. The main focus areas were the operators' commitment to implement energy management as part of their existing environmental management system, to improve energy efficiency, to lower energy consumption and to lower flaring. These measures are still in place.

3.9 Marine Strategy Act

The EU has a marine strategy that aims to maintain or establish a 'Good Environmental Status' (GES) in all European marine areas by 2020. This strategy is set forth in Directive of the European Parliament and by the Council of 17 June 2008 on establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). The directive is implemented in Danish legislation through Marine Strategy Act (Consolidation act no. 1161 of 25/11/2019).

The Danish Ministry of Environment defines what is regarded as 'Good Environmental Status' of the marine environment using 11 different descriptors. For each descriptor a set of qualitative environmental targets and preliminary indicators are set. In Table 3-1 all 11 descriptors are listed together with relevant environmental targets.

Table 3-1 Overview of the 11 MSFD descriptors and a short description of the environmental targets.

	Descriptors	Relevant environmental targets
D1	Biodiversity (birds)	Populations and habitats for birds are conserved and protected in accordance with objectives under the Birds Directive
D1	Biodiversity (mammals)	Harbour porpoise, harbour seal and grey seal achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive
D1	Biodiversity (pelagic habitats)	The abundance of plankton follows the long-term average.
D2	Non-indigenous species	The number of new non-indigenous species introduced through ballast water, ship fouling and other relevant human activities is decreasing
D3	Commercially exploited fish stocks	Within the framework of the Common Fisheries Policy, spawning biomass exceeds the level that can ensure a maximum sustainable yield.
D4	Marine food webs	The relevant environmental targets under descriptor 1 (biodiversity) and descriptor 3 (commercial exploited fish stocks)
D5	Eutrophication	Danish part of discharges of nitrate and phosphor (TN, P) follows the maximal acceptable discharges set in HELCOM.
D6	Sea floor integrity (losses and physical impacts)	In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority encourages assessment and reporting to the Danish Environmental Protection Agency (monitoring programme) of the extent of physical losses and physical disturbances of benthic broad habitat types.

	Descriptors	Relevant environmental targets
D6	Sea floor integrity (habitat types on the sea floor)	The marine habitat types under the Habitats Directive achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive
D7	Alteration of hydrographical conditions	In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority is encouraging reporting to the Danish Environmental Protection Agency (monitoring programme) of hydrographical changes and the adverse effects of these.
D8	Contaminants (concentrations and species health)	Discharges of contaminants in the water, sediment and living organisms do not lead to exceeding of the environmental quality standards applied in current legislation.
D8	Contaminants (acute pollution events)	The spatial extent and duration of acute pollution events is gradually reduced as much as possible through prevention, monitoring and risk-based scaling of contingency and response facilities Adverse effects on marine mammals and birds from acute pollution events are prevented and minimised as much as possible. For example, this may be secured by means of floating booms as well as through contingency plans for marine mammals and birds injured in oil spills.
D9	Contaminants in fish and other seafood for human consumption.	Emissions of contaminants generally do not lead to exceeding the maximum residue levels applicable in the food legislation for seafood. The trend in total Danish dioxin emissions into the air is not increasing.
D10	Marine litter	The amount of marine litter is reduced significantly in order to achieve the UN goal that marine litter is prevented and significantly reduced by 2025.
D11	Underwater noise	As far as possible, marine animals under the Habitats Directive are not exposed to impulse sound which leads to permanent hearing loss (PTS). The limit value for PTS is currently assessed as 200 and 190 dB re.1 uPa2s SEL for seals and harbour porpoise, respectively. The best knowledge currently available is on these species.

It should be noted that the environmental status has not been mapped for all descriptors and thresholds are only defined for a few descriptors (contaminants and underwater noise).

OSPAR is currently working on a common framework of indicators and assessment values to be used in the Northeast Atlantic. In this EIA, a draft version of the list of indicators has been used to assess the impact of the project on the objectives of the Marine Strategy.

Eight areas in the North Sea have been appointed as marine protected areas according to the Marine Strategy Framework Directive. Activities within these areas are strictly regulated, however neither Hejre nor South Arne are located within one of these areas.

3.10 Maritime spatial plan

Maritime spatial planning is regulated through the Danish legislation in the Act on Maritime spatial planning (Consolidation act no. 400 of 06/04/2020).

The Danish Maritime Authority is responsible for establishing Denmark's first maritime spatial plan. The maritime spatial plan is to form the basis of the coordination of the many uses of Denmark's sea area in a manner that can support the conditions for sustainable growth in Blue Denmark. The maritime spatial plan is to establish which sea areas in Danish waters can be used for inter alia, offshore energy extraction, shipping, fishing, aquaculture, seabed mining and environmental protection towards 2030.

The maritime spatial plan 2.0 is currently through the process of public hearing and awaits final adoption. The areas of spatial planning at sea of relevance are primarily the zones for offshore energy exploration, see Figure 3-1.

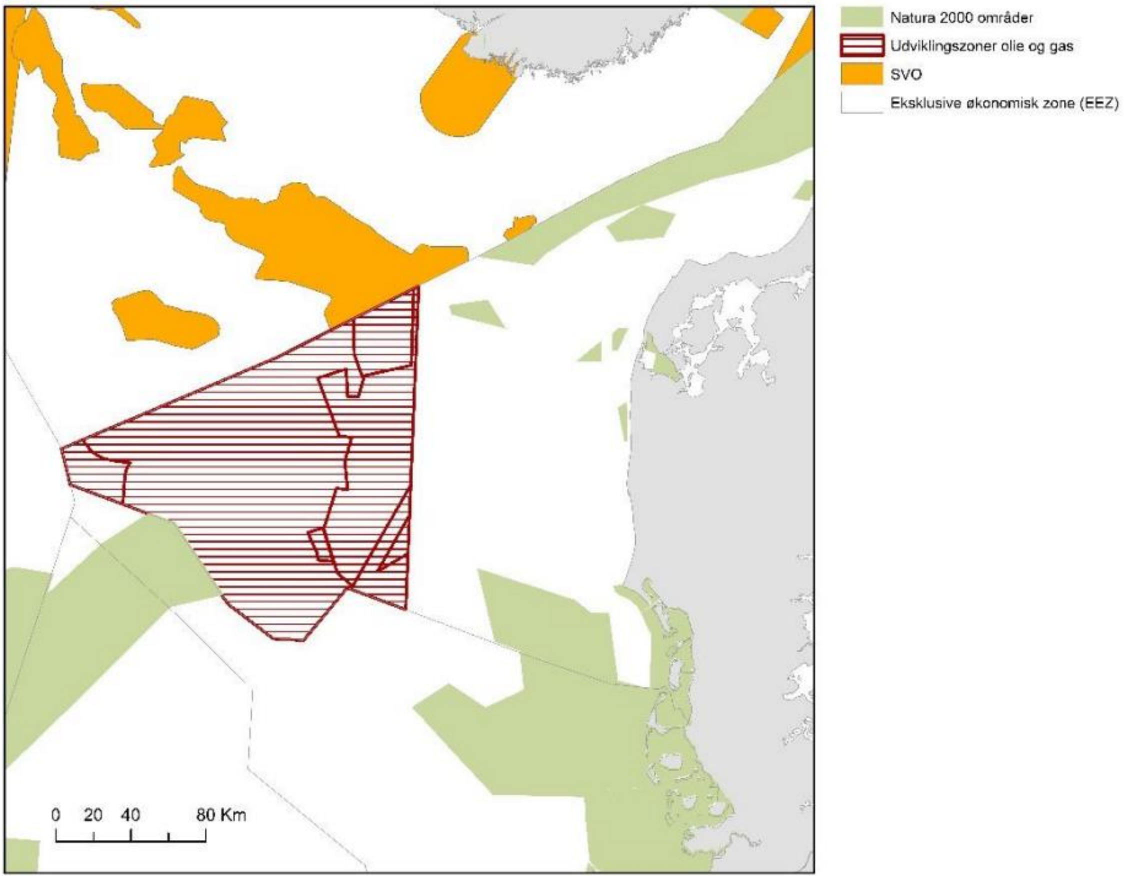


Figure 3-1 Development zone for oil and gas exploration in relation to Norway SVO-areas (especially valuable areas) and Natura 2000 areas in German and Danish sector (COWI, 2021).

3.11 Decommissioning

Decommissioning is regulated through Danish legislation in the Subsoil Act (Consolidation act no. 1533 of 16/12/2019) and the Marine Environment Act (Consolidation act no. 1165 of 25/11/2019).

According to the subsoil act decommissioning plans for offshore oil and gas installations shall be prepared, submitted and approved by the DEA before the installations can be removed. DEA has prepared a guideline for these decommissioning plans "Guideline on decommissioning plans for offshore oil and gas facilities or installations" dated August 2018. The guideline explains the legal framework and the required contents of the plans.

In addition, decommissioning is regulated through the following international conventions and declarations.

- IMO's Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (known as the London Convention 1972) including the 1996 Protocol which became effective in

2006.

The London Convention is a global convention that aims at protecting the marine environment from human activities by promoting control of sources of marine pollution and by taking steps to prevent pollution of the ocean. Under the convention all dumping of waste is prohibited except certain types of waste listed on the convention's 'reverse list'.

- Ministerial Declaration of the Ninth Trilateral Governmental Conference on the Protection of the Wadden Sea (known as the Esbjerg Declaration 2001).
- OSPAR Commission's OSPAR Convention (1992 and 1998), Annex III on Prevention and elimination of pollution from offshore sources, Decision 98/3 on Disposal of disused offshore installations, and recommendation 77/1 on Disposal of pipes, metal shavings and other material resulting from offshore petroleum hydrocarbon exploration and exploration operations.Regarding decommissioning, the Esbjerg Declaration states that more environmentally acceptable and controllable land-based solutions are preferred, and that decommissioned offshore installations therefore shall either be reused or be disposed on land.

The OSPAR Commission establishes the framework for decommissioning including guidelines and procedures. Recommendation 77/1 states that dumping of bulky waste such as pipes and containers is prohibited without special permission excluding inter-field pipelines. All dumping or leaving wholly or partly in place of offshore installations in the North Sea is prohibited according to Decision 98/3. However, derogation from this regulation is possible when there are significant reasons why an alternative disposal is preferred. Decision 98/3 does not include decommissioning of pipelines.

4. Alternative concepts

The chosen concept for the Hejre re-development is the Hejre tie-back to South Arne concept described in detail in Chapter 5. A number of alternative concepts have been considered and studied during the feasibility phase of the Hejre re-development project and are described in this chapter. An overview of the alternative concepts is shown in Table 4-1. Alternatives considered since 2017 have been included, and each presented in more detail in the following sections including the 0-alternative.

The selected concept has been measured on a number of parameters against alternatives and deemed to be the optimal concept across these parameters. These parameters include:

- Economic feasibility: The Hejre to South Arne concept is the most attractive financial concept, driven by the relatively small construction scope at Hejre and new pipelines and the utilization of existing infrastructure in the form of the South Arne installation.

- Environmental impact: Due the smaller construction scope, the environmental impact from the selected concept is similar smaller when comparing to alternatives. The design with no flare at Hejre also reduces the environmental impact.

Table 4-1 Overview of alternatives considered during the re-development of the Hejre project

Concept	Description	Type	Status	Comment
Process, Utility and Quarter (PUQ) Topsides	New process, utility and living quarter platform at Hejre for processing of Hejre fluids. Use of existing Hejre jacket and pre-drilling wellhead module. Use of existing export routes from Hejre. Various configurations within the overall concept investigated such as inclusion of third-party fields (e.g Solsort) as joint development.	Stand-alone	Screened out	Not economically viable. Evaluation based on significant reduction of the modelled reserves as compared to the original assessment and part of the Hejre legacy sanctioning basis.
Mobile Production Unit (MPU)	Converted jack-up drilling rig with process module located at the Hejre field for processing of the Hejre fluids. Use of existing Hejre jacket and pre-drilling wellhead module. Use of existing export routes from Hejre. Various configurations within the overall concept investigated such as different export specifications.	Stand-alone	Screened out	Not economically viable. Technology not used in Danish sector, which includes a risk of a longer process for approval.
Valhall tie-back	Tie-back to Valhall (Norway) through a new multiphase pipeline from Hejre to Valhall. New Bridge Linked Platform (BLP) at Valhall for processing of Hejre fluids. Use of existing Hejre jacket and pre-	Tie-back	Screened out	Not economically viable. No available capacity at Valhall before after 2030 requiring establishment of new BLP.

	drilling wellhead module.			
Harald tie-back	Tie-back to Harald through a new multiphase pipeline from Hejre to Harald. Umbilical for supply of power, chemicals etc. from Harald to Hejre. New module at Harald for processing of Hejre fluids. Use of existing Hejre jacket and predrilling wellhead module.	Tie-back	Screened out	The concept is considered less economical viable. The modifications at Harald are quite extensive including large risk of delay and cost increase. NGL extraction facility required at Nybro gas treatment plant. Due to the need for onshore processing this solution will also have a significantly higher power consumption and by that a higher climate change impact.
Siri tie-back	Tie-back to Siri through existing Hejre gas export pipeline to the South Arne Harald WYE[2] at which a new 43 km pipeline is established to Siri. A new gas export pipeline from Siri to tie in at Tyra East. New manned topside at Hejre with living quarter. Modifications at the Siri platform. Use of existing Hejre jacket and predrilling wellhead module.	Tie-back	HOLD	The concept is considered less economical viable. The pipelay scope and topside scope at Hejre is more extensive than the Hejre to South Arne.

4.1 0-alternative

A situation in which the present project is abandoned is interpreted as a status quo alternative, where no production will take place from the Hejre field. Consequently, the Hejre wells will be plugged and abandoned, the Hejre jacket will be removed, and the pipelines emptied and left buried in the seabed for *in situ* disposal if permitted by Authorities.

The environmental impact from the 0-alternative will be limited to emissions to air from use of vessels and disturbance of the seafloor during the decommissioning of the existing structures and discharge of treated seawater from the pipelines.

The offshore oil and gas production is important for the Danish economy though. According to Oil and Gas Denmark's report "The green transition – our shared responsibility" from 2019, thousands of people are employed in full-time jobs related to the offshore extraction industry, and the state benefits from the tax contribution from the oil and gas business are in the area of 5 billion DKK with an expected increase for the coming years to around 10-15 billion until 2037.

At present, Denmark can still not rely on renewable energy alone, and the political decided transition to renewable energy and reduction of carbon emissions whilst ensuring secure energy supplies means that the need for fossil fuels remains for the lifetime of the Hejre production. It is stated in Denmark's integrated National Energy and Climate plan from December 2019 that Denmark is expected to be independent of fossil

WYE is a subsea structure connecting multiple pipelines fuels in 2050. Until then, fossil fuels are still an integral part of a diverse energy mix and the re-development of the Hejre field is very much in line with the current Danish energy policy.

The consequences of a scenario where the Hejre field is not developed Denmark will face negative consequences in terms of a lower tax income, no positive socioeconomic effects (employment, financial benefits) and a lower level of national energy supply security. On the other hand, if the 0-alternative is chosen and the field is not developed for production, the consequences may involve less direct environmental impact on the Danish North Sea.

4.2 Stand-alone concepts

4.2.1 Process, utility and quarter (PUQ) topsides at Hejre

The re-development concept comprises the establishment of an integrated wellhead, process, utility and accommodation platform at the Hejre field. The topside is configured to interface the existing 8-legged jacket and the predrilling wellhead deck installed in 2014.

The concept is comprised of two different process system variations, one where the produced gas is exported at sales gas specifications, and one exporting gas as rich gas. In both cases, nitrogen injection would be required onshore at Nybro to meet the gas export quality specifications. For the rich gas export concept, further modifications onshore at Nybro would be required to treat the rich gas.

In addition, a combined development with a Solsort tie-back was investigated, as well as various sizes of the living quarter.

Irrespectively of the various configurations investigated, this concept is to a very large degree similar to the cancelled Hejre Legacy project but based on significant reduction of the modelled reserves as compared to the original assessment and part of the Hejre Legacy sanctioning basis, a stand-alone re-development of Hejre can no longer be economically substantiated.

From an environmental perspective, the integrated PUQ at Hejre concept would be of equal or worse impact when compared to the selected concept, due to the following considerations:

- Installation of the PUQ at Hejre would be with a larger installation vessel and of similar duration as for the unmanned Hejre topside (Hejre tie-back to South Arne). Having a higher fuel consumption per day this is expected to have a marginally larger negative impact on the environment compared with the Hejre tie-back to South Arne concept.

- As the existing export pipelines from Hejre Legacy are not completed, vessels would still be required for completion of the pipeline scope and for laying new pipelines. This is a marginal improvement on the environmental impact compared with the Hejre tie-back to South Arne concept due to less offshore duration for the pipelay installation vessels.

- Chemicals used during production will be the same as for the Hejre tie-back to South Arne concept, with the only difference being location of processing and injection. No difference in environmental impact.

- Produced water discharge will take place at Hejre with no reinjection possibilities. For Hejre to South Arne produced water will be reinjected at South Arne and no produced water will be discharged at Hejre. Negative impact on the environment compared with the Hejre tie-back to South Arne concept.

Based on the above, no environmental benefits are seen from the PUQ topsides at Hejre concept when compared to the Hejre tie-back to South Arne concept.

4.2.2 Mobile Production Unit (MPU) at Hejre

The re-development concept comprises a process and utility module integrated into the jack-up rig. The rig is located at the Hejre field with interface to the existing 8-legged Hejre jacket. The jacket will be modified to integrate a cooling module next to the pre-drill module.

The concept is comprised of two different variations, one exporting Sales Gas and one exporting rich gas. In both cases nitrogen injection would be required onshore at Nybro to meet the gas export quality specifications. For the Rich Gas export concept, further modifications onshore at Nybro would be required to treat the rich gas.

In addition, a combined development with a Solsort tie-back was investigated, as well as configurations where the process and utility module were located at the Hejre jacket, and the jack-up rig was only used for living quarters and utility equipment.

From an environmental perspective, the MPU at Hejre concept would have a similar or worse impact compared to the selected base case concepts, due to the following considerations:

- A jack-up rig would be permanently positioned at Hejre for the length of production. Towing the jack-up rig to site, permanent impact on the seabed etc. would have a negative impact on the environment compared with the Hejre tie-back to South Arne concept, where such activities are not taking place.

- Installation of a module/equipment at Hejre would still be required with similar vessels and duration as for the unmanned WHP (Hejre tie-back to South Arne). No difference in environmental impact.

- As the existing export pipelines from Hejre Legacy are not completed, vessels would still be required for completion of the pipeline scope. Marginal improvement on the environmental impact compared with the Hejre tie-back to South Arne concept due to less offshore duration for the pipelay installation vessel.

- Chemicals used during production will be the same as for the Hejre tie-back to South Arne concept, with the difference only being location of processing and injection. No difference in environmental impact.

- Produced water discharge will take place at Hejre with no reinjection possibilities. For Hejre to South Arne produced water will be reinjected at South Arne and no produced water will be discharged at Hejre. Negative impact on the environment compared with the Hejre tie-back to South Arne concept.

Based on the above, no environmental benefits are seen from the MPU at Hejre concept when compared to the Hejre tie-back to South Arne concept.

4.3 Tie-back concepts

4.3.1 Valhall tie-back

This concept is based on tie-back to the Valhall platform in Norway and the need for a new BLP at Valhall. The concept consists of a Hejre unmanned WHP with a multiphase pipeline to connect to the new Valhall BLP for processing of Hejre fluids. Oil and gas export will be through existing Valhall export routes.

From an environmental perspective, the Valhall tie-back concept would be of a similar or worse impact compared to the selected concepts, due to the following considerations:

- Installation of a module/equipment at Hejre still required with similar vessels and duration as for the unmanned WHP (Hejre tie-back to South Arne). No difference in environmental impact.

- Similar (compared to Hejre tie-back to South Arne) installation of new pipelines and umbilical. Similar or marginal negative environmental impact.

- New jacket and topside (BLP) required at Valhall with associated installation campaign. Negative environmental impact compared with the Hejre tie-back to South Arne concept.

Based on the above, no environmental benefits are seen from the Valhall tie-back concept when compared to the Hejre tie-back to South Arne concept.

4.3.2 Harald tie-back

The Hejre tie-back to Harald development concept comprises a multiphase tie-back from an unmanned wellhead platform at Hejre to the Harald platform. An umbilical from Harald to Hejre will provide Hejre with power, communication line, chemicals etc.

The multiphase production is exported through a new 22.5 km multiphase pipeline for processing at the Harald platform. The Harald live oil is exported through the existing Hejre to Harald WYE gas export pipeline to Hejre and from Hejre to shore through the existing Hejre to Gorm E pipeline and onwards to Fredericia Oil Terminal. The Hejre gas is exported directly from Harald through the existing gas export pipeline to the Nybro Gas treatment plant for further onshore processing to knock-out NGL and condition gas to export specifications.

From an environmental perspective, the Harald tie-back concept would be of a similar impact compared to the selected concepts, due to the following considerations:

- Installation of an unmanned topside at Hejre would still be required, with similar vessels and duration as for the unmanned WHP (Hejre tie-back to South Arne). No difference in environmental impact.

- Same level (compared to Hejre tie-back to South Arne) installation of new pipelines and umbilical. Comparable environmental impact.

- Installation of a new module and modification at the Harald platform – new module including separation, compression and power generation will be installed and debottlenecking of existing equipment. Similar environmental impact compared with the Hejre tie-back to South Arne concept due to similar vessel days for the heavy lift vessel.

- New gas conditioning plant onshore at the Nybro gas treatment plant. Negative environmental impact compared with the Hejre tie-back to South Arne concept as no onshore activities are expected, as the normal export of oil from South Arne is used and the Hejre gas is exported via the South Arne system to Nybro. The NGL's will be injected and stored. The energy consumption needed for onshore treatment at Nybro is at the same magnitude as for the offshore treatment, which makes this solution less energy efficient compared to the Hejre tie-back to South Arne solution only including offshore processing.

Based on the above, no environmental benefits are seen from the Harald tie-back concept when compared to the Hejre tie-back to South Arne concept.

4.3.3 Siri tie-back

The Hejre tie-back to Siri development concept comprises a manned topside with living quarters and multi-phase tie-back to the host Siri where well fluids are processed.

The multiphase production from Hejre will be exported using the existing 24 km gas export pipeline to the South Arne Harald WYE at which a new 43 km pipeline will need to be established to Siri.

The Hejre oil will be produced to the Siri oil storage tank and exported by shuttle tanker like the Siri oil. The gas will be exported through a new gas export pipeline to Tyra East and connection to the NOGAT system as Siri do not, at present, have any export infrastructure for gas (produced gas at Siri is used for gaslift and fuel and a minor volume is reinjected).

From an environmental perspective, the Siri tie-back concept would be of a similar or more negative impact compared to the selected concept, due to the following considerations:

- Installation of a manned topside at Hejre would be required, with similar vessels and longer duration as for the unmanned WHP (Hejre tie-back to South Arne). Marginal negative environmental impact compared to Hejre tie-back to South Arne.

- Larger scope of (compared to Hejre tie-back to South Arne) installation of new pipelines and umbilical. For Hejre to Siri approx. 67 km pipeline is installed, where the scope for Hejre tie-back to South Arne is reduced significantly to approx. 30 km. Negative environmental impact.

- Only brownfield modifications at Siri (Hejre-Siri), compared to a new tie-in module at South Arne (Hejre-South Arne) which requires dedicated vessel. Marginal positive environmental impact.

Based on the above, no environmental benefits are seen from the Siri tie-back concept when compared to the Hejre tie-back to South Arne concept.

5. Technical description of the Hejre tie-back to South Arne concept

5.1 Field description

The Hejre field is located within licence 5/98 on the Danish continental shelf approximately 300 km west of the Danish west coast. The field is a High-Pressure High-Temperature (HPHT) oil field with associated gas.

The Hejre jacket is located at the position 6.234.174,9 mN, 559.510,8 mE (reference UTM zone 31 on ED50 Datum) at approximately 68 m water depth.

The Hejre field, located in the southern part of the Central Graben, is dominated by extensive Late Jurassic rifting and subsequent Late Cretaceous inversion. The Gertrud Graben is bounded by the Mona fault and Piggvar Terrace towards the north, the Gerd Ridge towards the southwest and the Heno Plateau towards the south. The Gertrud Graben itself continues towards the northwest and merges with the Feda Graben. Below shows the extent of the interpretation used as input to the structural project.

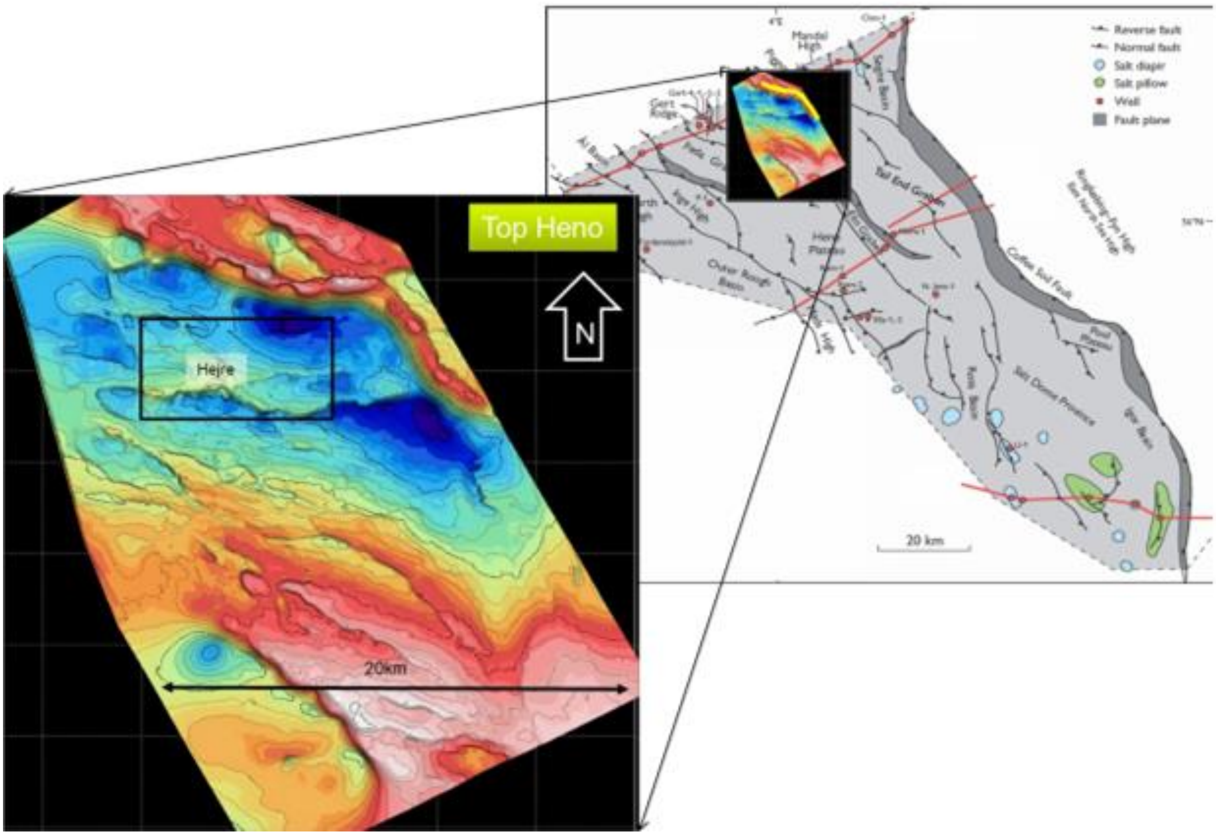


Figure 5-1 The Hejre area interpretation.

The Hejre field comprises several large segments, which are bounded by faults. Within the main Hejre field three of the main segments have been penetrated by exploration/appraisal and development wells and are considered as proven recoverable resources.

To date, 7 wells (including discovery well, Hejre-1 and appraisal well, Hejre-2) and 2 side-tracks (HA-1A and HA-3A) have been drilled on the Hejre field encountering the Gert reservoir in seven penetrations. Cores from 4 wells have been retrieved and provide crucial information to reservoir characteristics, interpretation of facies and depositional environment. Extensive sampling and analytical programming have been performed to characterise the sediment and diagenetical history. An overview of the drilled wells is shown on Figure 5-2.

Production is planned to take place from three of the existing Hejre wells HA-1A, HA-2 and HA-4, one in each segment of the Hejre field. The characteristics of the Hejre reservoir are provided in Table 5-1.

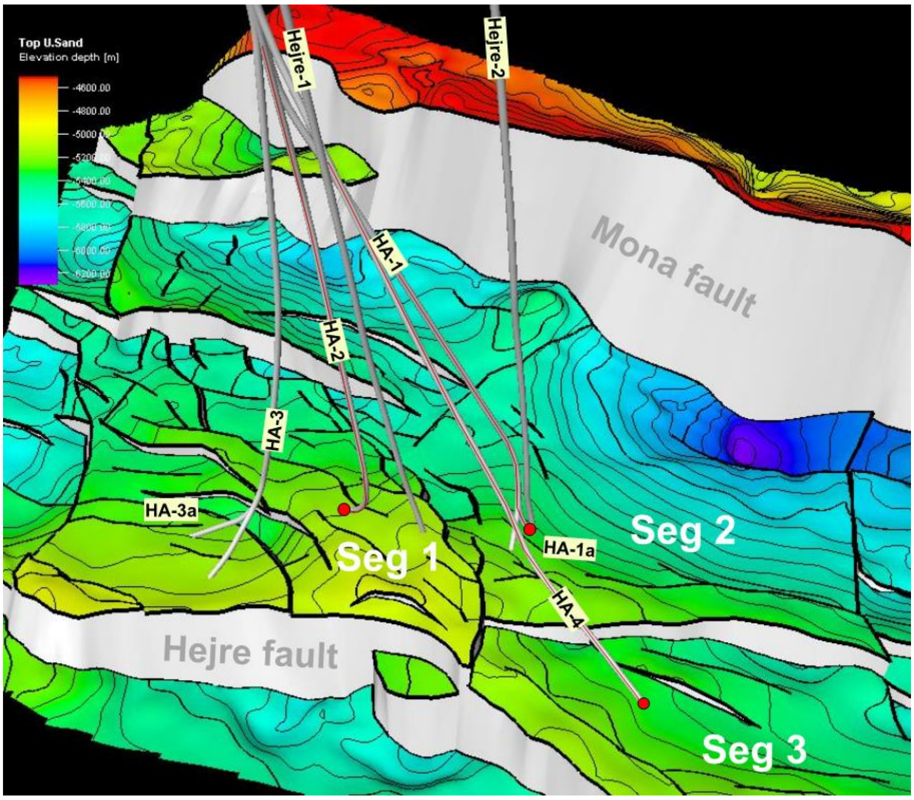


Figure 5-2 Overview of the 7 wells and 2 side-tracks drilled on the Hejre field.

Table 5-1 Hejre reservoir and fluid characteristics.

Parameter (unit)	Value
Reservoir depth (m)	5000-5500
Reservoir pressure (bar)	1000
Stratigraphy/Sedimentology	Jurassic shallow marine sands
Reservoir temperature (°C)	160
Reservoir thickness (m)	1-70
Oil density (API)	44
GOR (SCF/STB)	1300-2250

5.2 Project overview

The Hejre tie-back to South Arne development concept comprises a remotely controlled unmanned topside at Hejre and multiphase tie-back to the host South Arne where well fluids are processed. The multiphase production from Hejre will be exported to South Arne through a new 30 km multiphase pipeline (wet insulated or pipe-in-pipe).

The Hejre oil will be processed at South Arne main platform and produced to the South Arne Gravity Based Structure (GBS) for storage and exported by shuttle tanker like the South Arne oil, i.e., utilizing the existing South Arne oil export facilities. The gas will be exported through the existing South Arne to Nybro pipeline. NGL's will be injected at the host platform, South Arne, into the South Arne reservoir and will remain there.

The Hejre tie-back to South Arne project includes:

- Construction and installation
  - Construction and installation of a new unmanned topsides at Hejre
  - New fortified riser will be installed at Hejre
  - Perforation, clean-up and well test of 3 existing Hejre wells. Barrier repair of well HA-5
  - Drilling of a new well; Lunde (optional)
  - Modifications at Hejre jacket to remove the temporary items left over from the original installation in 2014.
  - Hook-up between the Hejre pre-drilling wellhead module installed in 2014 and the new topside.
  - Modification at the South Arne WHPE – a new tie-in module with a slug catcher, multiphase pig receiver, NGL pumps and new caisson with riser and power cable to be installed
  - Tie-in scope at South Arne Main – removal of obsolete degasser unit and new NGL injection booster pumps to be installed
- Laying and commissioning of pipeline and power cable
  - 30 km 10” or 12” multiphase pipeline from Hejre to South Arne
  - Installation of power cable with fibre optic from South Arne to Hejre with power and control from host
- Production
  - Processing of Hejre and Lunde well fluids at South Arne for 20 years
  - Operation and maintenance of multiphase pipeline and power cable
  - Operation and maintenance of Hejre platform and wells
- Decommissioning
  - Close-in, plug and abandonment of Hejre and Lunde wells
  - Flushing and dismantling of platform and subsea structures
  - Empty Hejre-South Arne pipeline and prepare for *in situ* disposal below seabed if permitted by Authorities

5.3 Existing installations

5.3.1 Hejre jacket and wellhead module

The existing Hejre structure comprises of an 8-legged steel jacket and a pre-drilled wellhead deck which were installed in 2014. Figure 5-3 shows the Hejre jacket present day (pictures taken in year 2019 during a maintenance campaign):

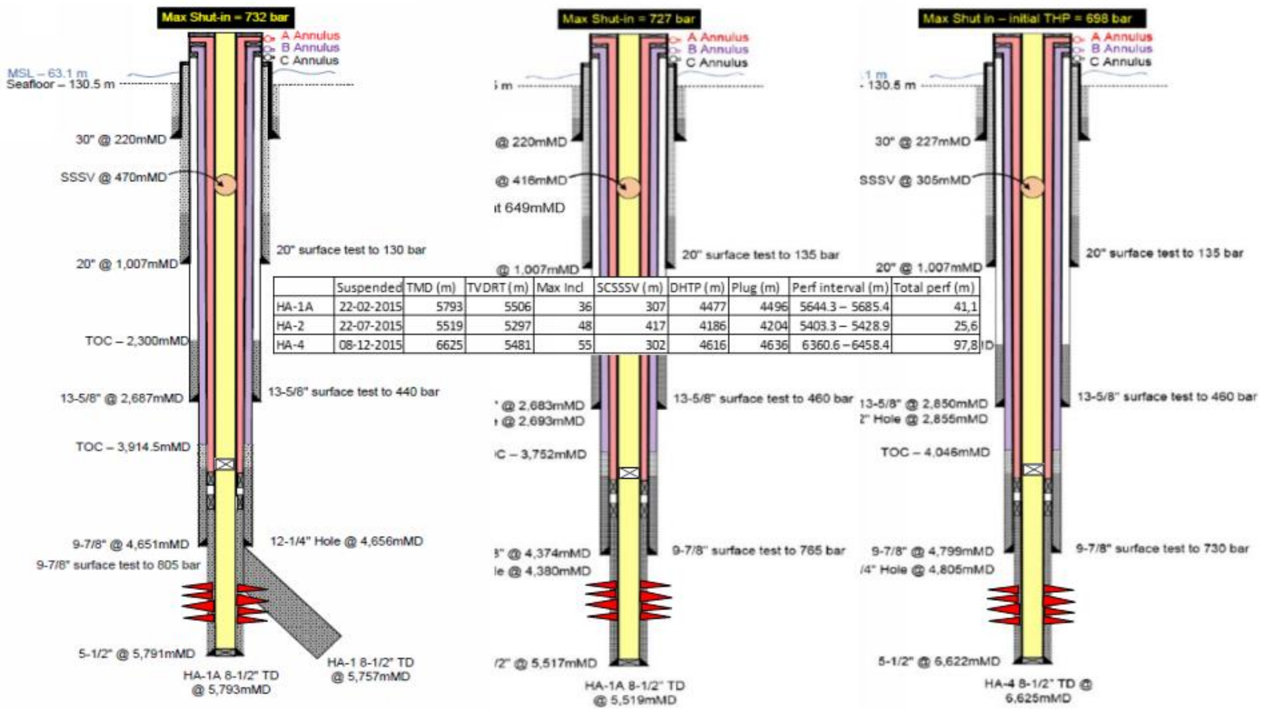
Figure 5-3 The Hejre Jacket

5.3.2 Hejre wells

Five HPHT wells have been drilled from the Hejre platform including two side-tracks. Drilling was completed in 2016 as part of Hejre Legacy,

Three of the wells (HA-1A, HA-2 and HA-4) have been drilled and completed with a 5-1/2" cemented liner across the reservoir and 5-1/2" production tubing to surface and Xmas Tree installed. The wells are ready for production pending pulling of deep-set plugs, perforation and clean-up. The wells are temporarily abandoned with seawater treated with corrosion inhibitor for protection of the wells.

The design of the 3 production wells can be seen on the figure below.



	Suspended	TMD (m)	TVDRT (m)	Max Incl	SCSSSV (m)	DHTP (m)	Plug (m)	Perf interval (m)	Total perf (m)
HA-1A	22-02-2015	5793	5506	36	307	4477	4496	5644.3 – 5685.4	41,1
HA-2	22-07-2015	5519	5297	48	417	4186	4204	5403.3 – 5428.9	25,6
HA-4	08-12-2015	6625	5481	55	302	4616	4636	6360.6 – 6458.4	97,8

Figure 5-4 Illustration of the design of the 3 HPHT production wells (from left: HA-1A, HA-2 & HA-4).

Two wells, HA-3A and HA-5, were decided to be plugged back and suspended at the 13-5/8" casing. These wells can be side-tracked at this point for future activities. A barrier repair of HA-5 is required.

5.3.3 South Arne host platform

The facilities at South Arne main consist of a combined wellhead, processing and accommodation platform, connected by a bridge to a wellhead platform, SA WHPE, and an unmanned satellite platform, South Arne Well Head Platform North (SA WHPN), see Figure 5-5. SA WHPE is placed about 80 m east of the existing South Arne platform and connected to the platform by a combined foot and pipe bridge while SA WHPN is an unmanned platform with a helideck about 2.5 km north of the existing South Arne main platform. A bundle pipeline has been established between SA WHPN and SA WHPE, which incorporates a production pipeline, lift gas and water-injection pipelines and power supply cables. South Arne main has accommodation facilities for 75 persons.

The processing facilities at South Arne consist of a plant that separates the hydrocarbons produced and an 87,000 m^3 oil storage tank on the seabed from which the oil is exported to shore by tanker. The treated gas is exported by a pipeline to Nybro. All the produced water is processed and treated, after which as much as possible is reinjected and the rest is discharged to sea.

Figure 5-5 South Arne and well head platform East.

The amounts of oil, gas and water produced at South Arne in 2020 are listed in Table 5-2.

Table 5-2 Key activity figures from South Arne 2020 (South Arne OSPAR report 2021).

Activity	Unit	Value
Oil production	thousand Sm³	479
Gas production*	million Sm³	82
Produced water, discharged	thousand Sm³	290
Displacement water discharged	thousand Sm³	481
Injected water	thousand Sm³	2,218

* Including for flaring and used locally as fuel

5.4 Drilling, construction and installation

5.4.1 Hejre Legacy wells

The scope for the present EIA related to the Hejre Legacy wells covers perforation and clean-up of HA-1A, HA-2 and HA-4 and barrier repair of HA-5. These activities are described further below.

5.4.1.1 Well perforation and clean-up of HA-1A, HA-2 and HA-4

A rig is required to re-enter the wells. The rig activities for completion of the wells will consist of:

- Move rig to location
- Rig up coil tubing
- Perforate, clean up and test wells

- Move rig away.

It is expected that a three-legged jack-up rig will be used for all well activities. The jack-up rig will be towed to and positioned alongside the Hejre platform. When the rig is in position, the rig's legs with spud cans will be lowered into the seabed to ensure that the rig will stay stabilized during drilling operations. A spud can is a flat conical shaped foot attached to the leg of the rig, which ensures that the rig will not sink too deep into the seabed.

The spud cans will typically penetrate 0.5-3 m into the seabed, depending on the underlying sediment. If necessary, the spud cans can be supported by rock dumps. Each spud can will have a size of 201 m², which is 603 m² in total. The substructure of the leg will be an open construction with 3 rig legs each having a size of around 671 m², which results in 2013 m² (0.002 km²) in total.

The drilling derrick will then be positioned over the platform so that the wells can be accessed or drilled through the selected slots on the platform.

Once the rig is in place and all interfaces established and verified, coiled tubing equipment will be rigged up on the completed wells. Coiled tubing will be used for pulling of the deep-set plugs and perforation of the wells. On each of the wells, a survey tool will be run on coiled tubing to verify and correlate depth and intervals for later perforation. After accurate well correlation, the perforating assemblies will be run in hole in each well and the wells perforated at correct depth and orientation.

Table 5-3 provides an overview of the estimated amounts of completion chemicals to be used for the Hejre Legacy wells. Possible amounts for contingencies are included in the figures.

Table 5-3 Estimated usage of completion and clean-up chemicals for the Hejre Legacy wells. All the usage figures include 100% for contingencies.

Completion chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
Lubricant	0.2	0	R
Viscosifier	1	0.2	G
Brine	1203	0.1	G
Hydrate removal	12	0	G
MEG	533	0	G
Brine	300	0	G
Manage Clays	900	0	G
Well cleanup	127	0	Y
Viscosifier	15	0	Y
Corrosion Protection	3	0	Y
Brine	2400	0	Y
Lubricant	12	0	Y
Friction reducer	3	0	Y
H_2S scavenger	5	0.5	Y
Biocide	4	0.2	Y

After the well have been perforated, the well will start to flow unassisted based on low density inhibited completion brine. The initial flow will be completion brine from the well head to the perforation depth. Following the completion brine, the perforations debris with the formation fluid (oil + associated gas) will start flowing to surface. As a minimum, a 12-hour flow period is expected after the appearance of formation fluids at surface. Following the clean-up, the well will be closed-in for 2 hrs, then opened-up for a 24 hour well test until acceptable production fluid values are reached.

Clean-up and well test will take place via rig-based test equipment until acceptable production fluid values are reached. Well fluids will be produced to a test oil separator on the rig. Debris will be shipped to shore, produced oil will be pumped back to the South Arne process facility and gas will be burned via a rig-based burner. Minor droplets of oil can reach the sea which can create a sheen at surface (expected order of magnitude: ~1 litre per well). When the perforation, clean-up and well test has been completed the wells are handed over to the Production Operations Department.

The clean-up and well test is expected to produce approx. 2,600 Sm^3 oil per well and up to 1,200,000 Sm^3 gas per well.

5.4.1.2 Barrier repair of HA-5

The temporarily abandoned well HA-5 has an issue with the downhole cement plug set inside the 13-5/8" casing to create a barrier against any potential shallow permeable layers.

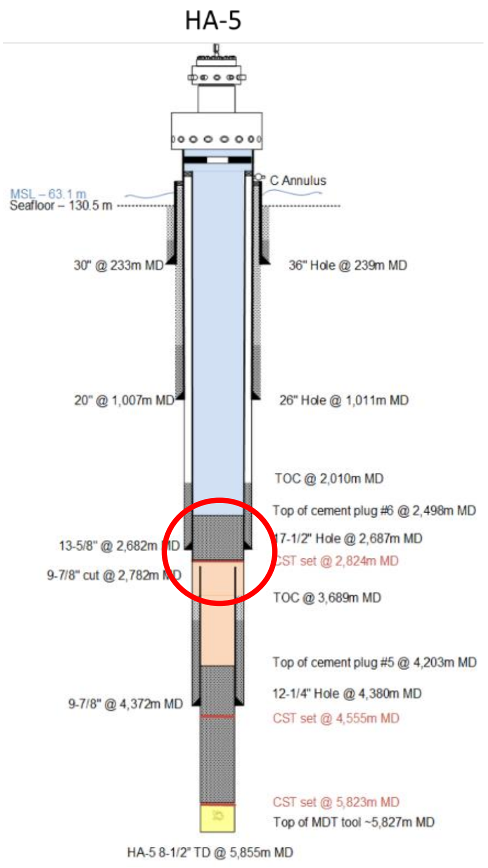


Figure 5-6 HA-5 cement plug.

The pressure between the plug and the surface barrier is slowly building up, and it will be required to enter the HA-5 well to repair the cement plug. The repair work will include the following activities:

- Skid to HA-5
- Remove the temporary abandonment (TA) cap, rig up the blow-out preventer (BOPs) and riser on HA-5

- Enter the well and drill out/dress-off part of the established cement plug
- Set a new cement plug on top and load- and pressure test same
- Rig down, re-install TA cap and skid away from HA-5.
- The existing plug will only be partly drilled out, to keep the plug as an additional safety barrier, while setting the new cement plug above.

For completion of the three existing Hejre wells chemicals will be used for the completion brine. No discharge is expected except for utility chemicals. Initial well flow during clean-up will require methanol injection to avoid hydrates across the production choke and a glycol water mix will be required for service equipment pressure test. The majority of these chemicals will be left in the well, whereas a smaller part will be discharged via South Arne.

For repair of the HA-5 barrier repair, drilling mud, cement and completion fluid will be used for drilling out the cement plug, setting a new cement plug and displacing the well to inhibited fluid whereafter the well will be left as temporarily abandoned. OBM will be used to drill out the cement plug. All OBM will be contained and shipped to shore for re-use or disposal. The cementing chemicals will run through the OBM system and will thus also be shipped to shore for re-use or disposal. The inhibited fluid in the wells will be led to the rig's slop unit and further on to South Arne for processing and reinjection with produced water. New inhibited water will be left in the HA-5 well. Thus, no discharges will take place.

Table 5-4, Table 5-5 and Table 5-6 provides overview of chemicals used for drilling out the plug, cementing and inhibited fluid for preservation, during repair of HA-5.

Table 5-4 Estimated use of chemicals for drilling out the plug of HA-5. All the usage figures include 100% for contingencies.

Drilling out plug	Planned use [tons]	Planned discharge [tons]	Colour code
Base Oil	258	0	Y
Viscosifier	11	0	Y
Alkalinity	16	0	G
Emulsifier	13	0	Y
Brine	70	0	G
Fresh water	103	0	G
Filter loss	8	0	R
Weight material	1,018	0	G

Table 5-5 Estimated use of chemicals for cementing of HA-5. All the usage figures include 100% for contingencies.

Cementing	Planned use [tons]	Planned discharge [tons]	Colour code
Anti-sedimentation	4	0	G
Dispersant	2	0	G
Viscosifier	0.2	0	G

Dispersant	0	0	Y
Anti-Foam	0.2	0	Y
Fluid Loss Control	0.5	0	Y
Solvent	0.5	0	Y
Surfactant	0.6	0	Y
Cement	41	0	G
Weighting Agent	21	0	G

Table 5-6 Estimated use of inhibition chemicals for preservation of HA-5. All the usage figures include 100% for contingencies.

Preservation	Planned use [tons]	Planned discharge [tons]	Colour code
Drill water/freshwater	460	0	Y
Biocide	0.7	0	Y
pH control	1.4	0	G
Alkalinity control	2.3	0	G
Oxygen scavenger	0.7	0	Y

A limited number of chemicals will be used on the rig. It is assumed that all rig chemicals will be discharged to sea via e.g. open drain.

The rig wash will be discharged with the washing water. It is assumed that the amount of water is 10 m³ and will be discharged within 1 hour. The use and discharge of rig wash is estimated to 0.3 tons rig wash per event and there will be approx. 25 events per well. In total that is 30 tons rig wash for the four wells.

The jacking grease is used when the rig is jacking up and down and thus only in the beginning and finalization of the rig activities. It is assumed that the jacking grease will be discharged over 10 days with a flow rate of 10 m³/day.

The hydraulic oil is assumed to be discharged over 10 days with a flow rate of 10 m³/day.

Table 5-7 Estimated use of utility chemicals. All the usage figures include 100% for contingencies.

Utility chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
Rig wash	30	30	Y
Jacking grease / skid grease	0.2	0.2	Y
Pipe dope / tubing dope	3.2	0.3	Y
BOP control fluid	116	23	Y
Hydraulic fluid	1.6	0.1	Y
Wireline fluid	20	10	Y

5.4.1.3 Summary of use and discharge of chemicals

In summary, the expected usage of chemicals in the different stages of the perforation, clean-up and repair of the Hejre Legacy wells are listed in Table 5-8 segregated into the main hazard categories (DEPA colour classification red, yellow and green).

Table 5-8 Overview of expected usage (in tons) of chemicals per classification.

Activity	Red chemicals		Yellow chemicals		Green chemicals	
	Use (tons)	**Discharge (tons)**	**Use (tons)**	**Discharge (tons)**	**Use (tons)**	**Discharge (tons)**
Perforation & clean-up	0.2	0	2569	0.7	2949	0.1
Drilling out plug	8	0	282	0	1,267	6
Cementing	0	0	2	0	68	0
Preservation	0	0	462	0	4	0
Utility	0	0	171	64	0	0

5.4.1.4 Emissions to air

Emissions to air in relation to rig and well activities are related to:

- Rig activities (mainly running power generator)
- Crew transport activities by helicopter and standby boat
- Transport of rig (rig move)
- Flaring during well clean-up and well test
- Supply vessels (transport of goods).

Table 5-9 Type of transport related to completion activities for 3 production wells and repair of HA-5.

Vessel type	Number of vessels	Days	Fuel consumption [m3/day]
Rig operation during completion and clean-up			
Rig	1	100	10
Supply vessel	1	13	10
Standby boat	1	100	3
Tugs	1 (main) + 2 (assisting)	20	20 (main) + 10 (assisting)
Helicopters (kerosene)	1	13	1.2

The assumptions are:

- All estimated days include weather delays and unforeseen events.
- The rig is operating 100 days in total for all three wells.

- The supply vessels operating 11 hours/day, 2 times a week in 100 days equivalent to approx. 13 full days in total.
- The standby boat is available 24 hours/day while rig is operating.
- The helicopters are operating 3 hours/day in 100 days equivalent to 13 full days.
- The clean-up and well test is expected to produce approx. 2-4 well volumes. The total gas volume expected to be flared from the three wells is up to 3,600,000 Sm^3.

5.4.2 Lunde well

INEOS has optional plans to drill a new production well, Lunde. The Lunde discovery was made in the 5/98 Licence by the HA-4 well, which encountered oil bearing reservoirs in the uppermost part of the Farsund Formation referred to as the Gertrud sands, while drilling to the target of the deeper Gert Member sand-stones (Hejre Field). Lunde covers an area of 5 km^2 and is located less than 2 kilometres east of the Hejre template, in the Danish Central Graben area, see Figure 5-7.

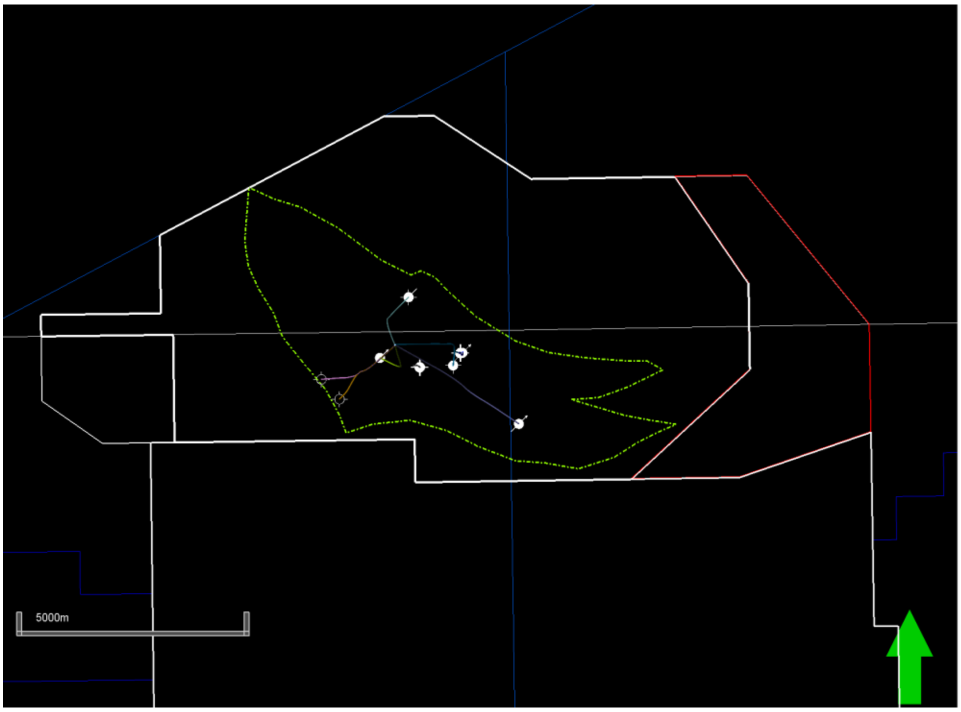


Figure 5-7 The Lunde discovery at the Hejre Field

Well logs, pressure and mobility data were obtained during the drilling operation and proved two separate oil-bearing Gertrud reservoirs to be present in the depth interval from 4427.7m to 4483.4m TVDSS (~55m gross thickness). Oil down-to situations with very high oil saturations occur in both reservoirs.

The Lunde Gertrud sands was deposited in a deep marine basin floor fan complex. Sediment was trans-ported into the late Jurassic – early Cretaceous Gertrud Graben, derived from a sandy shelf environment located north-east of the Lunde discovery area

The two reservoir zones with movable oil in Lunde discovery could be produced by drilling a well from the Hejre facilities to a position near the HA-4 well trajectory. Within the frames of the current development plan the Lunde could be co-produced with Gert reservoir reserves from the Hejre Field.

5.4.2.1 Well design and drilling

Drilling of the potential Lunde well is planned to take place in 2027 at the earliest, after finalising work on the Hejre Legacy wells, or alternatively in a later campaign. The potential Lunde well is expected to be drilled from the Hejre platform using a similar type jack-up rig as for the Hejre Legacy wells. The planned drilling period is estimated to last approximately 160 days. Additionally, there is a possibility of drilling technical side-tracks or geological side-tracks (to be decided later).

The expected depth of reservoir drilling is around 4,427-4,482 meters True Vertical Depth (TVD). The well design considered consists of five sections: a 30” conductor pipe, a 20” surface casing, a 13-5/8" intermediate casing, a 10-3/4” by 9-7/8” production casing and a 5-½" completion.

When drilling the well, first the conductor is drilled and cemented into the seabed. Installation of the conductor typically takes between 24 and 86 hours.

5.4.2.2 Use of chemicals in the construction phase

Chemicals will be used for a variety of purposes. Chemicals are added to the drilling muds to optimise the drilling process and subsequently for cementing and completion of the wells prior to initiation of the production. Also, chemicals are needed on the rig itself (utility chemicals).

The processes and the associated use of chemicals are described in more detail in the following sections, which include tables providing an overview of the expected amounts of chemicals with different functionalities to be used in the different construction sub-phases. Each chemical is assigned to an environmental category by use of colour codes.

It should be noted that many of the chemicals mentioned in the following tables are not or only to some extent being discharged to the sea after use. Some will remain completely or partially in the formation, while others are brought onshore e.g., along with cuttings/mud for treatment and disposal.

Furthermore, it has not yet been decided whether the mud system will be water-based mud (WBM) or oil-based mud (OBM) and thus the chemicals mentioned below include all chemicals for both mud systems including contingency, optional sidetrack and with a safety factor applied. Thus, the total amounts of chemicals used and discharged is overestimated as only one of the mud systems will be applied. The total estimated use and discharge of chemicals can be seen in Table 5-8.

5.4.2.3 Drilling muds and chemicals

Offshore drilling typically applies two types of drilling mud: water-based mud (WBM) and low toxicity oil-based mud (OBM), see Table 5-10. WBM is applied in the 36" (30” casing) and the 26” (20” casing) sections, and OBM is applied in the 17-1/2” (13-5/8” casing), the 12-1/4” (9-7/8” casing) and in the bottom 8-1/2” (5-1/2” completion) sections. Table 5-11 and Table 5-12 show the planned usage of chemicals for the drilling of the well.

Table 5-10 Types of drilling mud for the Lunde well for the two types of mud systems. Water-based mud (WBM), low toxicity oil-based mud (OBM).

Section	Casing size	Mud system
36"	30”	WBM
26”	20”	WBM
17-1/2”	13-5/8”	OBM

12-1/4" (incl. sidetrack)	10-3/4" x 9-7/8"	OBM
8-1/2" (incl. sidetrack)	5-½"	OBM

Drilling muds have the following primary purposes:

- Moving the cuttings (produced by the drill bit) from the well to the surface.
- Lubricating and cooling the drill bit during operation.
- Maintaining hydrostatic pressure in the well so that gas and fluids in the surrounding environment do not enter the well, thereby minimizing the risk of a kickout or a blowout.
- Building a protective layer on the well wall to prevent loss of fluids.
- Supporting and preventing collapse of the wellbore.
- Inhibiting wellbore and cuttings

The drilling rig circulates the mud by pumping it through the drill string to the drill bit. From there it travels back up the annulus space between the drill string and the walls of the hole being drilled and the last casing installed. Cuttings are separated from the mud on the shale shaker. During drilling of the lower part of the well using OBM, the rig switches to total containment mode to obtain zero discharge, in accordance with OSPAR Decision 2000/3. It is a closed circulating system where the mud is recycled throughout the drilling period for the well. The principle is illustrated in Figure 5-8 below.

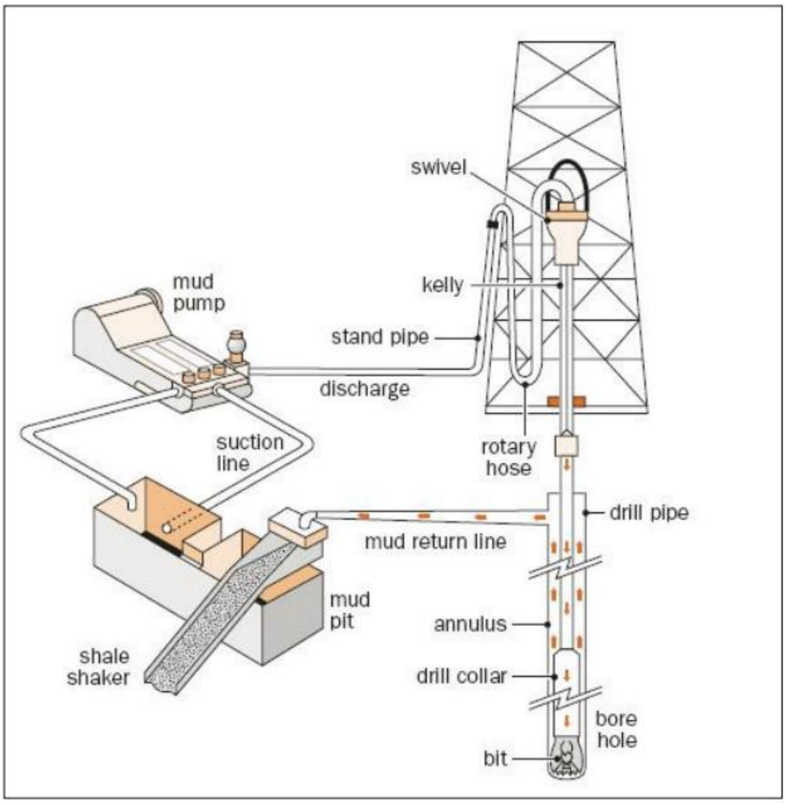


Figure 5-8 Drilling fluids system schematics.

All WBM and the associated chemicals and cuttings are discharged to the sea a few meters below the sea surface. All OBM fluids used to drill the lower sections will either be left in the well or circulated to surface where they are either reused or shipped for onshore disposal or recycling. Associated drill cuttings will also be shipped to shore.

It is envisaged that a water treatment unit similar to the type used during drilling of the Hejre Legacy wells may be used for treatment of fluids during drilling of the Lunde well. In that case, the water phase ('slop') from the OBM drilling and completion will be treated in the unit and discharged to sea. The majority of water discharged will be slop processed from collected rainwater and water used for cleaning drilling unit while drilling. As part of the treatment process, oil will be separated from the water before discharge takes place. In general, the oil in water concentration in the discharged water is expected to be in the level of 5-10 ppm. The discharged water will also contain traces of water soluble chemicals used during OBM drilling.

Table 5-11 Estimated usage of WBM chemicals for the Lunde well. All the usage figures include 200% for contingencies.

WBM chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
Viscosifier	3	3	G
Weighting agent	10,000	10,000	G
Lubrication	307	307	G
pH control	142	142	G
Torque reducer	30	30	G
Fluid Loss	6	6	G
Reduce Calcium	9	9	G
Manage Clays	900	900	G
H2S scavenger	0.23	0.23	Y
Biocide	30	30	Y

Table 5-12 Estimated usage of OBM chemicals for the Lunde well. All the usage figures include 200% for contingencies. Discharges of water soluble chemicals from a water treatment unit not quantified.

OBM chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
Fluid Loss	455	0	G
Weighting agent	10,000	0	G
Fluid Loss	75	0	G
Inhibition	900	0	G
Wetting Agent	27	0	G
Well stimulation	1	0	G
pH control	142	0	G
Torque reduce	30	0	G
Manage Clays	900	0	G
Fluid Loss	180	0	G
Viscosifier	45	0	G
Fluid Loss	55	0	R
Polymer	182	0	R
Emulsifier	212	0	R

Well cleanup	20	0	Y
Viscosifier	20.3	0	Y
Lubrication	75	0	Y
Emulsifier	502	0	Y
Filtration control agent	104	0	Y
Formation damage removal	31	0	Y
Oxygen scavenger	1	0	Y
H2S scavenger	0.23	0	Y
Biocide	0.10	0	Y
Weighting agent	0.56	0	Y
Oil mud base	3013	0	Y

5.4.2.4 Cementing

Casing is cemented into place in all the sections of the well. When drilling of each section is completed, sections of metal casing, slightly smaller than the well diameter, are placed in the hole to provide structural integrity. These are fixed into place by pumping cement into the annulus space between the casing and the well wall.

The cement fluids are pre-mixed in mix tanks on the drilling rig before being pumped into the well. To minimize the quantities of chemicals used, a cement liquid additive system is used to calculate the volumes of pre-mixed fluids required. The majority of the cement will be left in the well. Possible dead volumes may remain in surface tanks and lines after the operation and excess cement may return from the well. In both cases, the cement will be sent to slops and further to shore for disposal. No red chemicals will be discharged to sea.

Table 5-13 gives an overview of the estimated usage of cementing chemicals at Lunde.

Table 5-13 Estimated usage of cementing chemicals for the Lunde well. All the usage figures include 200% for contingencies. Discharges of water soluble chemicals from a water treatment unit not quantified.

Cementing chemicals	Planned use [tons]	Planned left in well [tons]	Planned discharge [tons]	Colour code
Weighting agent	168.6	54.7	113.9	G
Hydration process	307.0	307.0	0.1	G
Cement	606.9	601.8	5.1	G
Cement additive	17.7	17.4	0.3	G
Increase slurry stability	1.0	0.9	0.1	G
Retarder	4.3	3.9	0.4	G
High specific gravity material	10.2	9.3	0.9	G
Improve hardening	70.9	69.0	1.9	G
Free water control	2.0	1.8	0.2	G
Loss cirulation preventer	7.1	6.7	0.4	G
Maintain integrity	312.0	312.0	0.0	R
Dispersant	11.8	11.2	0.6	Y
Cement defoamer	0.8	0.8	0.0	Y
Fluid Loss	15.2	14.6	0.6	Y
Solvent	2.4	2.2	0.2	Y
Defoamer	1.4	1.3	0.1	Y
Cement retarder	18.9	17.8	1.1	Y

Emulsifier	2.8	2.6	0.3	Y

5.4.2.5 Completion and borehole clean-up

When reaching the reservoir, the completion process begins. A sand control completion is installed in the reservoir section. Then, the top completion takes place installing the production tubing, safety valves, sensor for pressure and temperature measurements and valves for injection required downhole chemicals.

Completion of a well consists of a few processes that start after the well has reached TD. The well must first be circulated clean for drill cuttings and the fluid conditioned to ensure the reservoir completion can be run to TD. The reservoir completion is run in weighted and cleaned drilling fluids. A tubing string is run to TD, cemented in place and later perforated. Then the top completion is installed and prior to setting the production packer the upper part of the well is displaced to a clean and inhibited completion fluid as the fluid could be static for a longer period between the production casing and the production tubing.

Table 5-14 provides an overview of the estimated amounts of completion chemicals to be used at Lunde. Possible amounts for contingencies are included in the figures.

Table 5-14 Estimated usage of completion and clean-up chemicals for the Lunde well. All the usage figures include 200% for contingencies. Discharges of water soluble chemicals from a water treatment unit not quantified.

Completion chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
Lubricant	0.2	0	R
Viscosifier	1	0.2	G
Brine	1203	0.1	G
Hydrate removal	12	0	G
MEG	533	0	G
Brine	300	0	G
Manage Clays	900	0	G
Well cleanup	127	0	Y
Viscosifier	15	0	Y
Corrosion Protection	3	0	Y
Brine	2400	0	Y
Lubricant	12	0	Y
Friction reducer	3	0	Y
H_2S scavenger	5	0.5	Y
Biocide	4	0.2	Y

The wellbore displacement to completion fluid will displace the OBM drilling fluid out of the well and up to the rig, where it will be treated and contained. In this process, a spacer train containing viscous and detergent pills is pumped into the well ahead of the completion fluid to maintain a good interface between the two types of fluids.

As much as possible of the returned drilling fluid from the borehole clean-up will be collected for reuse, recycling or disposal onshore.

After the well has been perforated, the well will start to flow unassisted based on low density inhibited completion brine. The initial flow will be completion brine from the well head to the perforation depth. Following the completion brine, the perforations debris with the formation fluid (oil + associated gas) will start flowing to surface. As a minimum, a 12-hour flow period is expected after the appearance of formation fluids at surface. Following the clean-up, the well will be closed-in for 2 hrs, then opened-up for a 24 hour well test until acceptable production fluid values are reached.

Clean-up and well test will take place via rig-based test equipment until acceptable production fluid values are reached. Well fluids will be produced to a test oil separator on the rig. Debris will be shipped to shore, produced oil will be pumped back to the South Arne process facility and gas will be burned via a rig-based burner. Minor droplets of oil can reach the sea which can create a sheen at surface (expected order of magnitude: ~1 litre per well). When the perforation, clean-up and well test has been completed the wells are handed over to the Production Operations Department.

The clean-up and well test of the Lunde well is expected to produce approx. 2,600 Sm^3 oil and up to 1,200,000 Sm^3 gas.

5.4.2.6 Utilities

A limited number of chemicals will be used at the rig (utility chemicals), mainly for cleaning, sealing and lubricating purposes. Table 5-15 lists the estimated amounts of utility chemicals planned to be used for Lunde. Discharge to sea via e.g. open drain.

Table 5-15 Estimated use and discharge of utility chemicals for the Lunde well. Numbers are totals for the four wells and include 100% contingency.

Rig chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
Thread compound	0.95	0.95	Y
Corrosion Protection	5	0	Y
BOP control fluid	116	23	Y
Rig wash	21	21	Y
Jacking grease	0.5	0.5	Y
Hydraulic fluid for well control	0.4	0.004	Y
Wireline fluid	10	5	Y

5.4.2.7 Summary of use and discharges of chemicals, mud and cuttings

In summary, the expected usage of chemicals in the different stages of the construction are listed in Table 5-16 segregated into the main hazard categories (DEPA colour classification red, yellow and green). As mentioned above, contingencies are included (200%).

Table 5-16 Overview of expected usage (in tons) per well of chemicals per classification. All the usage figures include amounts for contingency.

Activity	Red chemicals		Yellow chemicals		Green chemicals	
	Use (tons)	Discharge (tons)	Use (tons)	Discharge (tons)	Use (tons)	Discharge (tons)
Drilling, WBM	0	0	30.2	30.2	1,407	1,407

Activity	Red chemicals		Yellow chemicals		Green chemicals	
	Use (tons)	Discharge (tons)	Use (tons)	Discharge (tons)	Use (tons)	Discharge (tons)
Drilling, OBM	459	0	3,767	0	2,765	0
Cementing	312	0	55.8	2.9	1,196	123.4
Completion	0.2	0	2,557	0.7	2,950	0.4
Clean-up	0	0	0	0	10	2
Utility	0	0	154	51	0	0

During the construction of a well, a number of the materials or chemicals being used or generated will be discharged to the sea. In terms of tonnage, the discharge of cuttings and water-based drilling mud, WBM, are the most significant. WBM consists mainly of a brine with added bentonite and barite and a number of agents aimed at regulating viscosity and stabilising clay.

Table 5-17 provides an overview of the amounts of cuttings and mud/cement from different drilling sections including the optional sidetrack and their fate for the two options for mud systems. All OBM cuttings and mud will be shipped onshore for further treatment and disposal.

Table 5-17 Estimated generation/use and discharge of cuttings and drilling mud for the Lunde well including the optional sidetrack, including 100% contingency.

Section	Mud type	Cuttings [mT]	Discharge to sea
36"	WBM	380	Cuttings: 1,982 mT WBM: 2,150 mT
26"	WBM	1,602	
17-1/2"	OBM	2,013	Cuttings: 0 mT OBM: 0 mT
12-1/4" (incl. sidetrack)	OBM	926 + 926	
8-1/2" (incl. sidetrack)	OBM	348 + 348	

Cuttings shipped to shore are expected to be sent to a treatment facility approved by the authorities in Norway or the UK, while slop as a base case is shipped to shore is expected to be sent to Esbjerg and from there sent to a treatment facility approved by the authorities. The expected amount of slop is approximately 500 m^3. Alternatively, the slop will be treated on site in a water treatment unit and the water phase including small amounts of oil and water soluble chemicals will be discharged to sea after treatment.

5.4.2.8 Emissions to air

Emissions to air in relation to rig and well activities when drilling Lunde are related to:

- Rig activities (mainly running power generator)
- Crew transport activities by helicopter and standby boat
- Transport of rig (rig move)
- Flaring during well clean-up and well test
- Supply vessels (transport of goods).

Table 5-18 Type of transport related to drilling of Lunde well.

Vessel type	Number of vessels	Days	Fuel consumption [m3/day]
Rig operation during completion and clean-up			
Rig	1	159	10
Supply vessel	1	103	10
Standby boat	1	159	3
Tugs	1 (main) + 2 (assisting)	20	20 (main) + 10 (assisting)
Helicopters (kerosene)	1	20	1.2

The assumptions are:

- All estimated days include weather delays and unforeseen events.
- The rig is operating 159 days in total for the full drilling campaign.
- The supply vessels operating 60 hours/run, 1.5 times a week in the 43 days of drilling with WBM and 2.5 times a week in the 90 days of drilling with OBM, equivalent to approx. 103 full days in total.
- The standby boat is available 24 hours/day while rig is operating.
- The helicopters are operating 3 hours/day in 159 days equivalent to 20 full days.
- The clean-up and well test is expected to produce approx. 1,200,000 Sm^3 gas for flaring per well.

The total emissions to air from all activities in the construction phase can be seen in Table 8-15.

5.4.3 Platforms

5.4.3.1 Modification of the existing Hejre jacket

Before installation of the new Hejre topsides, some modifications of the existing jacket are conducted. The following activities are to take place:

- Removal of temporary items on the jacket left over from the original installation in 2014, and other temporary equipment such as solar panels.
- Completion of the Pre-Drilling Wellhead Module (PDWM) and removal of some caissons
- Installation of new fortified riser. The existing Hejre risers will remain in place as they could be utilised in the future. I.e., they can only not be used for the Hejre to South Arne concept due to the export pressure and temperature, which is different from the Hejre Legacy concept.

The activities will be conducted by a small Heavy Lift Vessel (HLV) and a flotel or similar will be at Hejre for accommodation

5.4.3.2 Installation of new Hejre topsides

The new Hejre topsides module main frame on Figure 5-9 is designed to fit onto the existing Hejre jacket. The module follows the existing jacket leg spacing with 20 meters in both directions. The deck height follows the existing wellhead module.

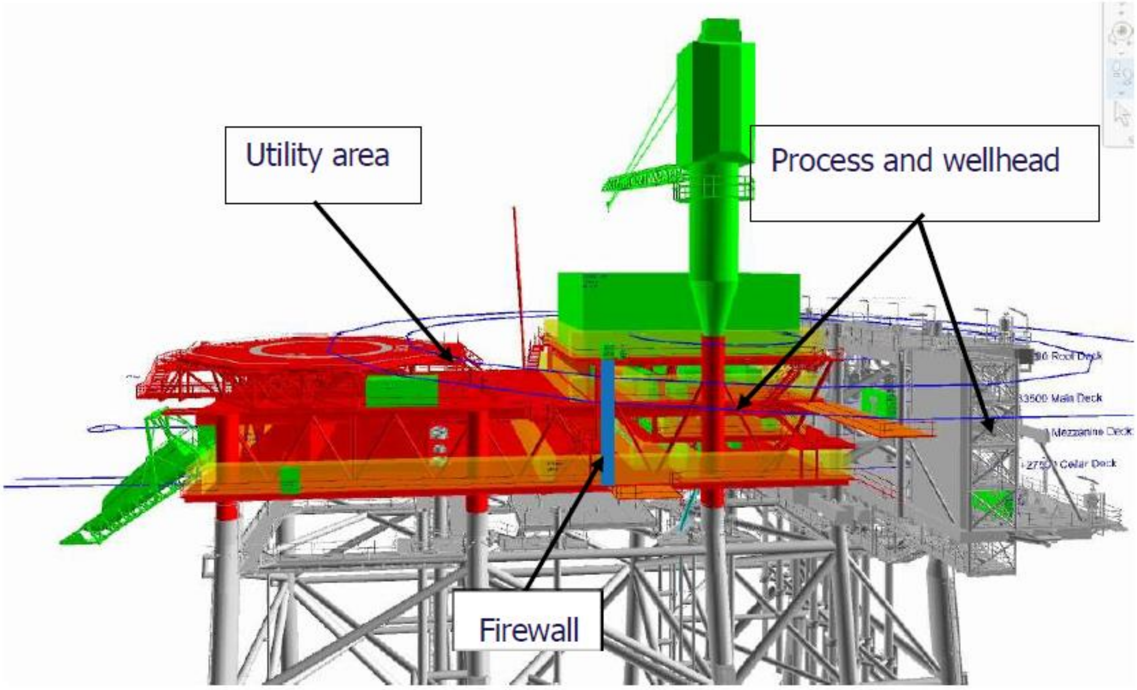


Figure 5-9 The Hejre new unmanned topside located on existing jacket structure. Grey is existing structure, red is new structure incl. helideck, green is new equipment such as lifeboat, crane, air-cooler. Blue is the firewall separating the utility area and the process and wellhead area.

The new unmanned topside structure includes:

- Permanent helideck
- Electrohydraulic crane
- Air-cooled exchange, well stream cooler (no processing)
- Shelter
- Over pressure protection fully rated to well shut-in pressure
- Necessary utilities incl. local chemical supply

The topsides will have an estimated weight of 2,100 ton in (dry weight).

The main principle of installation of the topside is that the module will be lifted in one lift using a HLV. A flotel or similar will be at Hejre for accommodation.

5.4.3.3 Modifications at South Arne WHPE and Main

The Hejre tie-back to South Arne concept will export the multiphase to South Arne.

The Hejre multiphase is intended to be produced through a new riser at South Arne WHPE. To tie-in the multiphase fluid from Hejre, the following new equipment are expected to be installed:

- Riser caisson at South Arne WHPE housing multiphase riser and power cable
- New tie-in module with slug catcher (metering on outlets), heater, pig receiver, NGL pumps at South Arne WHPE
- NGL injection booster pumps at South Arne Main platform

The riser caisson will be lifted by a small lifting vessel together with the tie-in module.

5.3.5.1 Emissions during installation

Emissions to air in relation to pre-installation activities, installation of the new Hejre topsides and the modifications at the South Arne WHPE and Main platform are related to: Transport activities and operations by the Heavy Lift Vessel (HLV), the flotel and special vessels used for installation of the risers at Hejre, the Hejre topside, the caisson with riser at South Arne and the tie-in module at South Arne.

The vessels listed in Table 5-19 are included in the fleet. The days include contingency for weather delays and unforeseen events.

Table 5-19 Type of transport related to topsides installation activities (INEOS).

Vessel type	Number of vessels	Days	Fuel consumption [m3/day]
Heavy lift vessel (HMC Balder or similar)	1	9	40 (mT/day)
Barge	1	35	Not applicable
Tugboats	2	35	20
Flotel for HUC (Seafox Marinia or similar)	1	125	3 (mT/day)
Heavy lift vessel (Seven Artic or similar)	1	18	30 (mT/day)

5.4.4 Pipeline and power cable

The pipeline system connecting the Hejre platform to the host platform South Arne WHPE will consist of one pipeline and one power cable: A new 30 km 10” or 12” multiphase pipeline, either wet insulated or pipe-in-pipe, from Hejre to South Arne WHPE and a new 30 km power cable with electrical power cables and fibre optic cables from Hejre to South Arne WHPE. The pipeline route is presented in Figure 5-10.

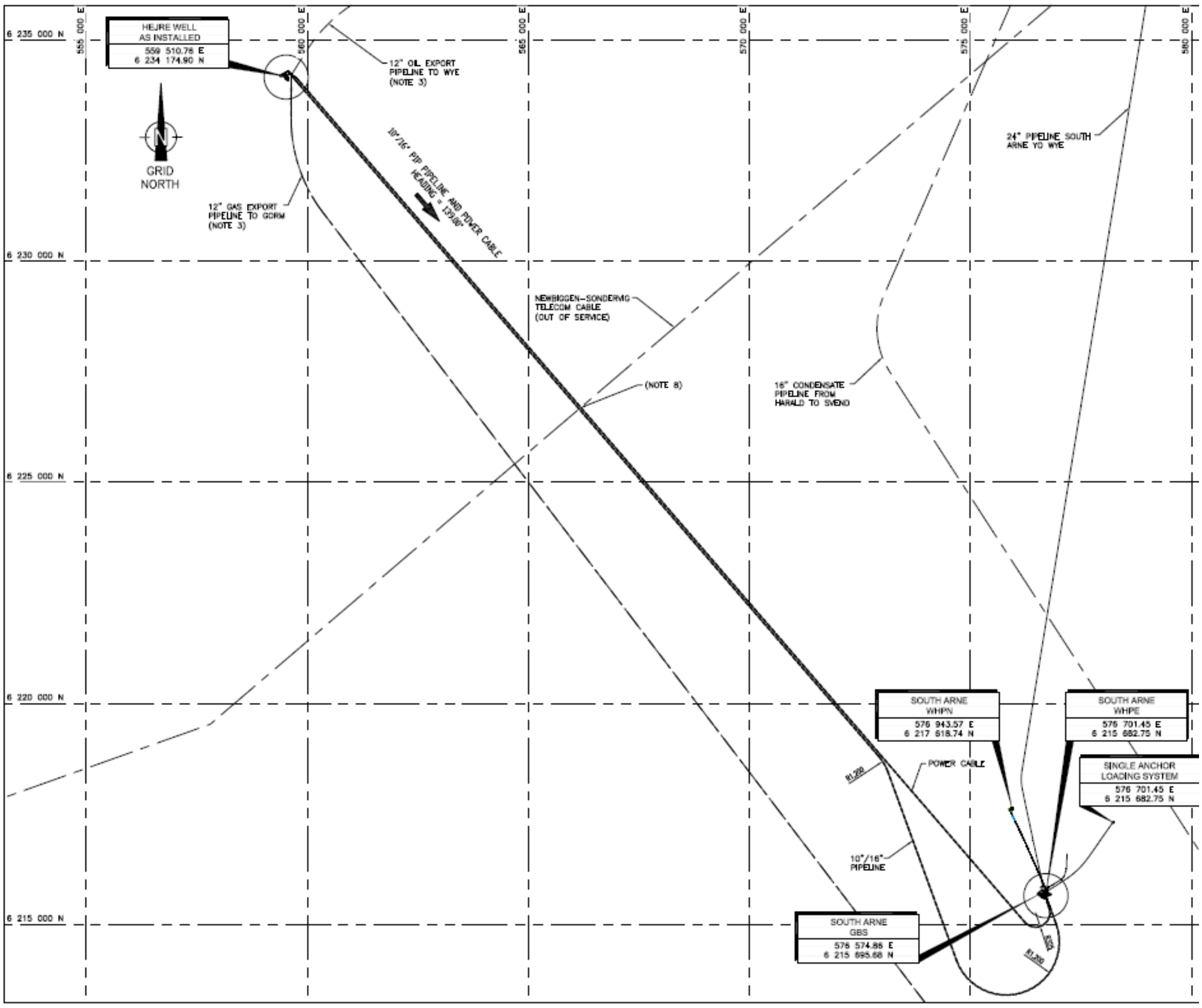


Figure 5-10 Pipeline and power cable route from Hejre to South Arne

The process of installation, burial and commissioning of pipelines and pipelines spools include the following activities:

- Pre-installation survey of the pipeline route
- Laying of the pipelines on the seabed
- Flooding with inhibited seawater
- Trenching and back-filling
- Tie-in spools
- Cleaning and gauging
- Hydrostatic testing
- Dewatering if required
- Commissioning

The pipeline alignment will initially be checked for presence of foreign objects that could interfere with the pipeline installation.

The pipelines will be laid out on the seabed using a dynamically positioned reel-lay vessel and will be flooded with inhibited seawater soon after laying to ensure the stability of the pipelines.

The pipelines will be trenched and buried in the seabed to protect from fishing trawling gear and other underwater equipment. Two trenching methods are considered, ploughing and water jetting, where the ploughing is considered the most cost-effective and a good solution for the area. The ploughing is generally giving an even vertical profile of the pipeline, which will eventually limit post-installation mitigation actions like rock dumping. In applying the ploughing method, a 1.5-2.5 m deep trench is constructed at a rate of 200-400 m per hour. Backfilling the pipeline trench is done at a similar rate. Applying the water jetting method, a 0.5 m wide and minimum 1.5 m deep trench is constructed at a rate of 200-1,000 m per hour. Use of this method is limited to sand and soft clay.

The pipeline and power cable will be trenched in parallel trenches with 50-meter distance between the trenches, see Figure 5-11 below for the pipelines approach at Hejre. After exiting the trench, the pipelines will be protected by rock dump and concrete mattresses.

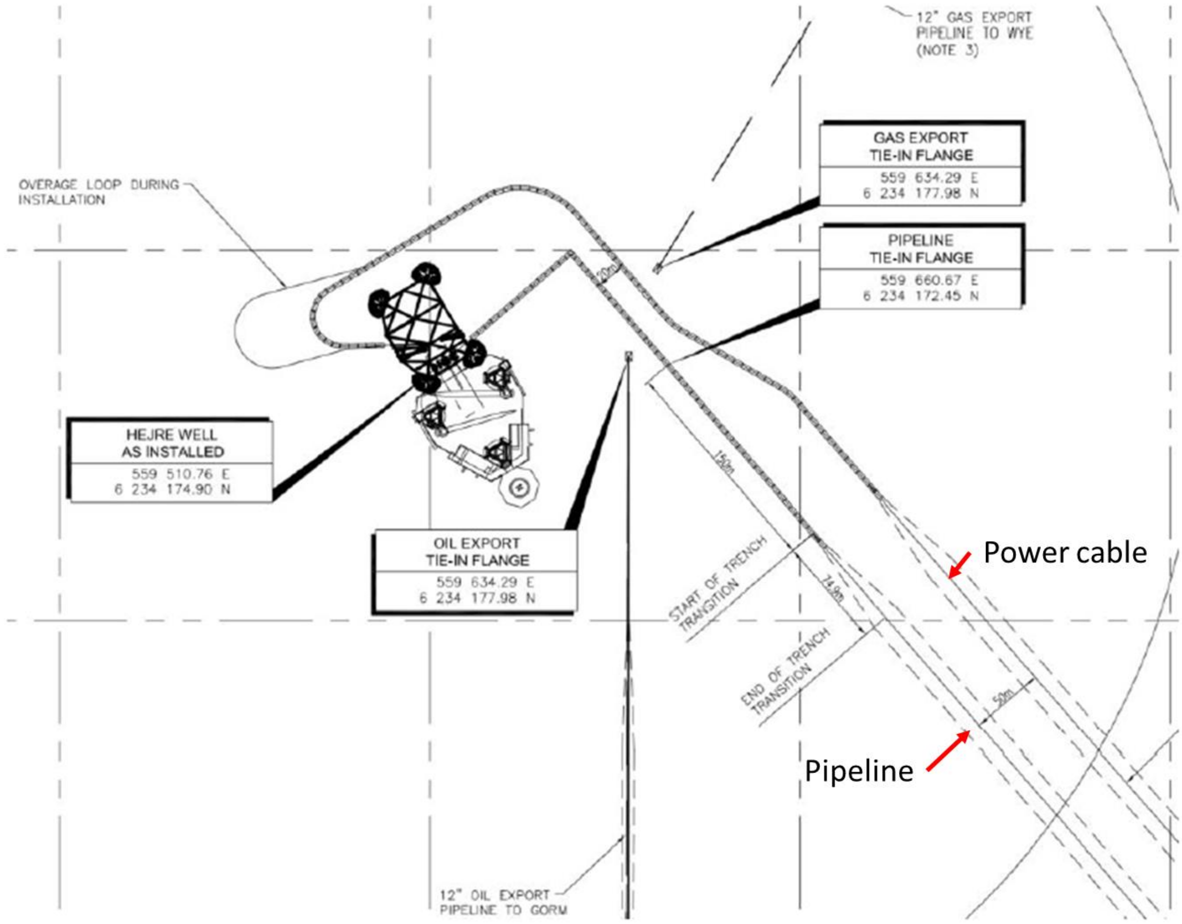


Figure 5-11 Pipeline and power cable approach to Hejre, showing the end of each trench. The untrenched part will be protected by rock dump

When the pipelines have been trenched and backfilled, the system is tied-in at the Hejre and South Arne WHPE platforms using bespoken spools, and a simultaneous cleaning and gauging process is performed by designated pigs at a speed of roughly 0.5 m per second.

Pipelines are hydrostatically tested before commissioning to make sure the pipelines do not leak. For 24 hours, the flooded pipelines are exposed to a test pressure, usually 15% greater than the design pressure, and is monitored for any pressure drops that would indicate a leak. Mechanical coupling locations, such as valves, flanges and spools have the highest probability of leaking, so these will be monitored during the hydrostatic test. The leak testing is facilitated by adding a fluorescent chemical, so even small leaks can be easily identified.

The Table 5-20 below gives an overview of the estimated amounts planned to be used during the pipeline tests. The amount is based on a dosage rate of 500 ppm in all pipelines that are tested. The dosage rate of the fluorescent is estimated to be less than 10% of the corrosion inhibitor.

Table 5-20 Estimated use of chemicals during pipeline tests

Pipeline testing	Planned use [tons]	Planned discharge [tons]	Colour code
Corrosion inhibitor	0.5	0.5	Y
Fluorescent tracer chemical	0.05	0.05	Y

The final step before commissioning is dewatering of the pipelines. If required, the multiphase pipeline will be dewatered in the direction from Hejre to the host using a pig that is forced through the pipeline.

5.4.4.1 Emissions during pipelay and power cable

Emissions to air in relation to pipelay are related to transport activities and operations by the fleet (pipelay vessel and special vessels) used for pipelay.

The operations by the fleet both include transportation activities and operations such as pipelay, rock dumping, trenching etc. The vessels listed in Table 5-21 are included in the fleet. The days include contingency for weather delays and unforeseen events.

Table 5-21 Type of transport related to pipelay activities (INEOS).

Vessel	Number of vessels	Days	Fuel consumption [m3/day]
Pipelay			
Pipelay vessel (Seven Navica or similar)	1	30	20
Survey vessel (ROV) (Seven Petrel or similar)	1	35	5
Trenching vessel (Skandi Skansen or similar)	1	20	20
DSV (Seven Atlantic or similar)	1	45	20
Guard vessel	1	30	0.5

5.5 Production phase

5.5.1 Production activities during operation of Hejre

In the following a description of production activities at the Hejre unmanned platform is presented.

The current project re-development plan with South Arne as host platform anticipates first oil exported from the Hejre field in 2027 with production rates as listed in Table 5-22. No produced water is expected from Hejre in the P50 scenario, but small amounts of water (up to 240 Sm³/d may appear in late life in other scenarios (P10 and P90). The prognosis for amount of produced water is although estimated with high uncertainty.Table 5-22 Overview of anticipated production rates from the Hejre and Lunde wells.

Production	Hejre design flow rates (P50)	Lunde design flow rates (P50)
Oil	4,000 Sm³/d (25,000 bbl/d)	3,200 Sm³/d (20,000 bbl/d)
Gas	1,220,000 Sm³/d (43 MMSCFD)	320,000 Sm³/d (11 MMSCFD)
Produced water*	0 Sm³/d (0 bbl/d)	56 - 1,430 Sm³/d (9,000 bbl/d)
Total produced liquid**	4,000 Sm³/d (25,000 bbl/d)	
*Min rate at start of operation, max rate towards end of life **The total combined fluids exported from Hejre is capped by the capacity offered at the host, South Arne (25,000 bbl/d).		

The production profile during the expected lifetime of Hejre is shown in Figure 5-12.

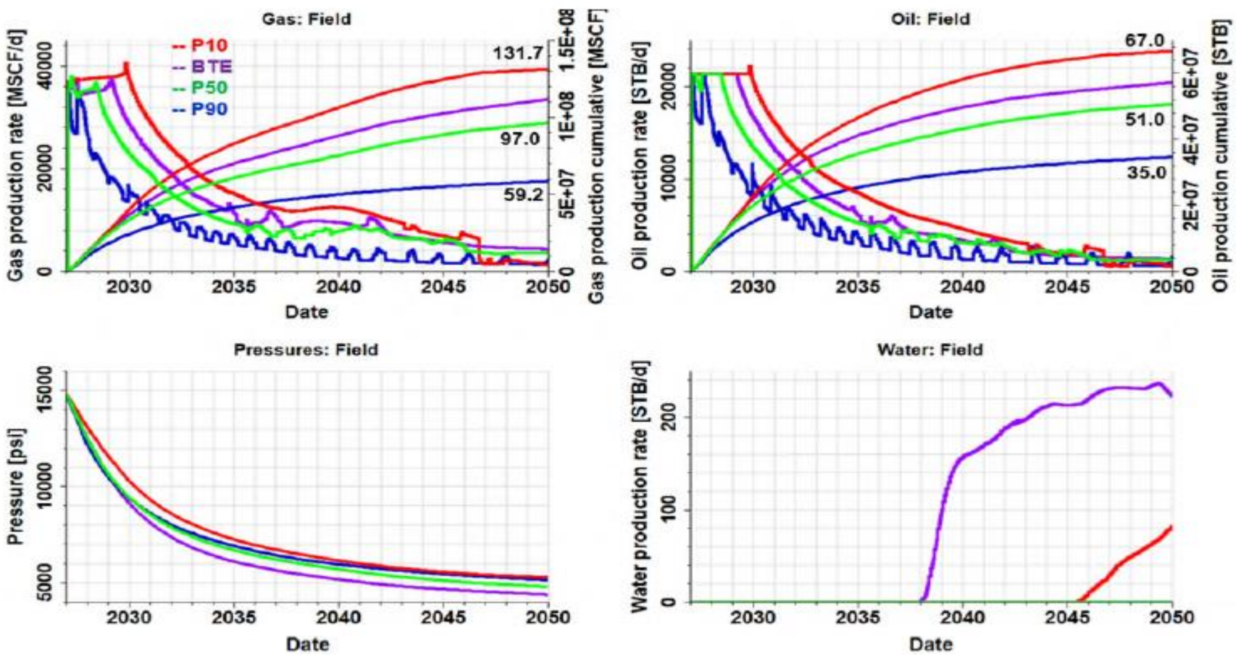


Figure 5-12 Expected production profile of production from Hejre, during the lifetime of the field. Production of oil and gas is expected to reach a maximum before 2030, after which it will gradually decline. Water production is expected to increase gradually during the lifetime of the field.

Estimated production rates from Lunde are also included in Table 5-22. Produced water is expected from the start of operation, with rates of reaching the max. level in 4-5 years, whereas oil and gas volumes will decline over the lifetime of the well.

The date for potential first oil from Lunde is not yet known, but will be later than Hejre, see Section 2.5. The Hejre and Lunde wells will not produce at their maximum at the same time, as production is limited by the capacity offered at the host, South Arne (25,000 bbl/day).

5.5.2 Discharge of produced water

During the processing on the South Arne platform, the produced water will be separated from the oil and gas and cleaned before it is discharged to sea if the produced water exceeds the injection capacity.

It is expected that the amount of produced water at South Arne to be discharged will not exceed the limits set in the existing South Arne EIA (Hess, 2006) due to tie-in of Hejre. Approximately 80% of the produced water at South Arne is reinjected.

5.5.2.1 Production chemicals at Hejre

The chemicals already in use at South Arne are assumed to be suitable for the Hejre production fluids as well. The chemicals used at Hejre and required for export of the Hejre multiphase to South Arne and treatment of the potential produced water later in the field life will be:

- Process corrosion inhibitor for continuous injection to multiphase export line
- Corrosion inhibitor for preventing corrosion in closed loop cooling system
- Wax inhibitor for continuous injection to multiphase export line
- Scale inhibitor to continuous injection to upstream choke
- MEG for intermittent services
- Hydraulic fluid to motive fluid for actuation of valves
- Cooling medium for use in closed loop cooling system.

The chemicals used at South Arne for treatment of the Hejre production will be:

- H2S scavenger for removal of H_2S from export gas to delivery specification.
- Demulsifier for continuous injection to improve separation of oil and water in the separator.
- Antifoam for continuous injection to improve the separation oil and water.

The use of chemicals will be evaluated on an ongoing basis to optimise the production process and reduce chemical consumption. The chemicals will be supplied via tote tanks at Hejre or injected locally at South Arne.

There will be no discharge point at Hejre. All water-soluble chemicals will be discharged at South Arne with the produced water. The remainder of the chemicals will be exported to shore with the export oil.

Table 5-23 provides an overview of chemicals to be used on Hejre during production. The numbers are based on the maximum oil production of 35.000 BOPD, which is a conservative estimate based on no restrictions in the production capacity at South Arne.

Table 5-23 Estimated use of chemicals at Hejre during production. Water soluble chemicals will be discharged with the produced water at the South Arne.

Hejre production chemicals	Planned use at Hejre [tons/year]	Planned discharge at South Arne [tons/year]	Colour code
Corrosion inhibitor	12	0	Y
Process corrosion inhibitor	35	0.35	Y
Scale inhibitor	3	3	Y
Wax inhibitor	610	6.1	R
H_2S scavenger	74	0	Y
Demulsifier	35	0.35	Y
Antifoam	35	0.35	Y
Cooling medium	246	0	Y
Hydraulic fluid	1	0	Y

5.5.2.2 Production chemicals at South Arne

The use of production chemicals at South Arne is based on production from the South Arne wells. The amounts of use and discharge is based on the 2021 expected use and discharge at South Arne and the additional expected use and discharges after tie-in of Hejre.

After tie-in of Hejre, South Arne will receive oil and gas from Hejre for processing. Chemicals exported with oil and gas from Hejre will be hydrate inhibitor, corrosion inhibitor, scale inhibitor, wax inhibitor, demulsifier and antifoam.

The estimated use and discharge of chemicals at South Arne after tie-in of Hejre is shown in Table 5-24.

Table 5-24 Estimated annual use and discharge of chemicals at South Arne after the Hejre tie-in.

South Arne production chemicals	Planned use after Hejre tie-in [ton/year]	Planned discharge after Hejre tie-in [ton/year]	Colour code
Antifoam (Deaerator)	2	2	Y
Biocide (process + deaerator)	18	4.4	Y
Corrosion inhibitor	60	9.3	Y
Demulsifier	41.3	0.7	Y
EVR	46	3.5	Y
H_2S scavenger	218.4	21.6	Y
H_2S scavenger	41	7.4	Y
Sodium Hypochlorite	110	110	R
TEG	8	2	Y
Antifoam (Process)	36.3	1.2	Y
Oxygen Scavenger	27	27	G
Scale inhibitor (down hole)	42	6.3	Y
Scale inhibitor (topside)	55	13.9	Y
Hydrate Disolver	40	273.2	G
Wax inhibitor		6.1	R
Total after Hejre tie-in	**745.05**	**488.65**	
Red	110	116.10	

Yellow	568.05	72.39	
Green	67	300	

Total South Arne (Hess, 2006)	**647**	**336**	
Red	82	82	
Yellow	495	188	
Green	70	66	

As can be seen in the table above the amounts of expected used and discharged chemicals will increase slightly compared to the South Arne EIA (Hess, 2006). The discharge of red chemicals will increase with approx. 42% after Hejre tie-in, the discharge of yellow chemicals will decrease, and green chemicals will increase by approx. 61% and 355% respectively compared to 2006 levels.

5.5.3 Emission sources

5.5.3.1 Emissions from Hejre

The Hejre platform is envisaged to be developed as a normally unmanned installation, controlled from Syd Arne. Similar to other tie-back satellite facilities operated by INEOS (such as Cecilie, Nini, Nini East), the over pressure protection philosophy is based on an inherently safe design with hydrocarbon containing process piping designed to withstand shut-in pressure. This approach eliminates the need for a flare system. Thus, no emissions will occur at Hejre apart from emissions related to transport by ship and helicopter in relations to facility maintenance.

Limited venting will take place, e.g., for routine maintenance of certain equipment and material for safety reasons prior to accessing the equipment.

5.5.3.2 Emissions from South Arne

The multiphase is transported to the South Arne Wellhead Platform East and further to the South Arne Main platform, where the processing of the oil gas and water takes place. In relation to the production, emissions to air will be generated from combustion of fuel gas, flare gas and diesel.

The tie-in of Hejre will be within the existing production capacity on South Arne. It is assumed that the emissions for combustion of fuel gas and diesel are proportional to the Hejre production volume and are within the existing environmental permits for South Arne. A temporary higher amount of flaring may be expected during tie-in of the Hejre wells compared to normal production flaring.

The emissions from South Arne are reported on a yearly basis in reports to OSPAR and the emissions from 2021 are used as the best forecast for the general level of yearly emissions at South Arne from power production and as well as for the emissions related to flaring after tie-in of Hejre, see Table 5-25.

Table 5-25 Emissions to air from South Arne, 2021.

Activity	CO_2 [10^3 ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]	CO_2-eq[1)] [ton]
Operation	180.2	219	3	111	333	180.3

5.5.4 Platforms

The Hejre platform is an unmanned platform and thus the crew will be transported via helicopter from South Arne.

Design of the Hejre topside is focused on high reliability, easy maintainability and good access without requirements for scaffolding or other temporary systems.

Transportation and logistics will be managed with the existing South Arne set-up, and activities will be coordinated and optimized.

5.5.4.1 Facility chemicals at Hejre and South Arne

In relation to cleaning and washing of the installations certain facility chemicals are used and discharged to sea as shown in Table 5-26. The use of facility chemicals at South Arne is additional to what is already in use on the platform today.

The chemicals will be discharged over a short period of time approx. a few hours per job and thus no continuous discharge of facility chemicals will occur during operation.

Table 5-26 Estimated annual use and discharge of facility chemicals at Hejre and South Arne

Facility chemicals	Planned use at Hejre [tons/year]	Planned discharge at Hejre [tons/year]	Planned use at South Arne [tons/year]	Planned discharge at South Arne [tons/year]	Colour code
Rig wash	3	3	0	0	Y
Wax remover	0	0	8	8	Y

5.5.4.2 Well service chemicals at Hejre

Also, well service chemicals will be used whenever needed at Hejre throughout the design life. The well service chemicals include chemicals for well head maintenance, coil tubing acid jobs, wireline jobs and coil tubing. The use and discharge of well service chemicals at Hejre can be seen in Table 5-27.

Well head maintenance chemicals are not expected to be discharged as the hydraulic fluid is used in a closed system and the remaining chemicals are for cleaning, flushing and topping up the system. Maintenance can require a small amount to be drained off. The fluid is collected and safely disposed of as per the waste management system. The well head system will subsequently be topped up with new hydraulics fluid.

Coiled tubing acid jobs are expected to be carried out 4 times over the 20 years. It will take up to 24 hours from the injection of chemicals to the discharge. The discharge is short-term at approx. a few hours per job.

Wireline jobs are expected to be carried out approx. 60 times on Hejre over 20 years. It will take up to 24 hours from the injection of chemicals to the discharge. The discharge is short-term at approx. a few hours per job.

The completion activities are expected to be carried out four times over 20 years. It will take up to 24 hours from the injection of chemicals to the discharge. The discharge is short-term over approx. 2 hours per job.

Table 5-27 Estimated use and discharge of well service chemicals at Hejre over 20 years.

Well service chemicals	Planned use Hejre [tons/year]	Planned discharge at Hejre [tons/year]	Colour code
Well head maintenance			
Wellhead hydraulic fluid	0.08	0	Y
Hydrate inhibitor	38	0	G
Base oil	4	0	Y
Grease	0.8	0	Y
Coiled tubing acid jobs			
Acid	56	56	G
Frac additive	0.2	0.2	Y
Corrosion inhibitor	1.4	1.4	Y
Corrosion inhibitor	1.4	1.4	G
Inhibitor aid	0.4	0.4	G
Iron stabilizer	0.2	0.2	Y
Wireline jobs			
Hydrate inhibitor	166	166	G
Brine lubricant	22	22	Y
Coiled tubing			
Hydrate inhibitor	4	4	G
Lubricant	10	10	Y

5.5.5 Pipelines

Multiphase pipelines, risers and pig traps will be designed for pigging by cleaning pigs and intelligent pigs. The multiphase system will be piggable from the Hejre platform to the South Arne platform.

5.5.6 Wells

The Hejre and Lunde HPHT wells will require regular interventions over field life. It will be possible to carry out most of the well service and maintenance activities from the Hejre WHP. More complex intervention jobs may, however, need the mobilising of a rig for equipment and crew. It is expected that a rig will be present at the Hejre platform 3 months during the lifetime of the field for maintenance of wells.

5.5.7 NORM

It is a general experience and well-known fact that offshore oil production in the North Sea is associated with contamination of certain parts of the processing equipment by small amounts of natural radioactive constituents in the reservoir, which are transported to the surface along with the extracted oil and/or particles. This material with low-level radioactivity is known as NORM (Naturally Occurring Radioactive Material).

NORM usually occurs in water injection systems where produced water is mixed with sea water but can also occur in separators, pipelines and in the production liners of the wells. In 2004, 16 tons of NORM was removed from separators and other process equipment on South Arne. The NORM deposits were reinjected into a dedicated reinjection well together with OBM-cuttings. Since start of production at South Arne in 1999, ~6 tons of NORM have been placed in temporary storage onshore.

NORM will most likely also be present at the Hejre field and will have to be handled and disposed of in accordance with the regulations for NORM administered by the Danish Health Authority, Radiation Protection. NORM contaminated equipment will be cleaned onshore and NORM material will be stored in a temporary storage approved by the authorities.

It is not possible to make an exact estimate of how much NORM will be produced at Hejre, but it is expected to be in the same range as the amount produced from South Arne in the period from 1999 to now.

5.6 Decommissioning phase

The expected lifetime of the installation is approximately 20 years. The decommissioning of the platform, wells and pipelines will be conducted in accordance with Danish legislation and international agreements in force at the end of the installation lifetime.

5.6.1 Decommissioning activities

The following is a general description of how an installation like Hejre may be decommissioned. The process will be the same as for the original Hejre project:

- Production strings are pulled out of the well and transported to shore for reuse or recycling.
- The reservoir will be secured by plugging and sealing the wells with concrete fillings in predetermined depths of the wells. The concrete fillings prevent the gasses and fluids from escaping from the wells into the marine environment or into other layers in the underground.
- The entire platform and subsea structures will be flushed for all hydrocarbons, dismantled, removed and transported to shore for recycling or reuse.
- Finally, pipelines are emptied of remaining hydrocarbons, which are transported to shore, and subsequently flooded with seawater. The pipelines remain buried in the sediment for in situ disposal if permitted by Authorities.

5.6.2 P&A of wells

When decommissioning the Hejre platform all wells will need to be plugged and abandoned (P&A) before removing the platform etc. The P&A activities are foreseen to be performed from a rig. During the P&A of the wells, different chemicals will be used for well activities and for the rig. The impact from chemical use is parallel to what is used for drilling activities.

At the moment the P&A program for Hejre has not been specified in detail. It will be developed further in due time before decommissioning. Below the indicative P&A program is described:

1. Bullhead the well free for hydrocarbons
2. Install deep mechanical barrier below Production Packer
3. Displace well to kill fluid
4. Install shallow barrier
5. Remove X-mas tree
6. Nipple up HP riser and BOP’s
7. Remove shallow barrier
8. Recover production tubing
9. Install 9 5/8” mechanical plug, and set +100m primary/secondary cement plug#1 above
10. Load and pressure test plug #1

11. Install 9 5/8” mechanical plug, and set +100m primary/secondary cement plug#2 above (stringers)
12. Load and pressure test plug #2
13. Set 9 5/8” mechanical plug below 13 3/8” shoe
14. Displace well above mechanical plug to 1.52 sg OBM (same as fluid in 9 5/8” vs 13 3/8” annulus)
15. Cut and pull 9 5/8” casing
16. Displace well to 1.40 sg WBM
17. Set +100m primary/secondary cement plug #3 across the 13 3/8” shoe
18. Load and pressure test plug #3
19. Set mechanical barrier inside 13 3/8” casing
20. Displace well to sea water
21. Multistring cut 13 3/8” casing and conductor 3m below seabed. Recover to surface
22. Set Plug #4 (Environmental plug) on top of mechanical barrier inside 13 /8” casing

When developing the P&A program also the specific chemical products will likewise be decided and thus the following is only indicative for the P&A program.

During the P&A the wells will be displaced to WBM and OBM. A spacer and wash trains will be applied for cleaning the wells. Cement will be used for plugging and slop chemicals are sent to the slop pits on the rig and discharged. Also rig chemicals will be used. OBM will be shipped to shore.

Table 5-28 provides overview of chemicals used for the P&A of the Hejre and Lunde wells. One red chemical may be discharged with water from the wash trains. A yellow substitute will be used if at all possible.

Table 5-28 Estimated use and discharge of chemicals for P&A activities of the wells.

P&A activities	Function	Planned use Hejre [tons]	Planned discharge at Hejre [tons]	Sent to shore [tons]	Colour code
WBM chemicals (chemicals mixed in 2,407 mT fresh water)	Brine	75	58	-	G
	pH	2.5	2	-	G
	Viscosity	10	9	-	G
	Weight material	1,373	1,071	-	G
OBM chemicals (chemicals mixed in 206 mT fresh water)	Weight material	1,518	0	1,518	G
	Base oil	849	0	849	Y
	Salinity	280	0	280	G
	Alkalinity	50	0	50	Y
	Emulsion	50	0	50	Y
	Viscosity	20	0	20	Y
	Viscosity	1.5	0	1.5	R
	Fluid loss	14	0	14	R
	Wetting agent	10	0	10	Y
Spacer	Cement cont.	90	90	-	G
	pH	90	90	-	G
Wash train (chemicals mixed in 90 mT fresh water)	Base oil	97	97	-	Y
	Viscosity	3	3	-	G
	Surfactant	35	35	-	R
	Solvent	40	40	-	Y
Slop chemicals	pH	7.5	7.5	-	G
	H_2S scavenger	5	5	-	Y
	Biocide	5	5	-	Y

Cementing chemicals	Anti-sedimentation	36	8	-	G
	Dispersant	10	4	-	G
	Viscosifier	1	1	-	G
	Dispersant	5.6	2	-	Y
	Anti-foam	1.4	1.2	-	Y
	Extender	4.5	1.7	-	G
	Accelerator	2.5	1.3	-	G
	Fluid loss control	11	3	-	Y
	Class G cement	332	86	-	G
	Weighting Agent	120	120	-	G
Total (excl. water)		**4,625**	**1,511**	**2,998**	
Total Red		**50.5**	**35**	**15.5**	
Total Yellow		**1,126**	**147**	**979**	
Total Green		**3,449**	**1,329**	**2,003**	

The WBM and the cementing chemicals will partly be left in the well, and the remainder will be discharged to sea. The OBM chemicals will be sent to shore for treatment and disposal.

A limited number of chemicals will be used on the rig. It is assumed that all rig chemicals will be discharged to sea.

The rig wash will be used for cleaning of the rig and rig equipment. The usage is estimated at 30 tons for the entire project corresponding, which will be 100% discharged over a period of 6 hours per day. The rig wash will be discharged with a concentration of 1:400 taking into account initial water use for dilution of the product and subsequent additional water use for rinsing.

The jacking grease will be used when jacking up and down and is expected to be 50% discharged over a period of 12 hours.

The drill pipe dope will be used in the wells and 10% is expected to be discharged over a period of 6 hours.

Table 5-29 Estimated use of utility chemicals.

Utility chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
BOP fluid	3.2	0	Y
Pipe dope	0.32	0.032	Y
Rig wash	30	30	Y
Jacking grease / skid grease	3	1.5	Y
Total Yellow	**36.52**	**31.53**	

5.6.3 Removal of installation and jacket piles

Before the removal of the topside process fluids, fuels and lubricants will be drained and transported ashore for disposal according to legal requirements.

The topside and the jacket will be dismantled and removed and transported to shore for further cleaning and recycling or reuse. Jacket piles will be cut approximately 1-3 meter below the seabed level dependent on sediment transportation in the area.

The topside is expected to be removed as a single lift either with a heavy lift vessel or by jack-up vessel similar to wind farm installation jack-ups.

The jacket is expected to be removed as a complete unit with a heavy lift vessel.

The removal of structures will prevent interference with fisheries in terms of damages to fishing gear. In addition, bans on fisheries within exclusion zones will be lifted.

Details about the structures to be removed is shown in Table 5-30.

Table 5-30 Information about facilities to be removed

Surface facilities information						
Facility type	Topside facilities		Jacket			
	Weight (Te)	Number of modules	Weight (Te)	Number of legs	Number of piles	Weight of piles (Te)
Fixed large steel jacket	1,650	1	7,683	8	16	1,393

5.6.4 Leaving of pipelines and jacket piles

The pipelines will be emptied for hydrocarbons and flooded with seawater. The presence of decommissioned pipelines left in-situ and jacket piles left below the seabed level will slowly degrade and will not result in any significant impacts to the seabed or the pelagic or benthic communities.

Exposed pipeline sections are rock-dumped or buried in the sediment for trawling protection.

5.6.5 Cutting piles

When a field on deeper waters is abandoned, piles of cuttings from the drilling operations are often encountered beneath platforms.

However, cuttings piles are not likely to remain develop in the relatively shallow waters (68 m) at Hejre and it also appears from subsurface surveys taken place around the Hejre jacket that the cuttings from the drilling operations has dispersed due to the relatively strong currents on the seabed and for that reason do not have a form to be able to remove.

5.6.6 Emissions to air

Air emissions can be expected from the operating fleet to execute and support the decommissioning activities such as jack-up rig, heavy lift vessel, standby boat and supply boats. The days include contingency for weather delays and unforeseen events.

Table 5-31 Overview of vessels to be used during decommissioning.

Vessel type	Number of vessels	Days	Fuel consumption [m³/day]
Rig	1	255	10[1]/ 30[2]
Heavy Lift vessel	1	83	47
Supply vessel	1	97	7
Survey vessel (ROV)	1	70	4

Pipe Trench/Jet Skid	1	5	30
Rock dumping vessel	1	8	27
Offshore construction vessel	1	28	20
Diving support vessel	1	320	24
Standby boat	1	255	10
Tugs	3	20	20
Helicopters	1	109	1.2
[1] for jack-up [2] average in DP mode			

5.7 Waste and waste handling

Household waste and waste will be generated at the Hejre platform throughout the different phases from construction to decommissioning.

All waste generated at the Hejre platform will be thoroughly sorted into categories agreed with the waste handling company and according to the regulatory requirements of the municipality of Esbjerg. The sorted waste will be transported to shore for treatment at approved waste treatment or waste-to-energy plants or, if necessary, for final disposal.

The amount and the composition of waste will depend on the level of activities and the number of persons on board. More waste will typically be generated during maintenance and well service campaigns than during normal day-to-day operations and these special operations will also generate other types of waste. E.g., painting campaigns will generate sand from sandblasting.

The amount of household waste is related to number of persons on board the rig or the installation.

5.7.1 Waste during construction

Waste generated during the construction phase will mainly be related to household waste from the rig and OBM mud and cuttings from the drilling operation.

Household waste and OBM mud will be transported by supply vessel to Esbjerg and from there to an approved waste treatment or waste-to-energy plant.

OBM cuttings will most likely be transported to UK or Norway for treatment and disposal as there at the time of writing of this report was no facility in Denmark able to handle this waste fraction. Cf. section 5.4.2.7, approx. 4,600 tons of OBM cuttings are generated from drilling of the Lunde well (including cuttings from the drilling of a potential sidetrack).

5.7.2 Waste during production

Waste production at South Arne is not expected to change significantly due to tie-in of Hejre, Waste production at South Arne was approx. 271 tonnes in 2021, see Figure 5-13. The waste categories are shown in Figure 5-13 and waste treatment in Figure 5-14. The three main waste categories in 2021 was industrial waste, iron and sand from sandblasting. Most of the waste is sent for recovery or for incineration for energy production.

As Hejre will normally be unmanned, waste generated during the production phase is mainly household waste and other waste related to maintenance campaigns. Waste related to the production phase is estimated to be in the magnitude of 20-25 tonnes per year for Hejre. The waste types are expected to be similar to the waste from South Arne, although the distribution may vary from year to year depending on activities.

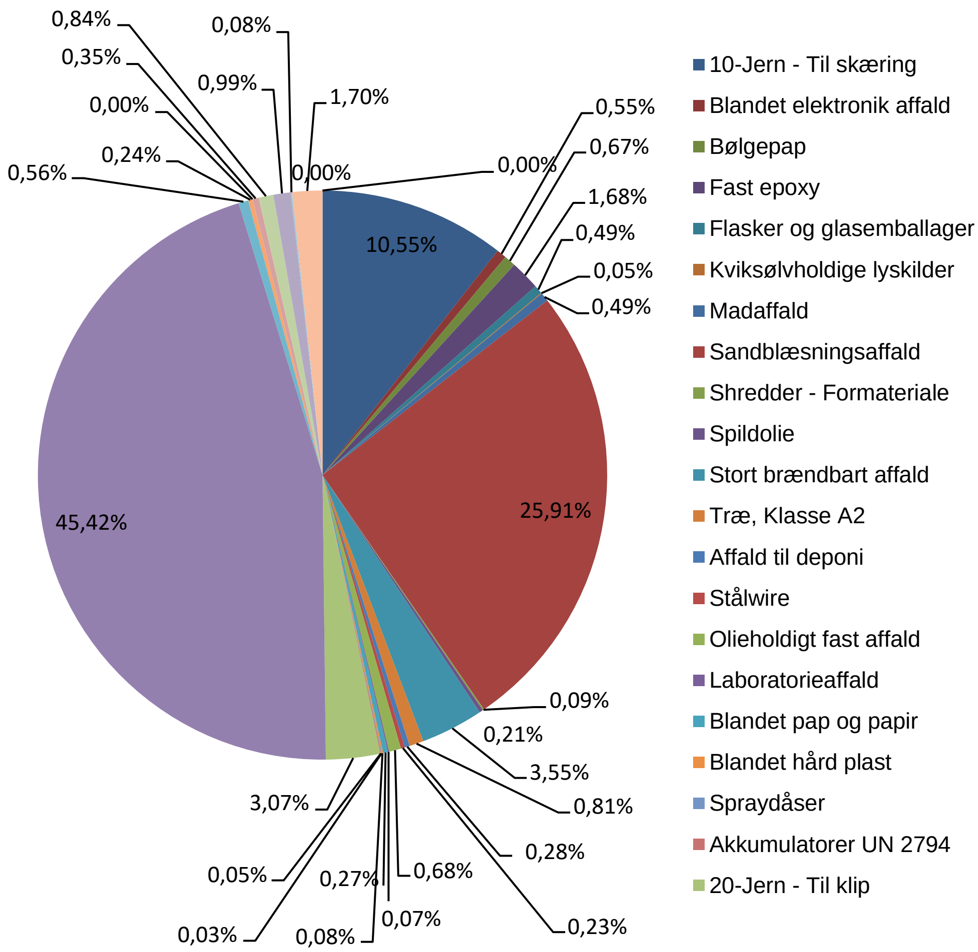


Figure 5-13 Waste generated at South Arne divided into waste categories by weight (2021).

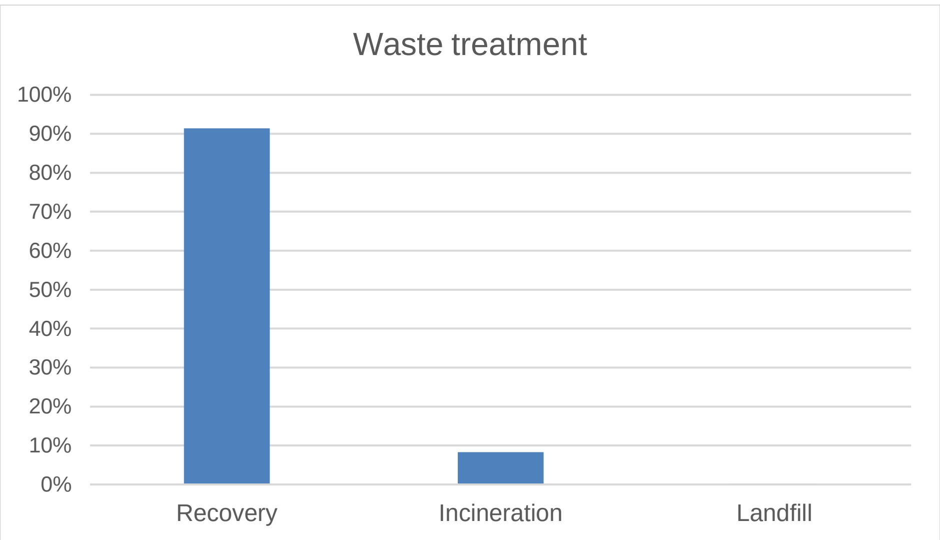


Figure 5-14 Information about treatment of waste from South Arne (2021).

5.7.3 Waste during decommissioning

Waste generated during decommissioning is mainly related to the offshore structures to be removed to shore for dismantling and recycling or reuse at an approved decommissioning yard in the North Sea region. Approx. 11,000 tons material is transported to shore, cf. section 0. The main waste fraction from the structures is steel.

Also, household waste from the vessels and rig performing the decommissioning work will be generated, as well as approx. 3,000 tons OBM waste from the P&A activities. All waste will be transported to shore for further treatment.

6. Description of the existing environment

This chapter describes the physical, biological, ecological and human use features and conditions in the North Sea, which are relevant for the assessment of impacts during the construction, operation and decommissioning phases of the Hejre tie-back to the host platform South Arne.

Please note that a full description of the existing environment can be found in the approved EIAs for Hejre Legacy and South Arne. This chapter updates these previous descriptions with the latest surveys in order to conduct the environmental assessments on the best possible foundation. However, this chapter focuses on describing the existing environment for those aspects that are potentially impacted by the activities described in this EIA Addendum.

6.1 Bathymetry

6.1.1 Bathymetry and water depths

The Hejre tie-back to the host platform South Arne is located centrally in the North Sea around 300 km west of Jutland. Both oil fields are situated northeast of the Dogger Bank on water depths around 62-73 m (Table 6-1).

Table 6-1 Water depth at Hejre (Dong E&P 2013) and South Arne (INEOS 2022).

Field	Water depth (m)
Hejre	68 – 73
South Arne	62

6.2 Hydrographical conditions

The North Sea is a semi-enclosed sea. The currents are mainly driven by the topography and determined by the water inflow from the North Atlantic through the English Channel, river outflow and the out-going currents from the Baltic Sea. The general circulation of the tidal currents in the North Sea are characterised by a strong north going current along the continental coast and an east going current in the central North Sea (Otto et al. 1990).

The prevailing currents at the Hejre and South Arne fields are east-going (Figure 6-1).

Hydrographical fronts are created where the different water masses meet and include upwelling, tidal fronts and saline fronts:

- "**Tidal fronts**", which are found in areas between stratified water masses and water, which is fully mixed due to tidal currents. Such fronts are developing in the western and southern parts of the North Sea during the summer;
- "**Upwelling fronts**" which may be encountered in areas along the coast where the water masses are stratified. The front develops when the wind blows surface water away from the coast and thereby forcing bottom water to the surface. Such fronts are frequently developing in Kattegat, Skagerrak and along the Norwegian coast;
- "**Salinity fronts**" are found in areas where high salinity water masses meet water masses with lower salinity.

Hydrographical fronts are generally high productive areas since nutrients are brought from the seabed to the surface waters. The Hejre tie-back to South Arne is located outside areas with the potential to develop hydrographical fronts and is consequently a low productive area (Edelvang et al. 2017, OSPAR 2000). Areas with hydrographical fonts are shown on Figure 6-1.

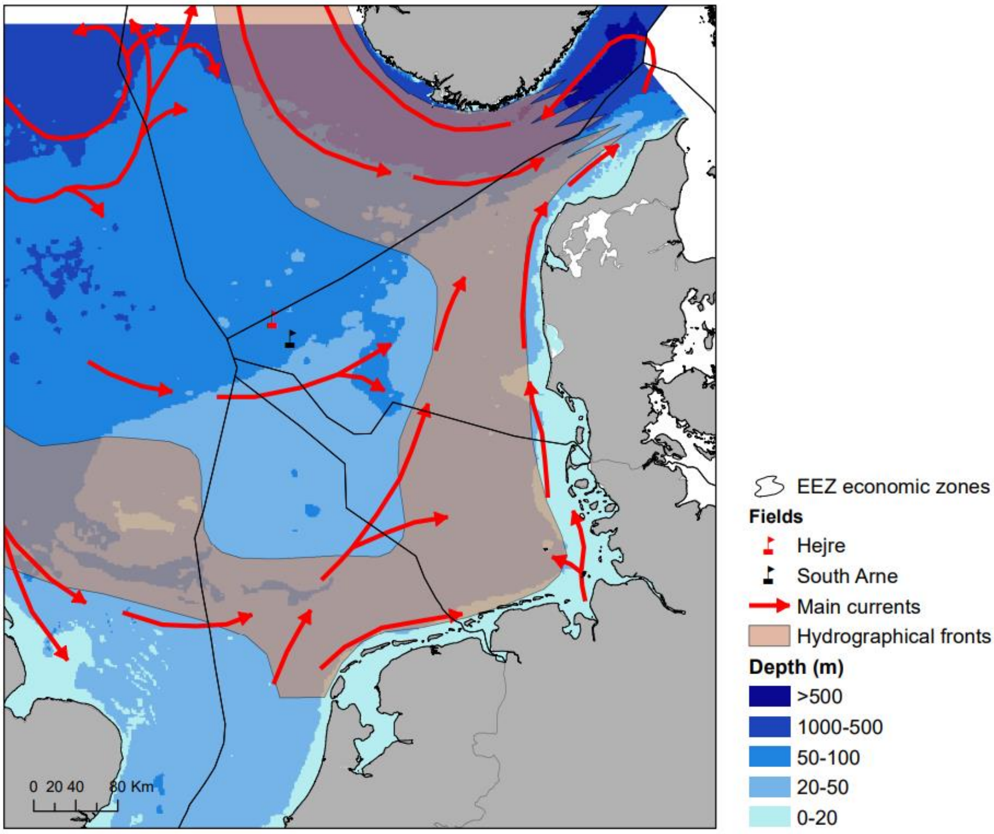


Figure 6-1 General circulation of surface currents in the North Sea and the location of areas in the North Sea where hydrographical fronts may develop (OSPAR 2000).

6.2.1 Thermocline

The water masses around the Hejre and South Arne oil fields are fully mixed during winter (OSPAR 2000). During the summer period, the sun heats up the upper water layers in the central and northern North Sea including the area of Hejre and South Arne. A thermocline is developed, which separates the upper and lower water masses (van Leeuwen et al. 2015). The separation is due to differences in density and prevents exchange of nutrients and oxygen between the water masses. During the autumn, storms and cooling of the surface waters breaks down the thermocline and the water masses are mixed again.

In more shallow waters of the southern and eastern parts of the North Sea, the water masses remain mixed during the summer due to strong currents (van Leeuwen et al. 2015).

6.3 Water quality

An integrated assessment of the chemical status in Europe's seas has recently been published (EEA 2018) and it is concluded that most assessment units in the Danish part are classified as "problem areas" and thereby not fulfilling the objective of a good environmental status according to the EUs Marine Strategy Framework Directive. This impaired state is caused by a combination of input of contaminants from sources on both land and sea, in addition to input from atmospheric deposition. However, there is a general tendency for the water quality to be less problematic the further away from land, and both Hejre and South Arne are located quite a distance from the nearest land.

The implementation of EUs Marine Strategy Framework Directive requires an assessment of the environmental status in the North Sea (among others). For contaminants the objective of achieving a good environmental status is currently not achieved due to an exceedance of the threshold levels in fish for PBDE and mercury (Ministry of Environment and Food 2019).

6.4 Seabed

The oil- and gasproduction operators in the Danish part of the North Sea conduct monitoring of the seabed at selected platforms every three years. This chapter is in general based on this long term monitoring, except for the general section "Sediment composition in the North Sea".

The most recent biological and chemical monitoring of the seabed around the South Arne platform was conducted during the period 6-12 June 2021. At South Arne monitoring has previously been conducted in 1997, 2002, 2006, 2009, 2012 and 2018.

The most recent and to date the only monitoring around Hejre was conducted in 2013. The results from this baseline monitoring has not been assessed in relation to the descriptors in the Marine Strategy Framework Directive. It is expected though, that Hejre will be comparable to the general findings for the area.

The monitoring of the chemical and biological conditions of the seabed around South Arne serves as basis to describe the conditions for the following descriptors according to the Danish Marine Strategy II:

- Descriptor 1: Biodiversity (state descriptor)
- Descriptor 2: Non-indigenous species (pressure descriptor)
- Descriptor 6: Seafloor integrity (state and pressure descriptor)
- Descriptor 8: Contaminants (pressure descriptor)

6.4.1 Benthic Fauna and Biodiversity (D1)

The benthic fauna includes invertebrates living in and on the surface of the seabed. The benthic fauna mainly includes species of bristle worms, bivalves, snails, echinoderms and crustaceans.

Bivalves, echinoderms and polychaetes are the most important components of the benthic biomass. The most abundant species included the bristle worms *Myriochele oculata (=Galathowenia oculata)*, *Spiophanes bombyx* and *Paramphius jeffreysii* and the echinoderm *Amphiura filiformis.* These findings comply with findings of Reiss et al. (2010).

During the June 2013 baseline survey at the Hejre field, 115 benthic fauna species were found with an average of 47 species per m² (DONG E&P A/S 2013). Bivalves and echinoderms dominated the biomass, contributing to 50% and 34% of the total fauna dry weight, respectively.

Polychaetes were the most species rich group making up 47% of the species followed by crustaceans (18%) and bivalves (12%) at Hejre (Figure 6-2). Similar species composition was found at the reference station. A sum of 277 individuals were found per 0.1 m². Polychaetes made up 82% of the abundance (Figure 6-2). In comparison, polychaetes made up 78% of the benthic fauna abundance at Ref.N-0-13.

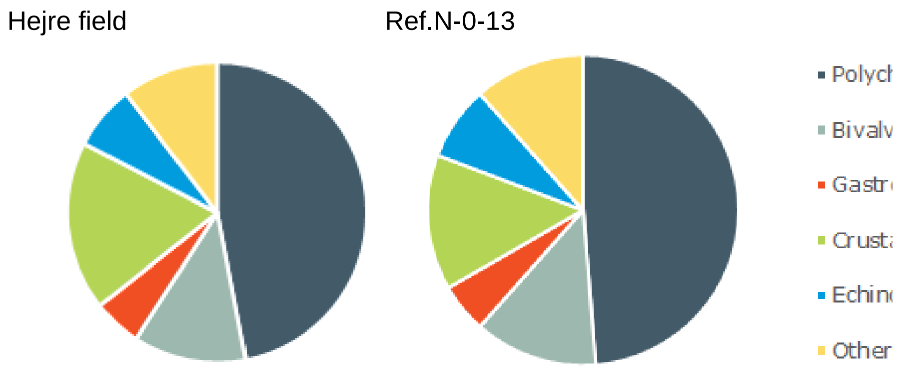


Figure 6-2 Benthic fauna composition at the Hejre field and reference station Ref.N-0-13p monitored in 2013 (DONG E&P 2013). The data is presented as species richness in percentage.

The seabed at and around the South Arne platform has no hard substrates but consists of a flat sandy seabed. The benthic fauna consists therefore mainly of benthic infauna, that is species living in the sediment rather than on the seabed.

On average a total of 31 (± 5 SD) species were found for all monitoring stations and there was no significant change in the number of species in relation to the distance from the South Arne platform. In contrast, the number of individuals was on average higher at the monitoring stations closer to the platform – up to a distance of 750m as the values at 1500m and 3000m were comparatively lower (INEOS E&P A/S 2022).

The species diversity seems to be lower around the South Arne platform compared to the reference station (Figure 6-3). Further there seems to be an increase in species diversity with increased distance from the platform.

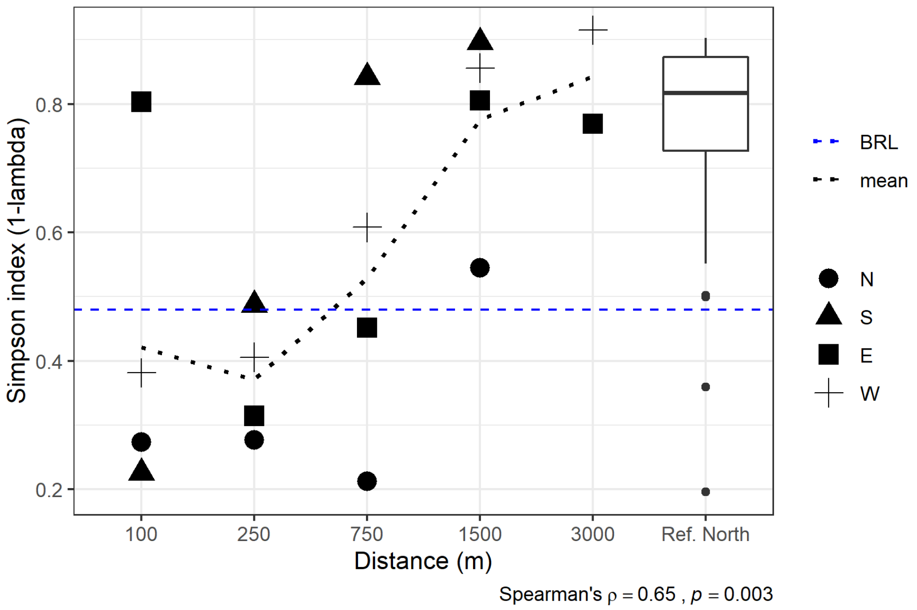


Figure 6-3 Species diversity expressed by the Simpson index, 1-λ', based on sample sizes of 0.1 m², at the stations around the South Arne platform (INEOS E&P A/S 2022). Note that the box plot represents the historical data from reference stations in the northern region of the Danish sector (Ref.North, including Ref.N.21), showing the 2.5, 25, 50, 75 and 97.5 percentiles. Black dots for Ref.North represent outliers.

An analysis of the 10 most important species, contributing most to the difference in abundance between the monitoring stations around the South Arne platform, has been performed and the results can be seen in Table 6-2.

Table 6-2 Overview of the 10 most important species contributing most to the differences between stations (on average) around the South Arne platform (INEOS E&P A/S 2022).

Species	**Contribution (%)**
Galathowenia oculata	16.3
Spiophanes bombyx	2.6
Mediomastus fragilis	2.3
Aonides paucibranchiata	2.3
Edwardsia sp.	2.2
Actiniaria	2.2
Pectinaria koreni	2.2
Ophiura sp.	2.1
Paramphinome jeffreysii	1.9
Nemertea	1.8

It is noted, that in the existing Danish Marine Strategy II (Ministry of Environment and Food 2019) a good environmental status (GES) has not been establised for D1. An environmental index for Biodiveristy (D1) has therefore been calculated and can be seen in Figure 6-4. There is a significant change in the environmental index with distance from the South Arne platform, with the lowest score close to the platform. This is due to a lower score of both species richness and species diversity close to the platform.

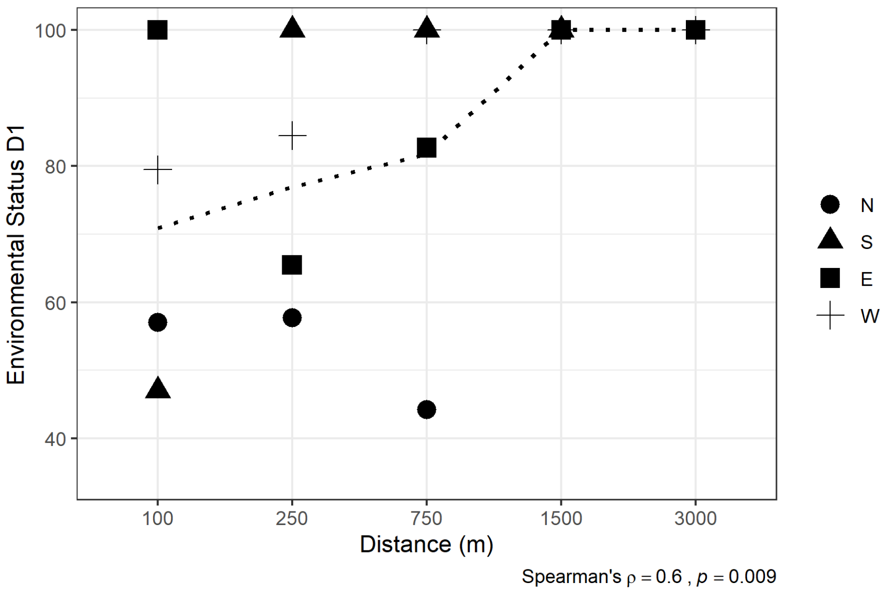


Figure 6-4 An environmental index for biodiversity (D1) where the dotted line represents the mean index across stations at the same distance from the South Arne platform (INEOS E&P A/S 2022).

6.4.2 Non-indigenous species (D2)

Non-indigenous species (NIS) are not as such a part of the regular monitoring performed by the operators, thus specific information on NIS are derived from two external resources, namely AquaNIS (information system on aquatic non-indigenous and cryptogenic species) and EASIN (European Alien Species Infor-mation Network). The species found at South Arne platform was compared to the species within the two databases and revealed the presence of one NIS at 5 stations, namely the bristle worm *Glycera celtica*. The 5 stations where *G. celtica* was found are all located close to the platform (≤750m) (INEOS E&P A/S 2022).

It is noted that in the existing Danish Marine Strategy II (Ministry of Environment and Food 2019) a good environmental status (GES) has not been establised for D2. An environmental index for non-indigenous species (D2) has therefore been calculated for the South Arne platform and can be seen in Figure 6-5. An environmental value of 100 indicates no non-indigenous species, so the closer the index is to 100 the less of an impact there is from non-indigenous species. As all the specimens of *G. celtica* were found close to the platform, there is an increase in the environmental index with distance from the platform.

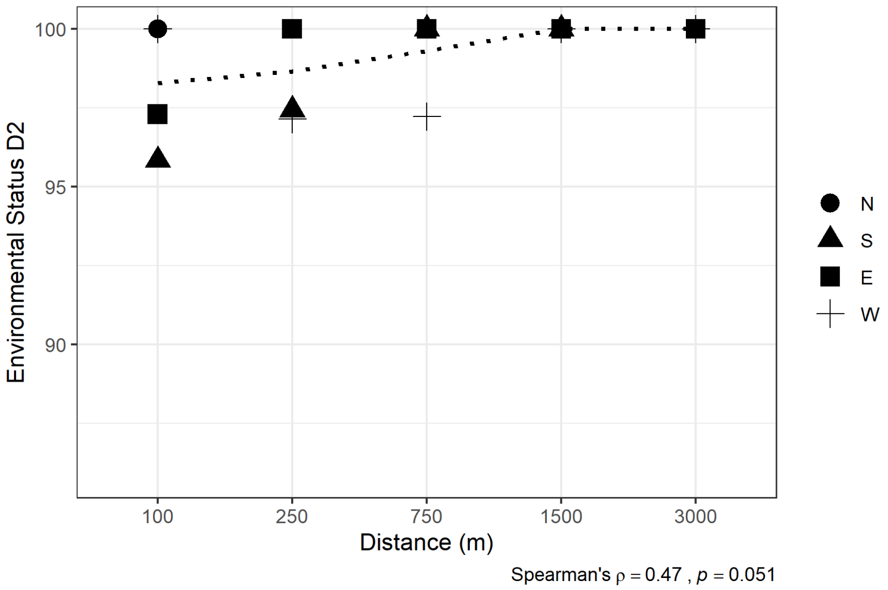


Figure 6-5 An environmental index for non-indigenous species (D2) where the dotted line represents the mean index across stations at the same distance from the South Arne platform (INEOS E&P A/S 2022).

6.4.3 Seabed Integrity (D6)

The AZTI Marine Biotic Index (AMBI) is used to describe the seafloor integrity. AMBI values can range between 0 and 7, where a value of 7 represents an azoic condition, i.e. where no macrobenthic organisms are present.

AMBI has been calculated for all monitoring stations around the South Arne platform including a regional reference station (Figure 6-6).

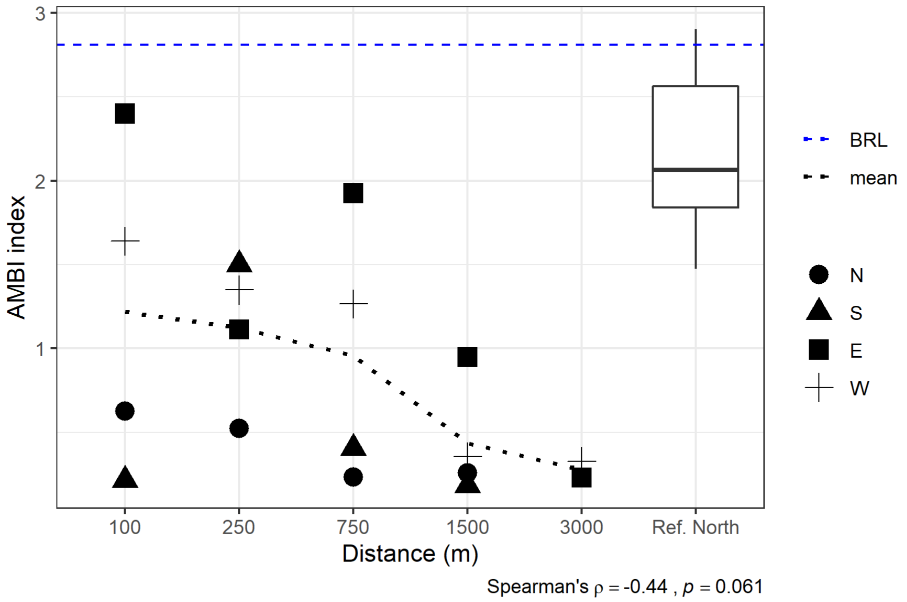


Figure 6-6 AMBI calculated for the stations around the South Arne platform (INEOS E&P A/S 2022). Mean value trends are indicated by the black dashed line. BRL: Background Reference Levels. The box plot represents the historical data from reference stations in the northern region of the Danish sector.

The average AMBI at the platform stations (0.86; SD = 0.68) was slightly higher (indicating fewer good conditions, see above), compared to the average of the regional reference stations (0.76). However, the AMBI changed significantly between monitoring stations and distances to the platform, with the eastern stations having the highest AMBI at most monitoring stations (indicating least good conditions). All monitoring stations had an AMBI well below the Background Reference Levels (BRL). There was a trend for a negative correlation of AMBI index to the distance to the South Arne platform, however it was not a significant trend due to high variability within the distances (INEOS E&P A/S 2022).

It is noted, that in the existing Danish Marine Strategy II (Ministry of Environment and Food 2019), a good environmental status (GES) has not been establised for D6. An environmental index for Seabed Integrity (D6) around the South Arne platform has therefore been calculated and can be seen in Figure 6-7. All monitoring stations scored an index value of 100 and therefore a general pattern for all platform stations cannot be established.

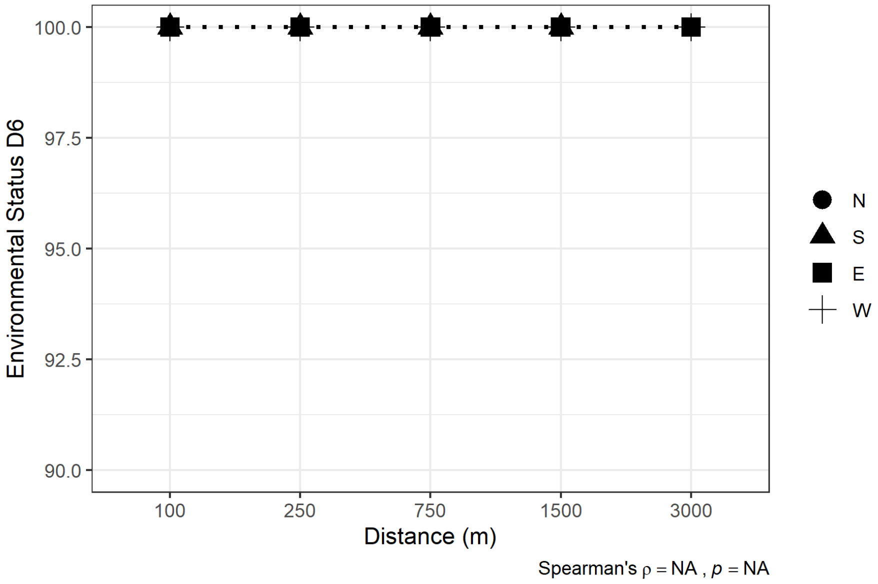


Figure 6-7 An environmental index for seabed integrity (D6) where the dotted line represents the mean index across stations at the same distance from the South Arne platform (INEOS E&P A/S 2022).

6.4.4 Sediment composition in the North Sea

The Danish sector of the North Sea is characterized by a sandy or sandy to muddy sediment. A few areas have silt or coarse sediment. The substrate type at the Hejre and South Arne fields is categorised as "mud to muddy sand" (Figure 6-8).

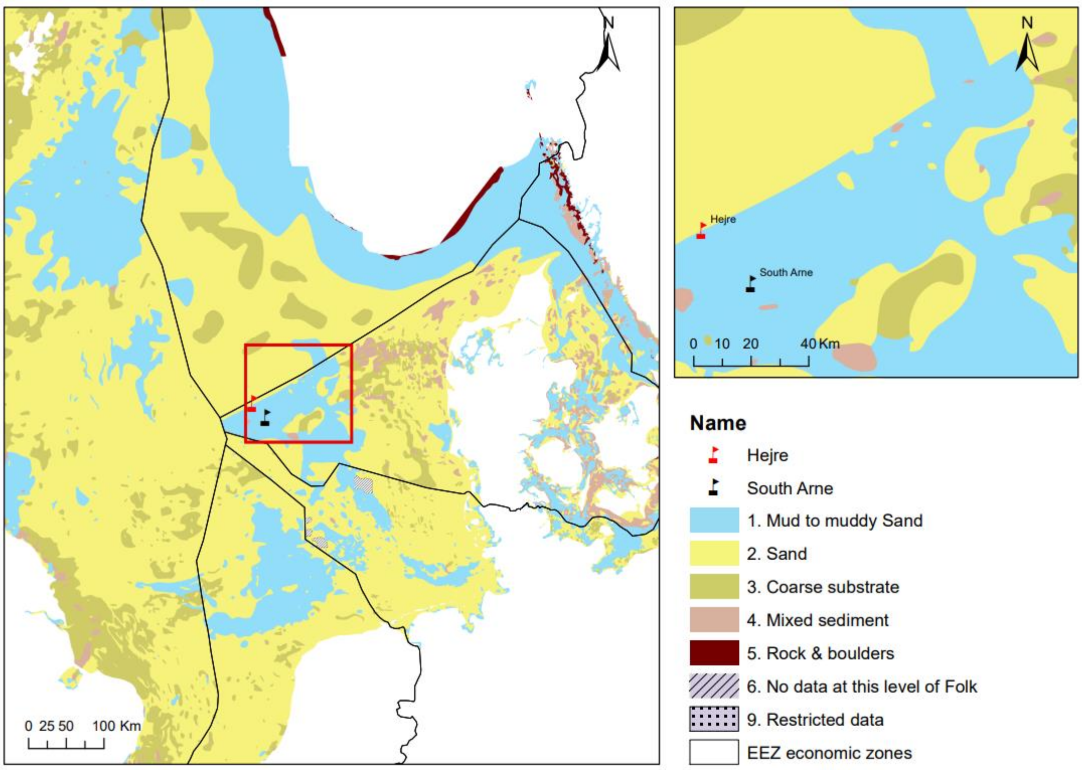


Figure 6-8 Substrates in the North Sea with indication of the project area. EMODnet reclassification substrate (GEUS2019). Note that classification of substrate may vary between national borders.

6.4.5 Sediment composition and sediment quality at Hejre and South Arne

Baseline descriptions of the composition of sediments and sediment quality at the Hejre and South Arne fields are based on monitoring data collected in 2013 at the Hejre field (DONG E&P A/S 2013) and in 2021 for the South Arne platform (INEOS E&P A/S 2022). The monitoring stations (24 stations) were positioned in a classical cross-design used by oil and gas operators since 1989. The stations are compared to a reference station (Ref.N) located approx. 12-39 km from the fields. In general, it has been found that the benthic fauna is not affected beyond 1500 meters from the platforms and that the local reference stations have good environmental status according to the MSFD (Oil & Gas Denmark 2017). Based on this, the local reference station is considered as appropriate background reference.

6.4.5.1 Sediment composition

A baseline survey was conducted at the Hejre field in May 2013 after the area has been explored, but before any drilling or construction activities took place. The investigation revealed a sediment consisting of fine sand with a very low content of organic material (DONG E&P A/S 2013). The grain size of the surface sediment was 0.17 ± 0.01 mm. Fine brown sand was found at all stations in the upper 2 cm of the sediment. Below the surface layer, grey sand with or without shells was found. Black spots in the sediment were found at one station indicating locally anoxic conditions.

The concentration of organic material measured as loss on ignition (LOI) was measured to 0.79 ± 0.13% with increasing concentration with distance from the Hejre field. The higher concentration of organic matter is caused by accumulation of organic material at the deeper stations, which are found in the periphery of the sampling area.

Smell of dissolved hydrogen sulphide (H_2S) was not detected confirming generally oxic conditions. Oil smell was observed, but the source is unknown.

Monitoring around the South Arne platform in 2021 (INEOS E&P A/S 2022) revealed that the seabed can be characterised as "fine sands". This characterization is based on a grain size analysis and the variation between the samples was relatively low with a median size (D50) of around 0.16 (± 0.003 mm SD). The colour of the surface sand was generally grey where the depth of oxidised sediment was between 3-7 cm. Some of the stations had a smell of hydrogen sulphide (H_2S) indicating anoxic conditions.

6.4.6 Contaminants (D8)

6.4.6.1 Contaminants in sediments

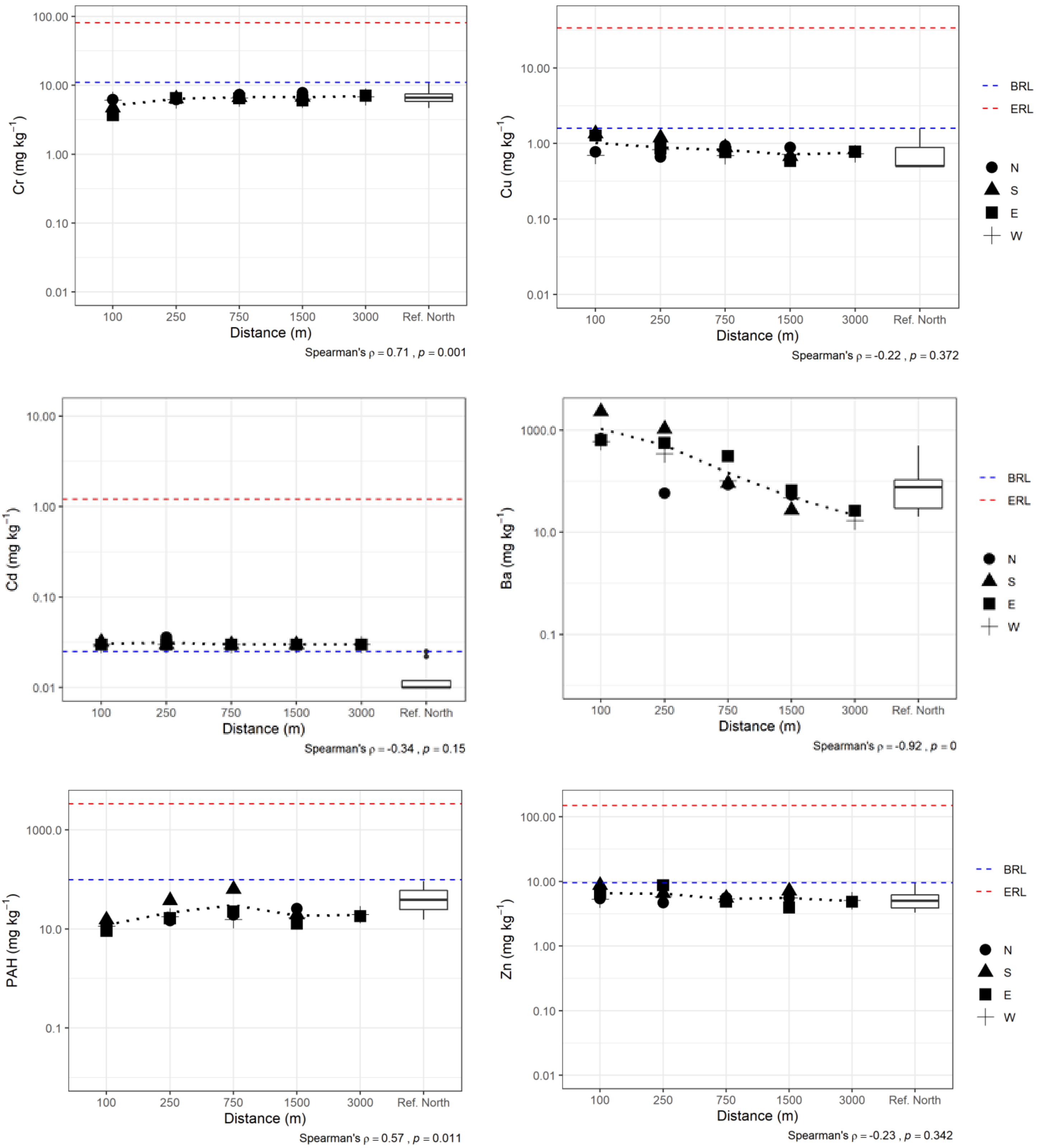
The 2013 baseline survey (DONG E&P A/S 2013) at the Hejre field included the following contaminants: Polyaromatic Hydrocarbons (PAH), sum of naphtalenes, phenanthrenes and dibenzthiophenes (NPD), Total hydrocarbons (THC) and heavy metals: Barium (Ba), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Lead (Pb) and Zinc (Zn). A reference station (Ref.N-15-0) located 39 km northeast of the Hejre field was used to estimate the Background Reference Level (BRL).

Absolute concentrations of PAH, NPD and heavy metals were below the assessment criteria (ERL). Overall, there were no difference between samples from the Hejre field and the reference station. The concentration of THC was under detection level (1 mg/kg) at most stations. However, at the most northerly station THC were significantly above detection level, but still below the assessment criteria (ERL).

Few stations at the Hejre field had increased level of Barium. Ba is a component of drilling mud and the enhanced levels may be due to previous drilling activities. Concentrations of Ba in the sediment profiles (0-10 cm) was between 38 and 180 mg/kg DW. Ba is not toxic, and therefore no assessment criteria are defined. Levels above ca. 10 mg/kg DW are considered above natural level.

Absolute concentrations of Cd, Cr, Cu, Zn and Pb were well below ERL and Lower Action Level for dumping of seabed material defined by the Danish EPA, and thus characterised as having no expected negative impact on marine organisms. Furthermore, Pb concentrations were all below detection level.

An assessment of contaminants in the sediment around the South Arne platform was conducted in 2021 (INEOS E&P A/S 2022). Chemical analysis was conducted for a range of parameters and the results can be seen in Figure 6-9.



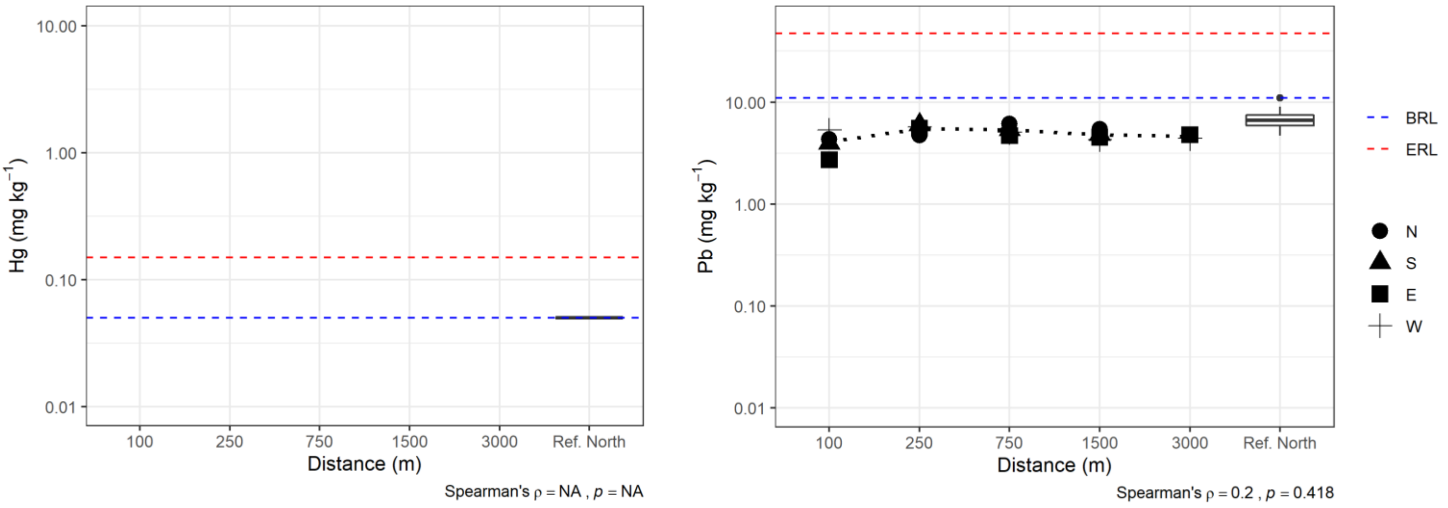


Figure 6-9 Concentrations of contaminants, metals and PAHs around the South Arne platform. The concentrations are in the surface sediment (0-1 cm)(INEOS E&P A/S 2022). Mean values are indicated by the black dashed line. BRL: Background Reference Levels (blue dashed line). ERL: Effects Range Low (red dashed line). PAHs included: Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(ghi)perylene, Chrysene/triphenylene, Dibenzoetiophene, Fluranthene, Indeno(1,2,3)pyrene, Naphtalene, Phenanthrene, Pyrene/thiphenylene.

For the heavy metals all concentrations were below the HELCOM/Danish Targets. For one metal, Barium, the concentration was at certain locations above the TEL (low range for potential toxicological effect) and significantly higher near the South Arne platform (Figure 6-9). There is however no ERL (Effects Range Low) available for Barium.

Similarly, for the hydrocarbons all concentrations were below the HELCOM/Danish Targets and potential effect levels, with the exception of Anthracene in one location (100m east of South Arne). However, as Anthracene (and other PAHs) binds to the organic component in the sediment, it relates proportionally to the TOC concentration. As the TOC concentration is very low around South Arne and particularly at the specific location 100m east of South Arne, both the TOC and Anthracene concentrations are close to the LoQs. Thus, the exceedance is not considered to be significant. One or more of the summed parameters (THC, ΣPAH_{EPA16} and ΣNPD) showed elevated concnetrations at the southern stations closest to the platform (100-750m). At these location the smallest of the PAHs Naphthalene was also detected.

In general, there were no correlation between distance from the South Arne platform and the concentration of metals, except for barium which tends to decrease in concentration with distance from the platform. Barium is associated with drilling activities.

Threshold valuse for 4 substances (PFOS, PBDE, benz(a)pyren and mercury) has been defined to describe Good Environmental Status, however these threshold values are based on concentrations in fish and mussels. These concentration have not been established as part of the regular monitoring program and therefore an environmental index for contaminants (D8) has been calculated and can be seen in Figure 6-10. The score was calculated to 98 at all stations except for the southern monitoring station located 750m from the South Arne platform, at this station most of the individual PAHs were higher than BRL. In relation to distance from the platform, no significant correlation was determined.

The main cause of the uniform score of 98 was mainly caused by the Cadmium load which was below the limit of quantification (0.1 mg/kg DW), corresponding to a limit of detection of 0.03 mg kg^{-1} on all stations at the South Arne platform. The BRL is 0.01 mg kg^{-1}, lower than the presented concentration levels, which then yields a score of 98 (INEOS E&P A/S 2022).

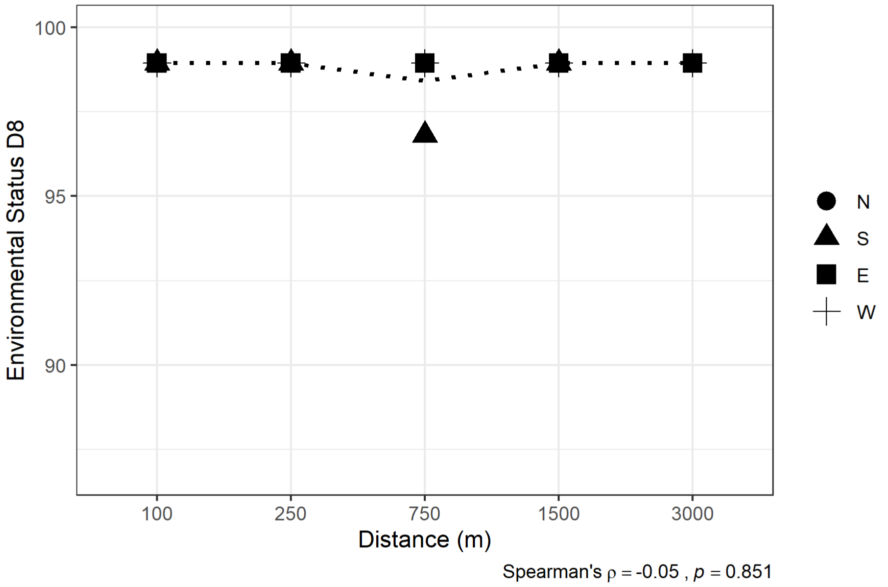


Figure 6-10 An environmental index for contaminants (D8) where the dotted line represents the mean index across stations at the same distance from the platform (INEOS E&P A/S 2022).

6.4.7 Environmental Status (ES)

Four MSFD descriptors have been assessed for the South Arne field above: Descriptor 1: Biodiversity, Descriptor 2: Non-indigeneous species, Descriptor 6: Seafloor integrity and Descriptor 8: Contaminants, each described by indicators, which were scored against a specific Background Reference Level (BRL) to give an indicator-index value. This index-value (environmental index) can score between 0-100, where the value 100 is when the pressure or state is comparable or superior to conditions described for the BRL-value. The indicator-index values were combined to an index (score) describing the environmental status (ES).

The Environmental Status Score (EnS) was on average for all stations 94 ±8 and was significant dependent on the distance to the South Arne platform. At 100m distance to the platform the average EnS was 89 while further away the average EnS was 100, however these scores exhibit large variation for each distance depending on the direction (Figure 6-11).

The northern direction had a lower than 90 EnS on all stations besides at 1500m distance, while west had a lower than 95 EnS on the two closest stations. Southern stations only had the station closest to platform an EnS of 79 while all other stations scored 100. Eastern stations showed EnS without a trend of distance dependency, interchangeably lower than average scores dependent on distance.

The overall Environmental Status score (EnS) at the South Arne platform showed that most stations scored on average 94, indicating a 'good' environmental status.

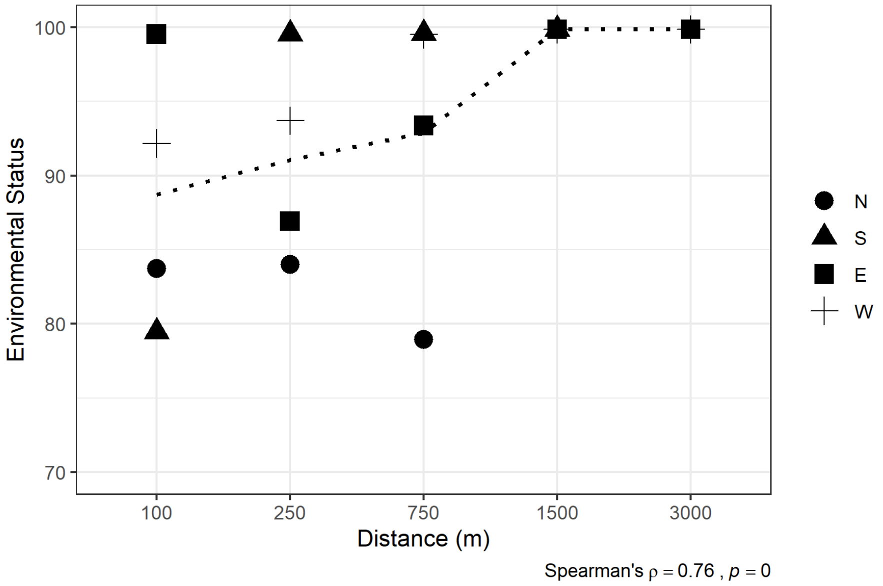


Figure 6-11 Environmental Status Score for each monitoring station and each distance, where the dotted line represents the mean index across stations at the same distance from the South Arne platform (INEOS E&P A/S 2022).

The ES of the Hejre field has not been assessed after the MSFD and the EnS is therefore unknown. However, the results from the baseline study prior to drilling activities is assessed to correlate with the conditions at the reference station (Ref.N).

6.5 Ecological conditions

6.5.1 General characteristics

The Hejre and South Arne fields are low productive areas and with low value for fish larvae and juvenile fish (although spawning takes place in the area), and the density of seabirds is low.

In the following, the ecological conditions in the project area are described in more detail.

6.5.2 Primary production

Hejre and South Arne are situated in an area with low primary production. This is due to the lack of hydrographical fronts and strong stratification of the water column in the productive summer season, which result in quick depletion of nutrients in the surface waters (Peeters & Peperzak 1990).

In the coastal areas of the North Sea, fronts may develop creating high productive areas (OSPAR 2000, Edelvang et al. 2017). In addition, runoff of nutrient rich water from land supports high primary production in the coastal areas.

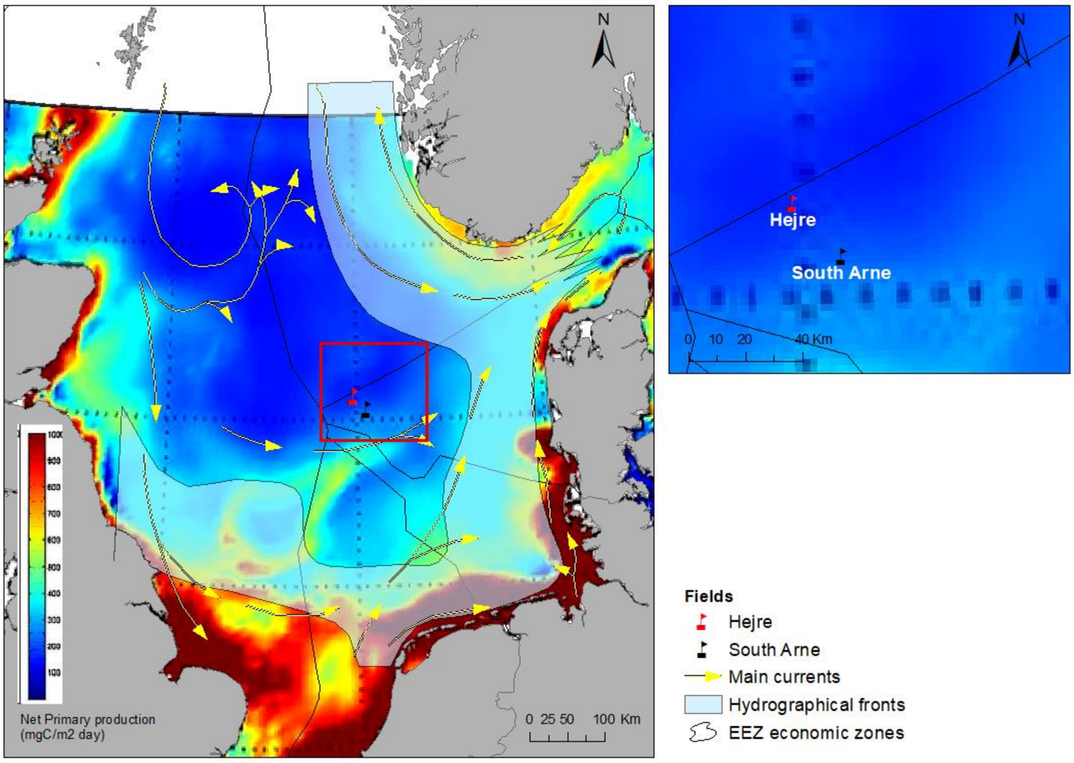


Figure 6-12 Net primary Production (mg m^{-2}d^{-1}), modelled yearly average for a representative year (OSPAR 2000).

6.5.2.1 Plankton

Plankton constitutes the base of the trophic food web and includes phytoplankton (pelagic microscopic algae) and zooplankton (pelagic microscopic animals) drifting passively with currents. Zooplankton includes both organisms that stay planktonic during the entire life cycle (holoplankton) and organisms that are only planktonic in the earliest life stages (meroplankton) such as larvae of fish, sea urchins, starfish, mussels, bristle worms, shrimps, crabs and lobsters.

6.5.2.2 Phytoplankton

Phytoplankton blooms occur during spring in the entire North Sea as the light returns and the water masses become stratified. Diatoms and autotrophic dinoflagellates dominate the phytoplankton in the North Sea. During summer, the biomass of plankton decreases due to stratification of water columns and the depletion of nutrients in the surface waters. A minor bloom is often observed during the autumn, when the waters are mixed again, and nutrients are again available in the surface waters.

6.5.2.3 Zooplankton

Copepods dominate the zooplankton in the North Sea. Copepods are food for fish and other organisms, including larvae, juveniles and mature individuals of many commercially important fish species such as herring and sprat. The composition of the copepod populations in the North Sea is dominated by *Calanus finmarchicus* and *C. helgolandicus.*

6.6 Fish

Approximately 230 fish species are found in the North Sea. Compared to other areas in the North Sea, the diversity is low, but increases westwards towards the coast. The fish species in the North Sea can be grouped in pelagic species (species living in the free water masses) and demersal (bottom dwelling) species. Biology and distribution patterns of common species are described below.

6.6.1 Pelagic species encountered in the project area

Pelagic species commonly found in the Danish sector of the North Sea include Herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and mackerel (*Scomber scombrus*). The biology of these species is described in Table 6-3.

Table 6-3 Biology of the dominating pelagic fish species that may be encountered at Hejre and South Arne.

Species	Distribution and biology	References
Herring *(Clupea harengus)* 	Herring is numerically one of the most important pelagic schooling species in the North Sea and is an important commercial species. Herring may be found all over the North Sea. They form large shoals, which tend to remain close to the seabed during the day. At dusk, the herring follow their prey (zooplankton), move towards the surface, and disperse over a wider area during the night. There are several different stocks of herring in the North Sea of which, the Orkney-Shetland, Bucan, Bank and Downs stocks represent the bulk of the stocks. During the spawning season the different stocks migrate to specific spawning grounds. Peak: December-January). Herring deposits its sticky eggs on coarse sand, gravel, shells, rocks or stones on the seabed. After hatching larvae drift with the currents south and eastwards towards nursery areas in the Skagerrak and along the Danish coast to Southern Bight.	ICES 2019a, Sundby et al. 2017, Warnar et al 2012, Schmidt et al. 2010, Worsøe et al. 2002
Sprat *(Sprattus sprattus)* 	Sprat is a small-bodied pelagic schooling species that is mainly landed for industrial processing. Sprat is most abundant in the eastern part of the central North Sea, in the southern North Sea and in the Kattegat. Sprat spawning areas extent through the southern North Sea, the German Bight, the west coast of Jutland and in Kattegat. Spawning also occurs northwards along the English and Scottish coast. The main spawning areas are found in the German Bight, in the Southern Bight and in the English Channel. Spawning occurs during spring and late summer, with peak spawning during the period May - August. Sprats are multiple batch spawners with females spawning repeatedly throughout the spawning season (up to 10 times in some areas). The eggs and larvae are pelagic.	ICES 2019a, Sundby et al. 2017.
Mackerel (*Scomber scombrus*) 	Mackerel are widespread throughout the North Sea. During winter, both immature and mature mackerel tend to be more abundant along the edges of the continental shelf and the Norwegian Deeps, as well as the central parts of the North Sea. Abundance increases during the summer, when mackerel enter the Southern Bight through the Channel and the northern North Sea around Scotland. Mackerel make extensive annual migrations between feeding, wintering and spawning areas. Spawning occurs in the central and northern North Sea between May and July with peak spawning in June. Eggs and larvae are pelagic.	ICES 2019a, Sundby et al. 2017 and Worsøe et al. 2002.

6.6.2 Demersal species encountered at the project area

The abundance of demersal (bottom dwelling) fish species in the project area is relatively low compared to other areas in the North Sea (ICES International Bottom Survey database, Reiss et al. 2010). The typical demersal fish species found at 50-100 m depth in the central North Sea include whiting (*Merlangius merlangus*), haddock (*Melanogrammus aeglefinus*), dab (*Limanda limanda*), long rough dab (*Hippoglossus platessoides*), plaice (*Pleuronectes platessa*) and grey gurnard (*Eutrigla gurnardus*). It should, however, be noted that the abundance of haddock is larger in the northern North Sea, compared to the central North

Sea. Cod (*Gadus morhua*), lemon sole (*Microstomus kitt*) and sandeel (*Ammodytes/Hyperoplus* sp.) are also relatively common.

The basic biology of these species is described in Table 6-4, Table 6-5 and Table 6-6.

Table 6-4 Biology of demersal cod fish species that may be encountered at Hejre and South Arne.

Species	Distribution and biology	References
Cod *(Gadus morhua)* 	Cod may be encountered within the project area although the area is not a core area for cod. South Arne is situated in a spawning area for cod (Figure 6-15). The spawning season is from the beginning of January to May and peaking in January – February. After spawning, the eggs are found floating near the water surface over large areas. The eggs hatch within 2-3 weeks, depending on water temperature. The pelagic eggs drift with the prevailing east, northeast and north going currents to nursery areas for larvae, which are mainly found in German Bight, north of German Bight, Jutland Bank, Great- and Little Fishing Bank and along the Norwegian Trench into Skagerrak. These areas are characterised by the formation of hydrographical fronts with high concentrations of zooplankton on which the larvae feed.	ICES 2019a, Sundby et al. 2017, Knutsen et al. 2004, Munk et al. 1999, Munk et al. 1995.
Haddock *(Melanogrammus aeglefinus)* 	Haddock is widespread throughout the deeper waters of the temperate northern Atlantic, shoaling loosely at depths from around 40 to 300 m with a preference for depths between 75 and 125 m. In the Norths Sea the bulk of haddock is found in the northern parts. Haddock may be encountered at Hejre and South Arne, but the area is not a core area for the species. Spawning takes place, at depths of 100 to 150 m in the northern part of the North Sea. Spawning period is from February to May, with peak spawning in March – April. Eggs and larvae are pelagic.	ICES 2019a, Sundby et al. 2017, Worsøe et al. 2002.
Whiting *(Merlangius merlangus)* 	Whiting is widely distributed throughout the North Sea, Skagerrak and Kattegat. High densities of whiting are found along the UK east coast, the southern and central North Sea (except the Doggerbank) and Kattegat Skagerrak The spawning areas of whiting are wide ranging and are distributed over much of the North Sea from Viking Bank-Shetland in the North to the English Channel in the south. Neither Hejre nor South Arne are located in a spawning area for whiting. However, as spawning areas for fish are not static and fixed delimited areas, it is very likely that whiting in fact spawns at these fields. Spawning takes place from March to June. Eggs and larvae are pelagic.	ICES 2019a, Sundby et al. 2017.

Table 6-5 Biology of flatfish species that may be encountered at Hejre and South Arne

Species	Distribution and biology	Reference
Plaice (*Pleuronectes platessa*) 	Plaice generally inhabits relatively soft substrata and are most abundant on water depths between 10 and 50 m. In the North Sea plaice is most abundant in the central and southern parts. Hejre and South Arne are situated in a plaice spawning area (Figure 6-16). Spawning takes place from December until March (peak: January and February). The pelagic eggs and larvae are transported by the currents, mainly in the eastern and north-eastern directions. During the transport larvae gradually meta-morphose and obtain the typical flatfish form. The juveniles settle on the seabed in in nursery areas in shallow inshore waters. The nursery areas in the Wadden Sea are of especially importance.	ICES 2019a, Sundby et al 2017 and Bromley 2000.
Dab *(Limanda limanda)* 	Dab is the most abundant flatfish species in the North Sea and is distributed over the whole of the North Sea in waters down to a depth of about 100 m. Dab spawn in the Central and Southern North Sea. As spawning areas for fish are not static and fixed delimited areas, it is likely that dab also spawns at these fields. The spawning takes place from April to June.	ICES 2019a, Sundby et al 2017.
Long rough dab *(Hippoglossus platessoides)* 	Long rough dab lives over clean, muddy and sandy bottoms usu-ally at deeper waters. It is not of commercial value. Neither Hejre nor South Arne are located within the mapped spawning area for long rough dab. However, as spawning areas for fish are not static and fixed delimited areas, it is very likely that long rough dab in fact spawns at these fields. Spawning takes place from February to May (Peak: April).	ICES 2019a, Sundby et al 2017.
Lemon sole (*Microstomus kitt*) 	Lemon sole is a medium sized flatfish. It mostly occurs on rocky or sandy bottoms at depths between 20 to 150 m. Hejre and South Arne are situated in a spawning area for lemon sole (Fig-ure 6-13). Spawning takes place from January to October.	References: ICES 2019a, Sundby et al 2017.

Table 6-6 Biology of sandeel and grey gurnard that may be encountered at Hejre and South Arne.

Species	Distribution and biology	Reference
Sandeel (*Ammodytes/Hyperoplus* sp.) 	Four different species of sandeels are encountered in the North Sea. They are an important food source for many predatory spe-cies, including other fish, marine mammals and seabirds. Sandeels are burrowing species that spend most of their time in sandy sediments, although during the spring and summer they enter the water column to feed. The spawning areas are shown in Figure 6-17. This means that South Arne is within the spawn-ing area of sandeel, while Hejre is just outside the major area of spawning. After hatching the juveniles, spend approximately 3-4 months in the plankton before settling on a suitable sandy sub-strate.	References: ICES 2019a.

Grey gurnard *(Eutrigla gurnardus)* 	Grey gurnard is one of the main demersal species in the North Sea. It occurs throughout the North Sea but there is a marked seasonal northwest-southeast migration pattern. During winter the population is concentrated in the central western North Sea to the northwest of the Dogger Bank at depths of 50-100 m. During spring there is a mass migration to the south-east. Spawning takes place in this area from April to August. The eggs are pelagic.	References: ICES 2019a.

6.6.3 The state of fish stocks

Most of the commercially exploited Norths Sea stocks of the typical fish species encountered in the project area are in good condition and are fished at a sustainable level.

However, the cod stock in the North Sea is in a poor condition. Spawning stock biomass is below the sustainable level and the fishing mortality is too high (Figure 6-15, Table 6-7).

Table 6-7 State of the North Sea stocks of the commercially exploited typical fish species encountered in the Hejre tie-back to the South Arne area.

Species	State of stock
Herring	The condition of the herring stock is good. The stock is fished at a sustainable level and the spawning stock biomass has shown a fluctuating but increasing trend since 1987 (ICES 2019b).
Sprat	The spawning stock of sprat has full reproductive capacity (ICES 2019c)
Mackerel	The condition of the mackerel stock is good. The spawning biomass is estimated to have increased in the late 2000s, reaching a maximum in 2014. It has declined since but has still full reproductive capacity. The Fishing mortality has declined from high levels in the mid-2000s and the stock is harvested sustainably (ICES 2019d)
Cod	The cod stock in the North Sea is in a poor condition. However, the state of the stock is gradually improving. Spawning stock biomass has increased from the historic low in 2006 but is still below sustainable level and the fishing mortality is still too high (ICES 2019e).
Haddock	The condition of the haddock stock is good. Spawning stock biomass has full reproductive capacity and the stock is harvested sustainably ICES (2019f)
Whiting	The condition of the whiting stock is good. Spawning stock biomass has full reproductive capacity and the stock is harvested sustainably ICES (2019g)
Plaice	The plaice stock is in excellent condition. The spawning stock biomass is at a record high and has increased almost fivefold during the last 15 years. The stock is harvested in a sustainable manner (ICES 2019h).
Dab	Sustainable levels for dab have not been defined. The ICES assessment of the dab stock is indicative only. The spawning stock biomass has been increasing since 2006 and total mortality has decreased since 2009. ICES (2019i).
Sandeel	The condition of the sandeel stock is good (Ministry of Environment and Food 2019). However, the spawning stock biomass has a reduced reproductive capacity (ICES 2019j).

6.6.4 Fish spawning at Hejre and South Arne

There are two main ways fish spawn: demersal and pelagic spawning. Demersal spawners lay their eggs on the seabed, pelagic spawners lay their eggs in the free water masses where they remain free flowing for fertilization.

Cod, plaice, dab, long rough dab, lemon sole, mackerel and whiting are pelagic spawners. All are encountered at Hejre and South Arne (Sundby et al. 2017, Warnar et al. 2012). Sandeel is demersal spawner (lay egg on the seabed) and is dependent on sandbanks. However, sandeel banks are not identified in the Hejre and South Arne area (Figure 6-17).

The locations of spawning areas in the North Sea for lemon sole, mackerel, cod and plaice are shown in Figure 6-13, Figure 6-14, Figure 6-15 and Figure 6-16. Hejre and South Arne are located inside the spawning area for lemon sole Figure 6-13 and Hejre at the border of a spawning area for mackerel while South Arne is located within a spawning area for mackerel (Figure 6-14), and close to spawning areas for cod (Figure 6-15) and plaice (Figure 6-16). Spawning areas for sprat, long rough dab and whiting.not static and fixed delimited areas, therefore although the species appear to spawn outside the areas where Hejre and South Arne are located, these species may spawn at Hejre and South Arne.

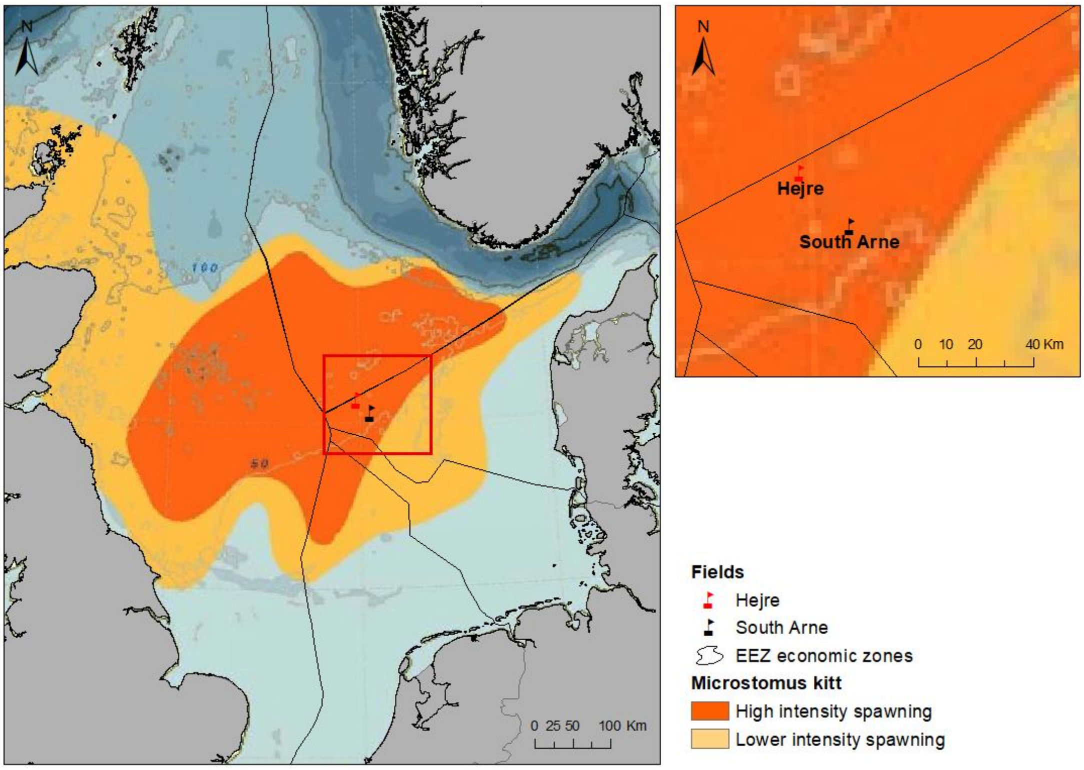


Figure 6-13 Spawning areas for lemon sole (Microstomus kitt) in the North Sea. The blue areas indicate the bathymetry. (Based on Sundby et al 2017).

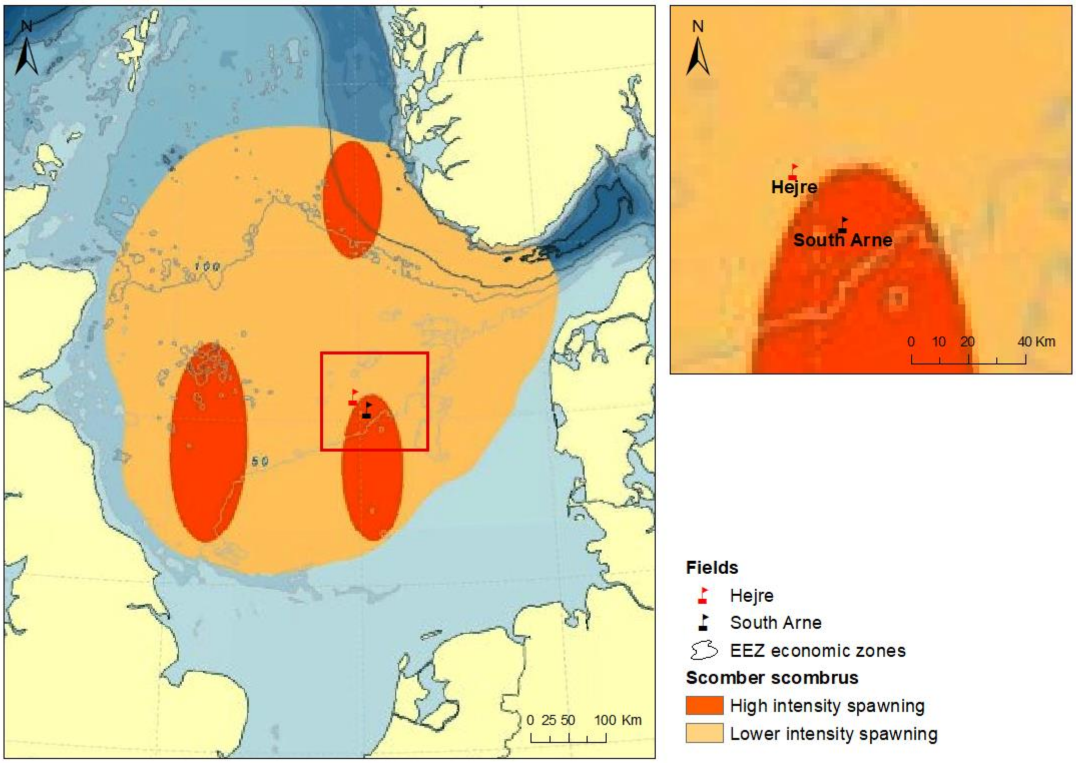


Figure 6-14 Spawning areas for mackerel (Scomber scombrus) in the North Sea (Based on Sundby et al. 2017). The blue areas indicate the bathymetry.

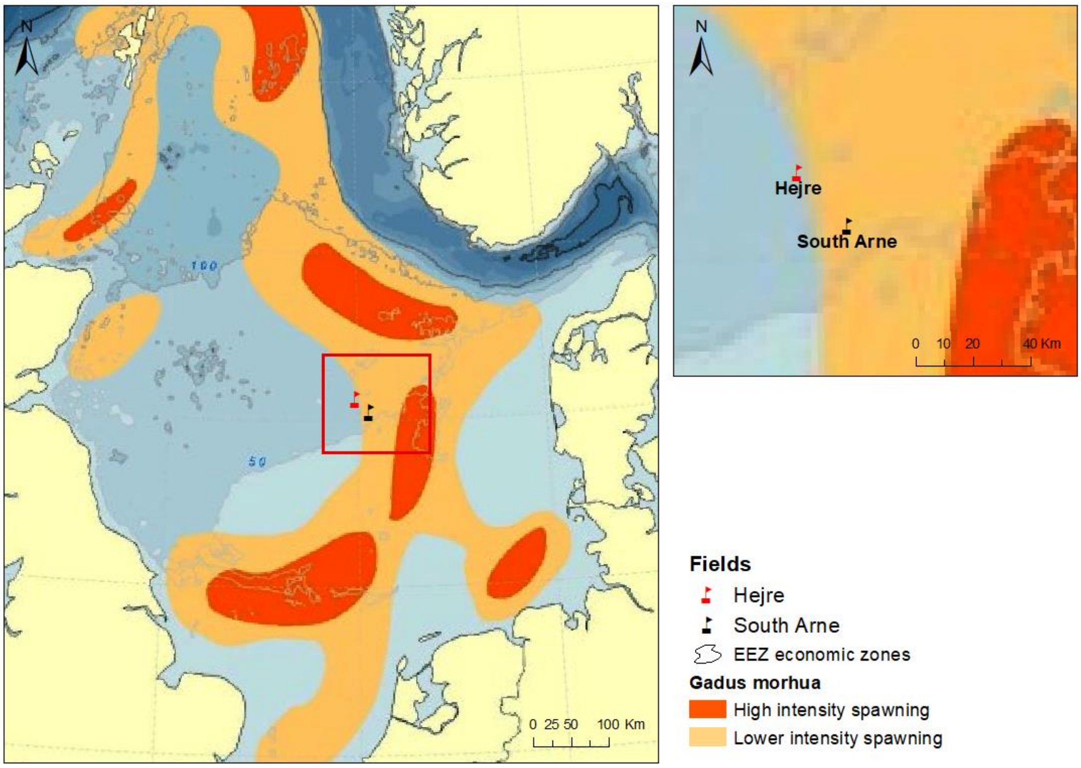


Figure 6-15 Spawning areas for cod in the North Sea. The blue areas indicate the bathymetry. Based on Sundby et al. 2017.

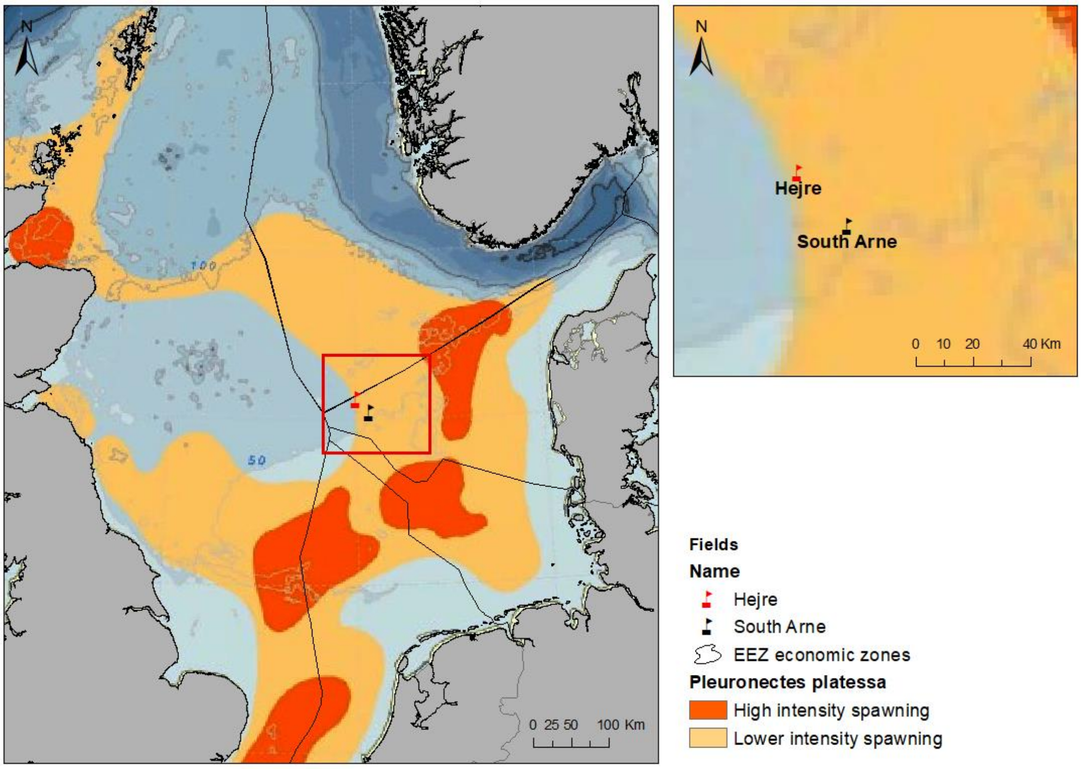


Figure 6-16 Spawning areas for plaice (Pleuronectes platessa) in the North Sea. The blue areas indicate the bathymetry. (Based on Sundby et al. 2017)

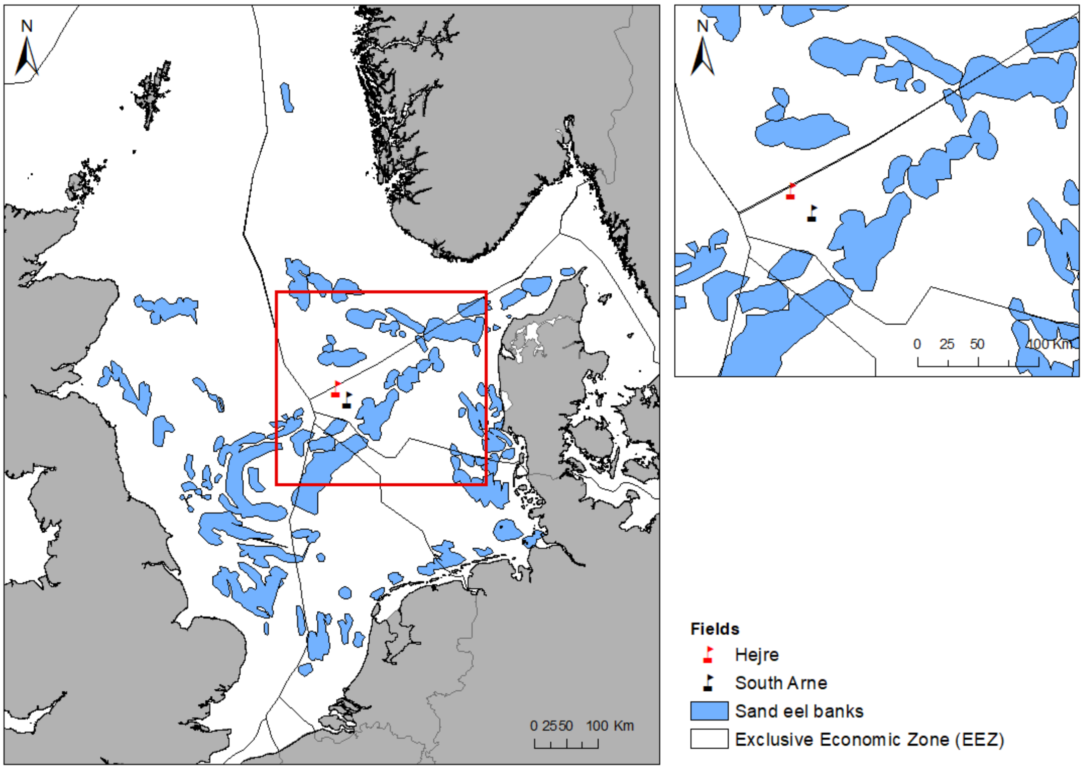


Figure 6-17 Spawning areas (banks) for sand eel (Ammodytes spp.) in the North Sea. (van Deurs 2019).

The spawning seasons for the species that are likely to spawn are shown in Table 6-8. It is seen that most spawning takes place during winter, spring and early summer.

Table 6-8 Spawning seasons for fish that may spawn at Hejre and South Arne (Sundby et al. 2017). Light grey: Total spawning period. Dark grey: Peak spawning.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cod												
Whiting												
Plaice												
Dab												
Long rough dab												
Lemon sole												
Mackerel												
Sandeel												

Eggs and larvae are carried with the prevailing east, north-east and north going currents to the front areas close to the coasts of the eastern North Sea and Skagerrak, where they can benefit from the high plankton production at the hydrographical fronts. Several field surveys have demonstrated that high concentrations of larvae of cod, whiting and sandeel are encountered in the front areas of Skagerrak and north-eastern North Sea south of Norway. Other surveys have shown that the front area along the Danish west coast and in the German Bight houses large concentrations of larvae of sandeel, plaice, cod and whiting (Knutsen et al. 2004, Munk et al 2002, Munk et al. 1999, Munk et al 1995).

6.7 Birds

The North Sea is an important area for seabirds. This is primarily caused by the high productive hydrographical front areas which are important feeding areas for birds. It is estimated that more than 10 million birds make use of the North Sea for breeding, feeding, or migratory stopovers every year. Furthermore, important breeding colonies fringe the coastlines (Skov et al. 1995). The Hejre and South Arne fields are both far from important bird areas (Figure 6-18).

The important bird areas in the North Sea coincide with the highly productive areas where hydrographic fronts can be formed, producing an abundance of food for seabirds (Figure 6-18).

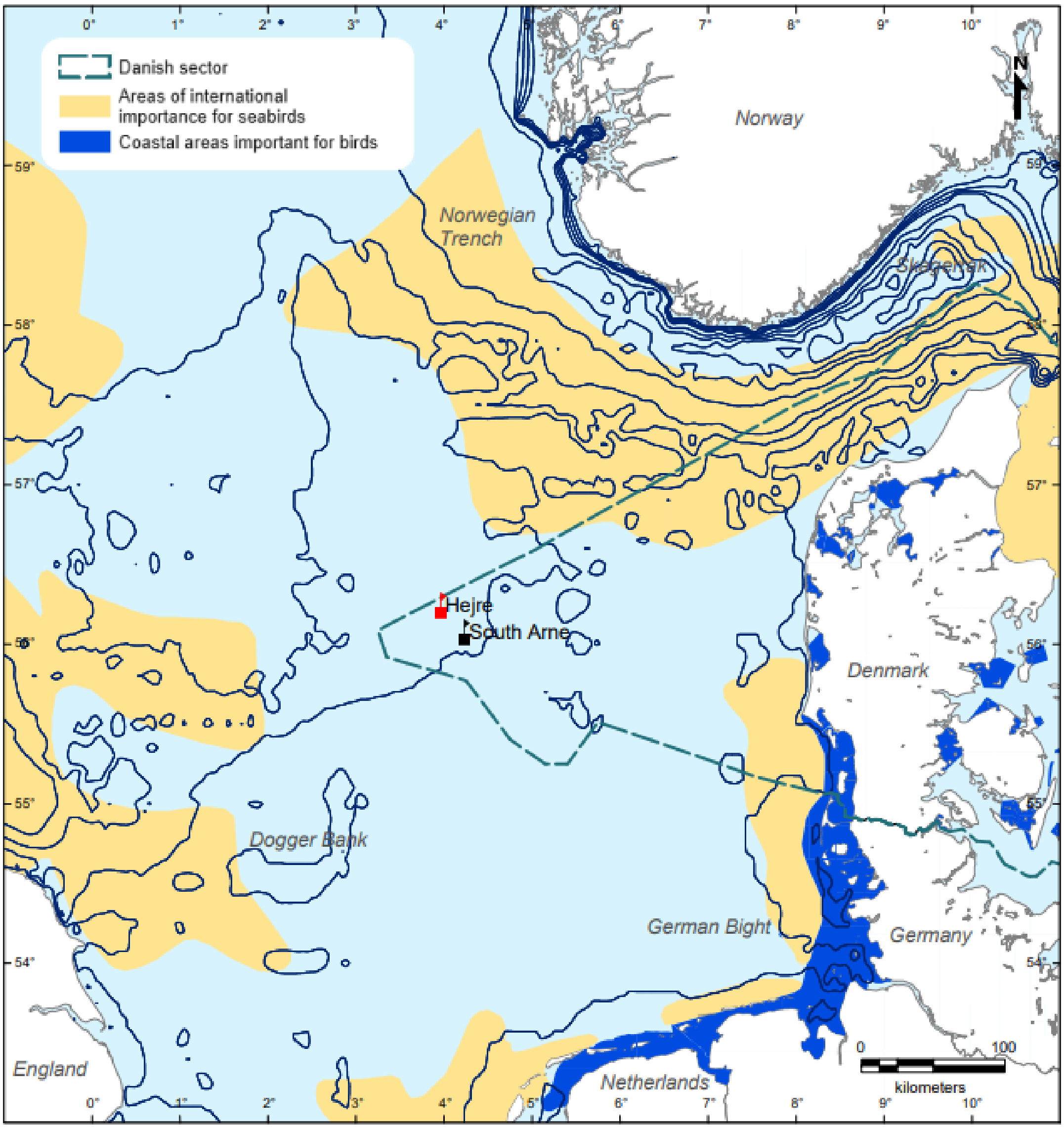


Figure 6-18 Areas of international importance for seabirds (light brown shading) and coastal areas important for birds (blue shading). (Data: Skov et al. 1995, Falk & Brøgger Jensen 1995).

6.7.1 Seabirds at Hejre and South Arne

During winter some seabirds may be encountered at Hejre and South Arne since these species are distributed over the entire North Sea during winter. The predominant species are fulmar (*Fulmarus glacialis*) and kittiwake (*Rissa tridactyla*) (Figure 6-19 and Figure 6-20). Additionally, Gannet (*Sula bassanus*), razorbill (*Alca torda*) and common guillemot (*Uria aalge*) occur in low densities (Appendix C, Environmental Atlas). These species are mainly associated with cliffs and offshore islands and only occur in the open sea outside the breeding season. They occur in larger densities in other areas of the North Sea with more favourable feeding opportunities that the central parts (COWI 2006, Skov et al., 1995). The biology of these species is described in Table 6-9.

Table 6-9 Biology of birds that may be encountered at Hejre and South Arne during winter (Source: Birdlife International 2014). Images from www.rsbp.org

Species	**Biology**
Fulmar (*Fulmarus glacialis*) 	The fulmar typically breeds on cliffs and rock faces, occasionally on flatter ground and up to 1km inland, nesting within colonies on narrow ledges or in hollows. The most important breeding colonies in the North Sea are found in Scotland, the Orkneys, and the Shetlands and at Flamborough head. Fulmars have a potentially large offshore foraging range from their colonies, as birds regularly depart for more than 4-5 days on foraging trips, both before egg-laying and during incubation. Fulmars prey on a wide variety of fish such as, sandeels, sprat, and small gadoids. Large zooplankton species (especially amphipods and copepods) and squid are also important food items. They will also scavenge offal including fishery waste, entrails, and whole fish discarded by fishing vessels.
Kittiwake (*Rissa tridactyla*) 	The kittiwake breeds from mid-May to mid-June in very large single- or mixed-species colonies. The most important breeding colonies in the North Sea are found in Scotland, the Orkneys, Shetlands and at Flamborough head. The kittiwake nest on high, steep coastal cliffs with narrow ledges. The nest is a compacted mass of mud, grass and feathers. During the breeding season, it generally feeds within 50 km of the breeding colony. After breeding, it disperses from coastal areas to the open ocean. The species begins to disperse from the breeding colonies between July and August, often moulting in large flocks of several thousand individuals on beaches between the breeding grounds and the open sea. During the winter, the species is highly pelagic, usually remaining on the wing out of sight of land. Its diet mainly consists of small pelagic shoaling fish such as sandeel, sprat and young herring, but squid shrimps or other invertebrates may also be included in the diet.
Gannet (*Sula bassanus*) 	The gannet is strictly marine, with movements largely confined to the continental shelf. Individuals nest on cliffs and offshore islands and occasionally on the mainland. Its diet consists primarily of shoaling pelagic fish, mostly caught by plunge diving. Birds can also be seen attending trawlers in large numbers. This is a ground nesting species, usually within large colonies. The nest is built with seaweed, grass and earth stuck together with excreta.
Guillemot (*Uria aalge*) 	The guillemot breeds in colonies primarily on steep cliff faces or low, flat islands. The most important breeding colonies in the North Sea are found in Scotland, the Orkneys, Shetlands and at Flamborough head It does not construct a nest but lays on broad or narrow cliff ledges and low, flat islands. Individuals mostly occur offshore during winter usually within the breeding range, but the species may be encountered in low to moderate density all over the North Sea. Most individuals return to the colony in March-April. Its diet consists mostly of schooling pelagic fish, mostly sandeel, herring and sprat with small gadoids important at some colonies. Crustaceans can also be the dominant food source. The food is usually obtained within 10-20 km of the colony (Bird Life International 2014)

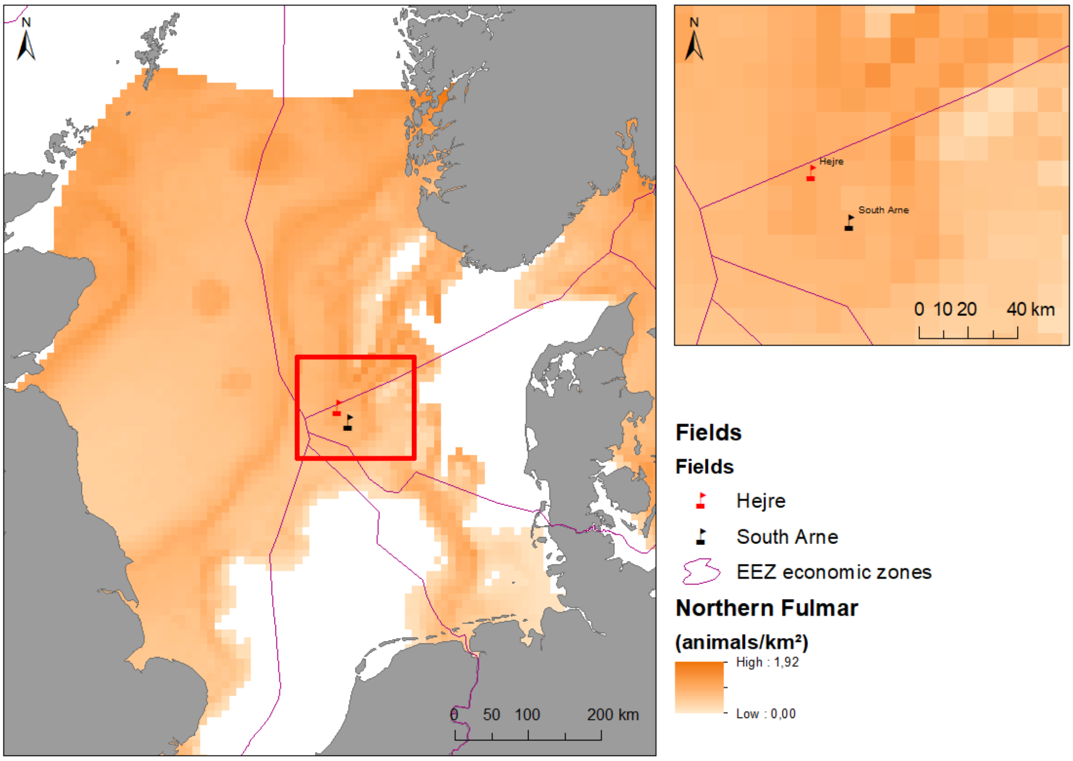


Figure 6-19 Relative abundance of Northern Fulmar (Fulmarus glacialis) in the North Sea (Waggit et al. 2019).

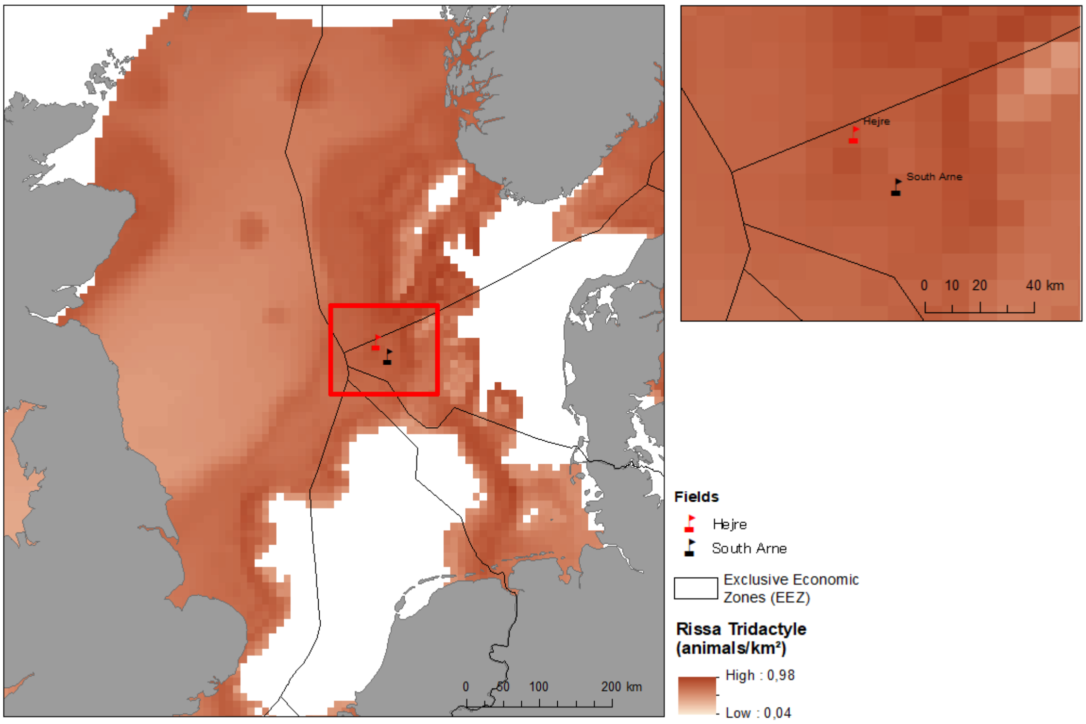


Figure 6-20 Relative abundance of Kittiwake (Rissa tridactyla) in the North Sea (Waggit et al. 2019).

6.7.2 Migrating land birds

Large numbers of land birds migrate across the North Sea between the UK and Western Europe including waders and species of thrushes, chats, warblers and finches (Baptist 2000, Lack 1959, 1960, 1963). Several of these species may sporadically be encountered at Hejre and South Arne.

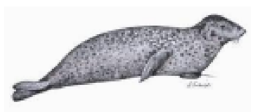
6.8 Marine mammals

6.8.1 Seals

Grey seals (*Halichoerus grypus*) and Harbour seals (*Phoca vitulina*) may occasionally be sighted in the project area, although the area is not a core area for these species (Tougaard 2007 and Tougaard et al. 2003). Their basic biology is described in Table 6-10.

Harbour seal is included in the basis for the designation of the German, Dutch and UK Nature 2000 areas DE 1003-301 Doggerbank, NL 2008-001 Doggerbank and UK0030352 Dogger Bank. Grey seal is also listed in the basis for the designation of NL 2008-001 Doggerbank and UK0030352 Dogger Bank areas (see section 7.5.1 below).

Table 6-10 Biology of seal species that may be encountered at Hejre and South Arne.

Species	Biology
Harbour seal (*Phoca vitulina*) 	Harbour seal (*Phoca vitulina*) is the only seal species that is observed regularly in the Danish sector of the central part of the North Sea. Harbour seals are primarily coastal, depending on isolated and undisturbed land areas for resting, breeding and moulting (such as undisturbed islands, islets sandy beaches, reefs, skerries and sandbanks). They are gregarious animals and when not actively feeding, they will haul onto a terrestrial resting site. The harbour seal does not generally venture more than 20 kilometres offshore. However, radio-tagging experiments using satellite tracing have indicated that harbour seals may undertake foraging migrations far out into the North Sea from their core areas along the coast (Tougaard et al. 2003, Tougaard 2007). They are known to prey primarily on fish such as herring, mackerel, cod, whiting and flatfish, and occasionally upon shrimp, crabs, molluscs and squid. Females give birth once a year, with a gestation period of approximately nine months. Harbour seal breed in large numbers in the Wadden Sea. It is less common along the British coast.
Grey seal (*Halichoerus grypus*) 	The grey seal (*Halichoerus grypus*) breeds in several colonies on islands on the east coasts of Great Britain. Notably large colonies are at Donna Nook (Lincolnshire), the Farne Islands off the Northumberland Coast Orkney and North Rona off the north coast of Scotland. In the German Bight, colonies exist off the islands Sylt and Amrum and on Helgoland. The pups are born in the period September-November. Within a month or so, they shed the pup fur and grow the dense waterproof adult fur, and soon leave for the sea to learn to fish for themselves. Tagging experiments have indicated that grey seals breeding in Great Britain migrate long distances into the North Sea from their breeding colonies (McConnell et al. 1999) but they have not actually been observed in the offshore parts of the Danish sector of the North Sea (Tougaard 2007). The grey seal feeds on a wide variety of fish including sandeels, cod and other gadoids, flatfish, herring and skates. They may also take octopus and lobster.

6.8.2 Cetaceans (Annex IV species)

All species of cetaceans (whales, dolphins and porpoise) are listed in Annex IV in the Habitats Directive and are therefore strictly protected. In addition, harbour porpoises are included in the basis for the designation of the German, Dutch and UK Nature 2000 areas DE 1003-301 Doggerbank and NL 2008-001 Doggerbank, UK0030352 Doggerbank.

A total of 23 different species of cetaceans have been observed in the North Sea. Only harbour porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhynchus albirostris*) and minke whale (*Balaenoptera acutorostrata*) are encountered regularly in the western part of the Danish sector of the North Sea

(Sveegaard et al. 2018, SCANS II, Kinze 2007, Reid et al. 2003). The biology of the three cetacean species is briefly described in Table 6-11. Other cetacean species are rare and do only occasionally migrate into in the North Sea from the Atlantic. This is consistent with the species assessed to be relevant for assessment of impulsive noise sources in Danish waters (DCE 2021).

The population characteristics of harbour porpoises is described in more detail below.

Table 6-11 Biology of species of cetaceans that may be encountered at the Hejre and South Arne area.

Species	Biology
Harbour porpoise (*Phocoena phocoena*) 	The harbour porpoise (*Phocoena phocoena*) is the most abundant whale species in the North Sea and occur regularly in the Hejre tie-back to South Arne development area. The population in the North Sea has been estimated to 300.000-350.000 (Sveegaard et al. 2018, Gilles et al. 2016). Harbour porpoises feed mostly on fish such as cod, whiting, mackerel, herring and sprat. Harbour porpoises tend to be solitary foragers, but they do sometimes hunt in packs. The mating season is July-August. The gestation period typically lasts 10–11 months and most births occur in late spring and summer. Calves are weaned after 8–12 months.
White-beaked dolphin (*Lagenorhynchus albirostris*) 	White beaked dolphin (*Lagenorhynchus albirostris*) is relatively common in the northern part of the North Sea and may be encountered in the Hejre tie-back to South Arne development area (Geelhoed et al 2014, Hammond et al 2013, Reid, et al. 2003). White beaked dolphin is much less abundant than harbour porpoise. The total population in the North Sea is only about 16,500 individuals (Hammond et al. 2013). White-beaked dolphins are acrobatic and social animals that are typically found in pods of 4-6 animals. They will frequently ride on the bow wave of fast-moving vessels and jump clear of the sea's surface. White beaked dolphin mates from May to August and the delivery occur the following summer after a gestation period of 11 months. They primarily feed on fish such as herring, cod, haddock, whiting and hake but may also prey on squid, octopus and benthic crustaceans
Minke whale (*Balaenoptera acutorostrata*) 	Minke whale (*Balaenoptera acutorostrata*) may be observed at the Hejre tie-back to South Arne development area (Geelhoed et al. 2014, Hammond et al. 2013, Kinze 2007, Reid et al. 2003). Minke whale is the only species of baleen whale that occurs regularly in the North Sea. The population in the North Sea has been estimated to about 19.000 individuals (Hammond et al. 2013). Mating and delivery take place from late winter to early spring. The female minke whale gives birth to a calf every year or every second year. The gestation period is 10 months and nursing of the calf takes place for 3-6 months. Minke whales primarily feed on pelagic fish such as herring and sprat and small crustaceans.

6.8.3 Harbour porpoises

The harbour porpoise is the most abundant whale species in the North Sea. It is regularly encountered in the waters around Hejre and South Arne although the areas are not a core area for the species. Harbour porpoises in the project area belong to the North Sea population. Through its migration and feeding pattern the species reaches into the Northern Kattegat and Skagerrak. The North Sea population has been estimated during international projects called SCANS (Small Cetacean Abundance in the North Sea) which took place in the period 1995 to 2016 (a total of three SCANS). The116opulartion was estimated to include 300.000 to 350.000 individuals indicating a stable population (Sveegaard et al. 2018).

Waggit et al. (2019) has modelled the distribution of harbour porpoises in the North Sea. The model shows that harbour porpoise is concentrated in the most Eastern part of the North Sea during winter and distributed over a larger area during summer (Figure 6-21). The most important area for harbour porpoise in the

North Sea is the waters between the western part of the Dogger Bank and the UK. The waters along the Danish, German and Dutch coasts, especially the German Bight/Horns Rev areas, are also important (Waggit et al. 2019, Gilles et al. 2016 and Sveegaard et al. 2018). It appears from the model that the Hejre and South Arne area are located within an area of some importance for harbour porpoises.

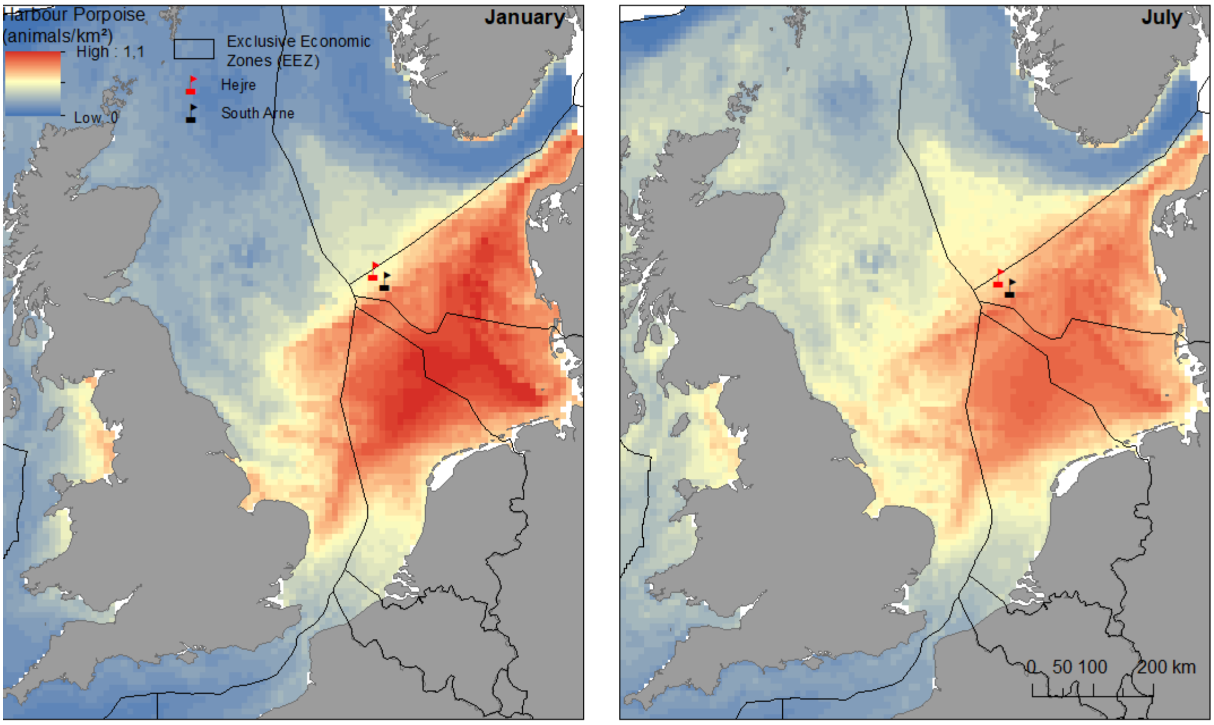


Figure 6-21 Distribution of harbour porpoise (Phocoena phocoena) in the North Sea Waggit et al. 2019).

6.9 Protected areas

6.9.1 Natura 2000 and annex IV species

The EU Habitats Directive (Council Directive 92/43/EEC of 21 May 1992) specifies natural habitats and wild fauna and flora for which the member states must ensure protection. The species and nature habitats to be protected are specified in the Annexes of the directive:

- Annexes I and II to the Directive contain the types of habitats (Annex I) and species (Annex II) whose conservation requires the designation of Special Areas of Conservation (SACs). For birds, Special Protected Areas (SPAs) are designated. Together Sacs and SPAs make up Natura 2000 areas.

- Annex IV lists species of animal and plants in need of particularly strict protection. Of the marine mammals encountered in the North Sea, all species of cetaceans are listed in Annex IV.

6.9.2 Valuable and vulnerable areas (SVO-areas)

Valuable and vulnerable areas (SVO-areas) is the management framework for marine protected areas in Norway. The SVO-areas include protected areas for red listed species and bird protection areas such as RAMSAR-sites (international conservation of wetlands). The SVO-areas have integrated management plans with criteria for protection.

6.9.3 RAMSAR

RAMSAR sites are designated through the RAMSAR convention. It is an intergovernmental treaty that provides the framework for national action and international management of wetlands. RAMSAR sites are of importance for birds. In Denmark they overlap with SPA (Natura 2000-areas) for birds.

6.9.4 Identified protected areas

6.9.5 Natura 2000

Hejre and South Arne are situated far from Danish designated Natura 2000 areas. However, around 49 km south of the field is a German designated Natura 2000 area: DE 1003-301 *Doggerbank*. As an extension of this area is the Dutch NL 2008-001 *Doggerbank* and the UK0030352 *Dogger Bank* in the UK sector (Figure 6-22).

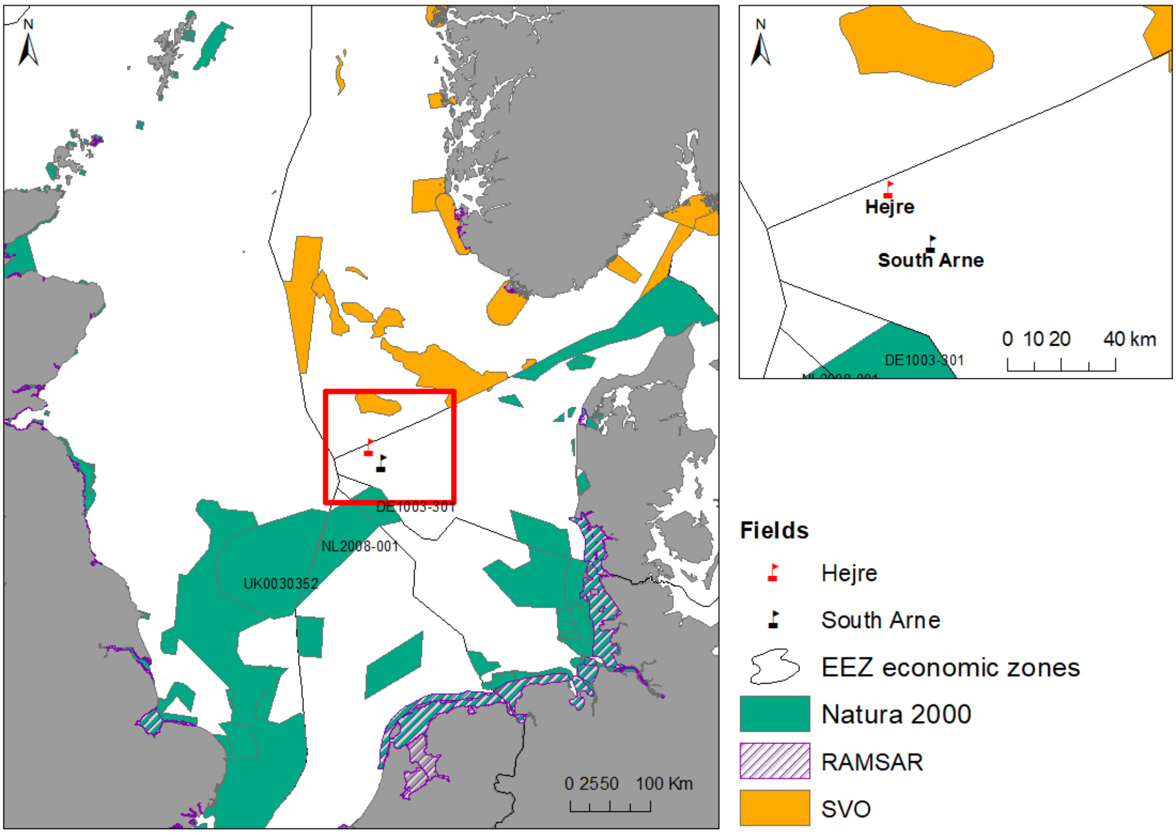


Figure 6-22 Location of Natura 2000-areas (SAC) in the North Sea.

The basis for the designation of these three SACs are listed in Table 6-12:

Table 6-12 Basis for the designation of the closest Natura 2000 areas.

Natura 2000 areas (SACs)	Basis for the designation
DE 1003-301 Doggerbank	Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time Annex II species 1351 Harbour porpoise and 1365 Harbour seal.
NL 2008-001 Doggerbank	Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time Annex II species 1351 Harbour porpoise, 1365 Harbour seal and 1364 Grey seal

UK0030352 Doggerbank	Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time Annex II species 1351 Harbour porpoise, 1365 Harbour seal and 1364 Grey seal

6.9.6 Valuable and vulnerable areas (SVO-areas)

The closest SVO's in the Norwegian sector of the North Sea include the Sandeel field North (Vikinge-banken) and South (Table 6-13). The Sandeel field North and South are designated as SVO to protect valuable spawning areas for sandeel. The SVO is located ca. 69 km from South Arne and 44 km from Hejre. The area is also designated to protect the two seabird species common guillemot (*Uria aalge)* and northern fulmar (*Fulmaris glacialis*).

Northwest of the Sandeel field South is the Mackerel field SVO, designated as important spawning area for mackerel. There are existing oil and gas activities in the SVO. The basis for the designation of the Sandeel fields SVO and the Mackerel field SVO area listed in Table 6-13.

Table 6-13 Basis for the designation of the closest SVO areas.

SVO	Basis for the designation
Sandeel field north (Vikinge-banken) and sandeel field south	The sandeel fields north and south are spawning and foraging area for eel. Furthermore, the sandeel fields are a valuable habitat for common guillemot (*Uria aalge)* and northern fulmar (*Fulmaris glacialis*) from April to December. Common guillemot overwinters in the North-western part of the area from December to March.
Mackerel field (Makrellfeltet)	The SVO is a spawning area for mackerel from May to July. The mackerel is monitored in the area through the international mackerel cruise (IESSNS)

6.9.7 Protected areas under the Marine Strategy Framework Directive (MSFD)

Eight protected areas under the Marine Strategy Framework Directive have been designated in the North Sea. The closest area H is located in the far western part of the Danish EEZ, that is immediately west of Hejre and South Arne (Figure 6-23). The second closest area G is located to the north-east of Hejre and South Arne. This protection regulates activities within the area itself but not activities outside the protected area (Ministry of Environment 2021).

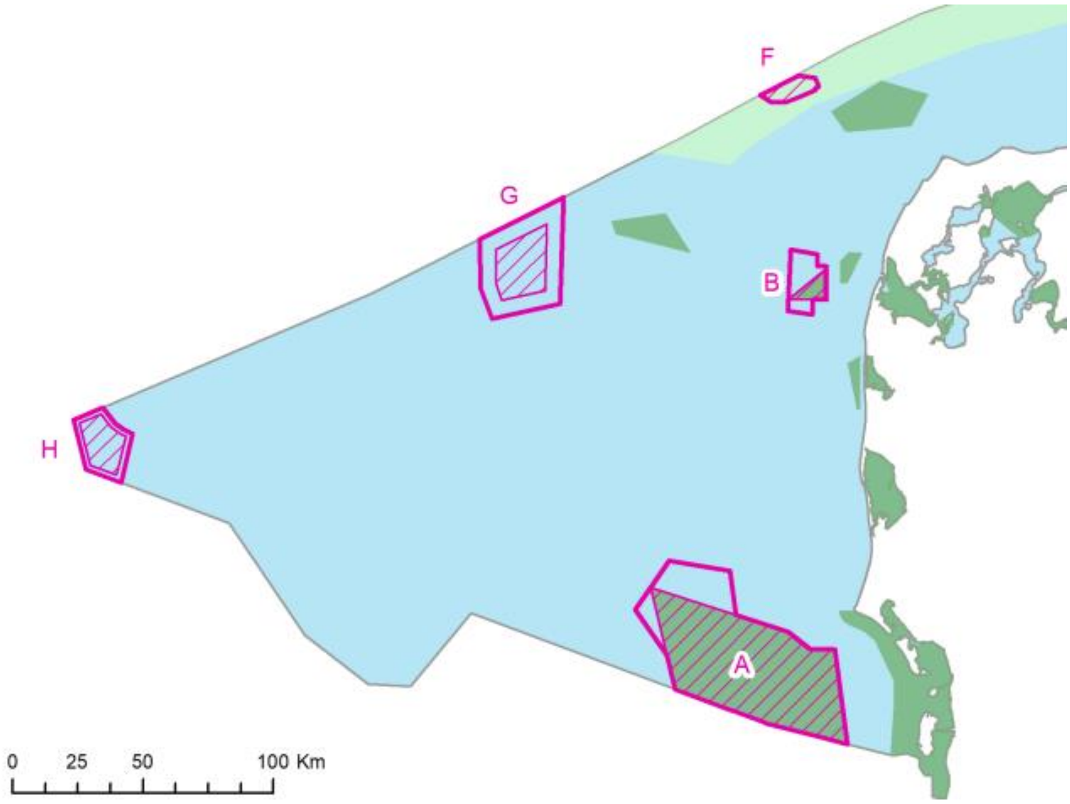


Figure 6-23 Selection of the protected areas in the North Sea under the Marine Strategy Framework Directive. Light green areas are new bird protected areas and dark green areas are existing protected areas (Ministry of Environment 2021).

6.10 Human environment

Commercial and cultural interests in the western part of the Danish sector of the North Sea include:

- Oil and gas extraction
- Shipping
- Wind power
- Fishery
- Cultural heritage

6.10.1 Oil and gas extraction

Hejre is located in a part of the central North Sea with other oil and gas activities. The closest existing oil and gas facilities in operation to Hejre is the Total operated Harald and Svend and the INEOS Energy Denmark operated South Arne (Figure 2-1).

6.10.2 Shipping

Data from the AIS system (Automatic Identification System) shows the intensity of merchant vessels in the central North Sea of the year 2018 (Figure 6-24).

It is seen that Hejre and South Arne are situated far from major shipping lanes. Hejre is situated at the outskirts of a minor shipping lane. Appropriate measures are already implemented to minimize the risk of ship collision with the Hejre field. These include safety zones around the platform in form of a circle with a radius of 500 m and exclusion zones of 200 m on either side of the pipeline to the host platform.

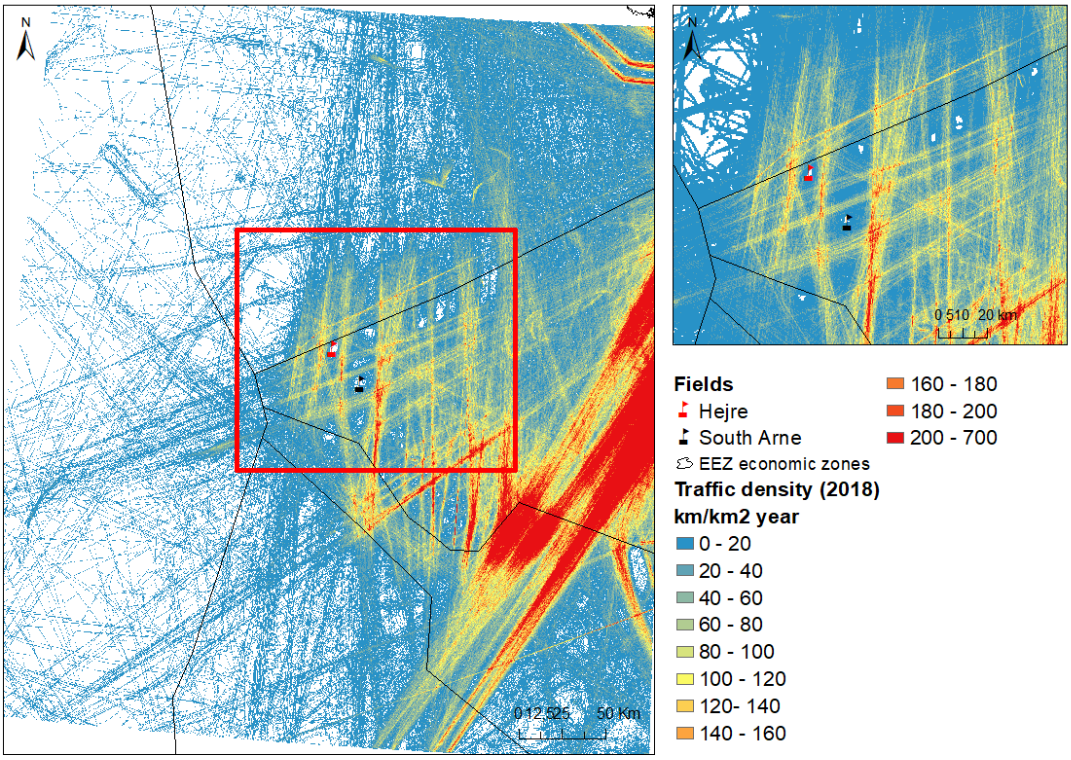


Figure 6-24 Ship traffic in the North Sea based in AIS data from all ships in 2018. Offshore service-related traffic is not included.

6.10.3 Wind power

The closest windfarm is located more than 200 km from the platform at Horns Rev. The offshore windfarms at Horns Rev include Horns Rev I, Horns Rev II and Horns Rev III with a total of 200 wind turbines. In addition, there is planned one offshore wind farms (Sørlige Nordsjø II) the Norwegian sector of the North Sea bordering the Danish sector of the North Sea (ca. 10 km from Hejre).

6.10.4 Fisheries

Figure 6-25 shows the fishing effort of Danish vessels using active gear (dredgers, beam trawl, pelagic trawl, otter trawl or demersal seiners) in the eastern North Sea during the period 2007-2015. Figure 6-26 shows the fishing effort using passive gear (i.e., mainly gill nets) in the same area during the same period.

It is seen that Hejre and South Arne are situated in an area with low fishery intensity. The fishery intensity in is concentrated in the following areas:

- Along the edge of the Norwegian trench and the Skagerrak;
- Along the Danish west coast.

The main fishing, which takes place in the Danish sector of the North Sea (COWI 2015) are:

- Fishery for Norway lobster, using otter trawls;
- Industrial fishery for sandeel by trawlers using small meshed demersal trawl in industrial fisheries (i.e. for fishmeal);

- Industrial fisheries for sprat for fish oil and fish meal using small-meshed trawls; and
- Mixed fishery for flatfish using primarily otter trawl and gill nets.

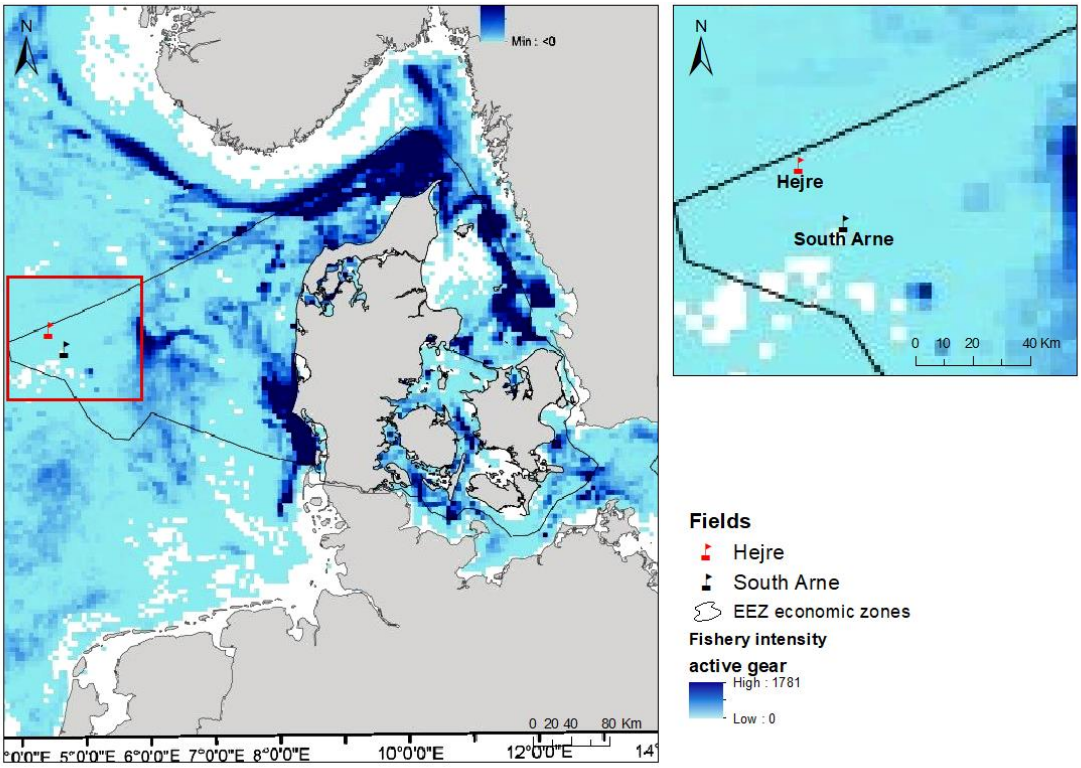


Figure 6-25 The distribution of active fishing intensity based on VMS and AIS data from the period 2007-2015 (Based on Egekvist et al 2018). Active fishing includes the use of dredgers, beam trawl, pelagic trawl, otter trawl or demersal seiners.

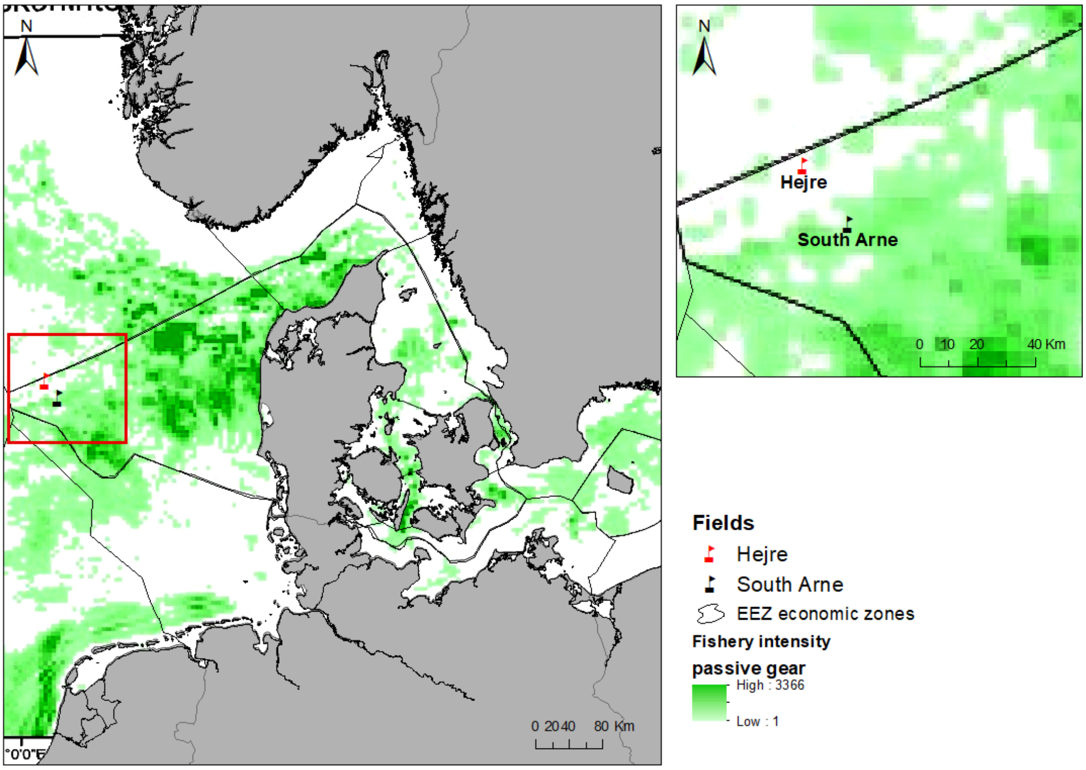


Figure 6-26 The distribution of passive fishing intensity based on VMS and AIS data from the period 2007-2015 (Based on Egekvist et al. 2018). In the area passive gear used is primarily gill nets.

6.10.4.1 Danish catches in the project area

In terms of value, the most important fish species around the South Arne are sand eel, plaice, turbot, lemon sole, cod and monkfish. Sand eel alone makes up 95% of the value of fish caught in this area. The distribution of the Danish total fishery catches is shown in Figure 6-27.

Compared to the fish catch in the North Sea, sand eel fishery is of some significance in the area around South Arne (ICES square 41F4), during the period 2014-2018. However, the remaining fish species are of less importance. The distribution of catches of the most important fish species (sandeel, plaice, turbot, lemon sole, cod and witch flounder) are shown in Figure 6-29 to Figure 6-34.

The waters around South Arne/Hejre field are without significance for the fishery of other countries (MMO 2012, Van Oostenbrugge et al. 2010, Agenda 1999, Rogers & Stocks 2001).

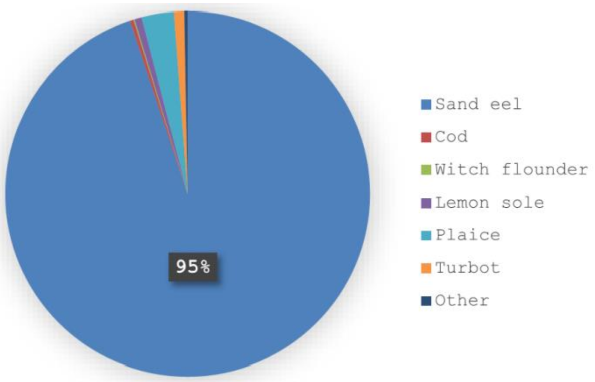


Figure 6-27 The value of key fish species caught in the South Arne area. Values represent an average during the period 2014-2018. Source: Fiskeristyrelsen 2019.

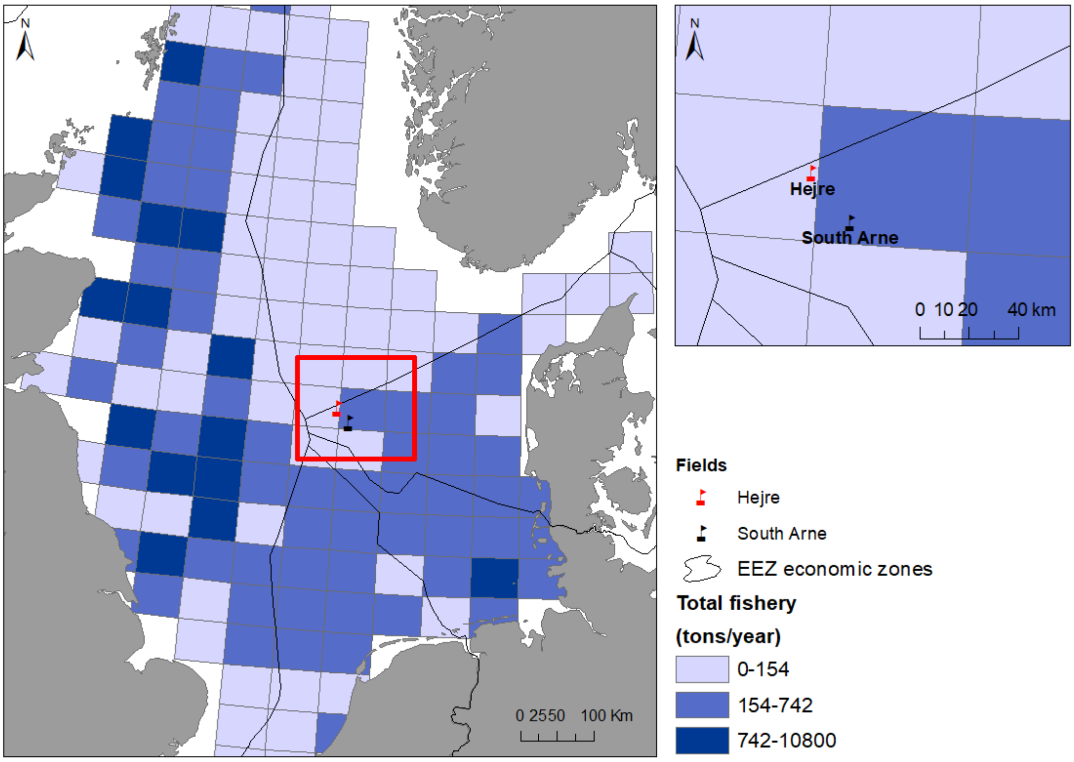


Figure 6-28 Mean catches of all fisheries in the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

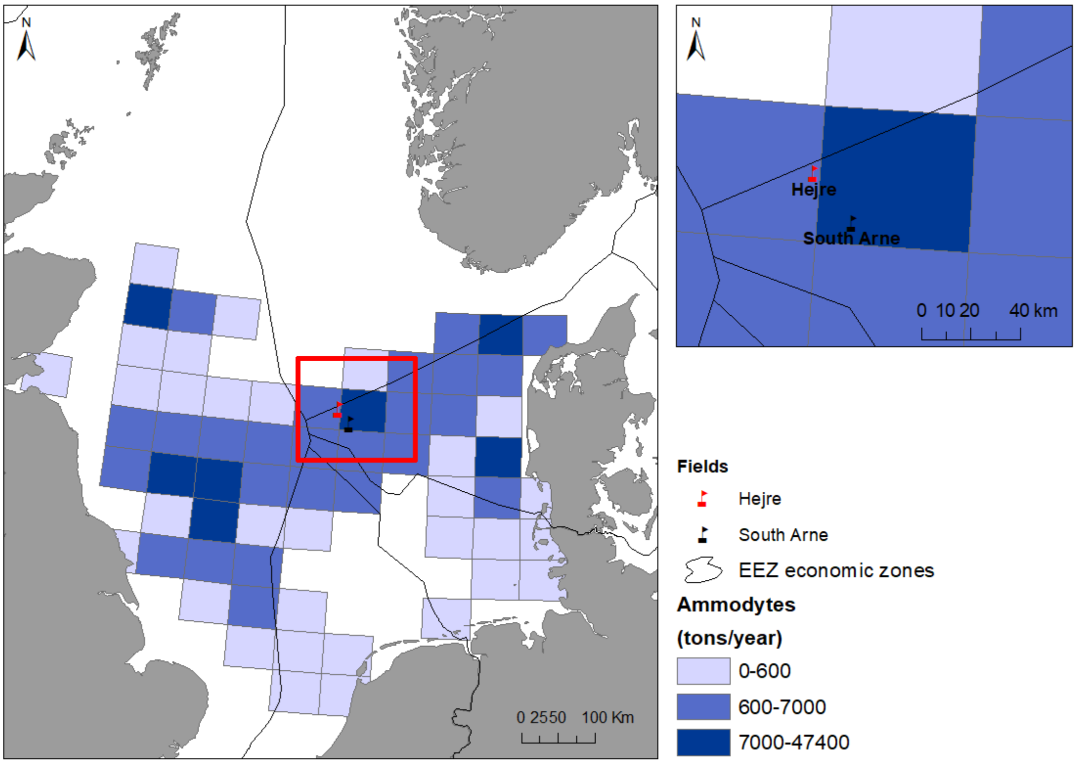


Figure 6-29 The value of the sandeel fisheries in the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

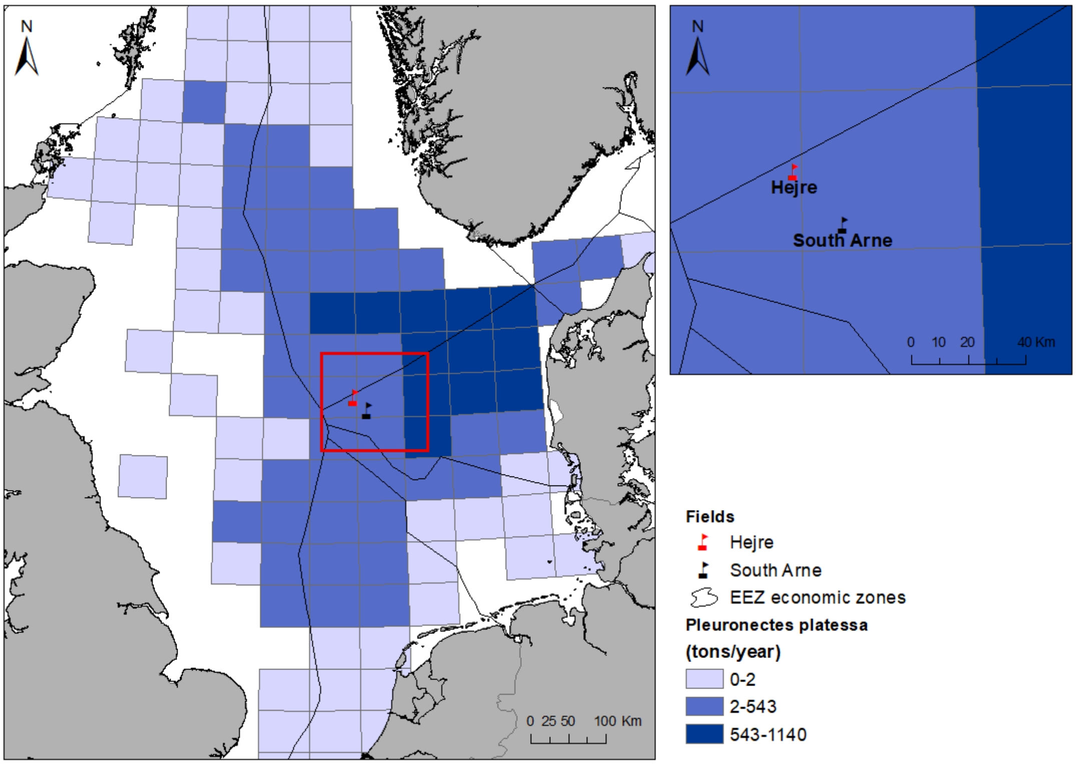


Figure 6-30 Mean Danish catches of plaice (Pleuronectes platessa), during the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

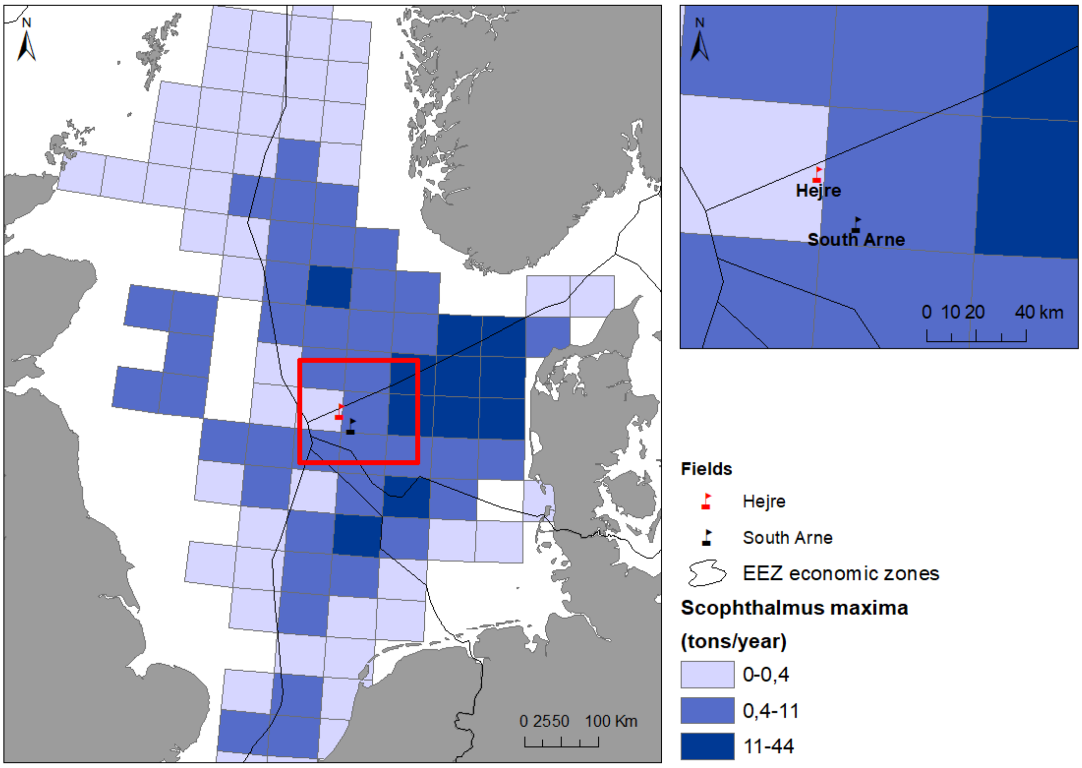


Figure 6-31 Mean Danish catches of turbot (Scophthalmus maxima) in the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

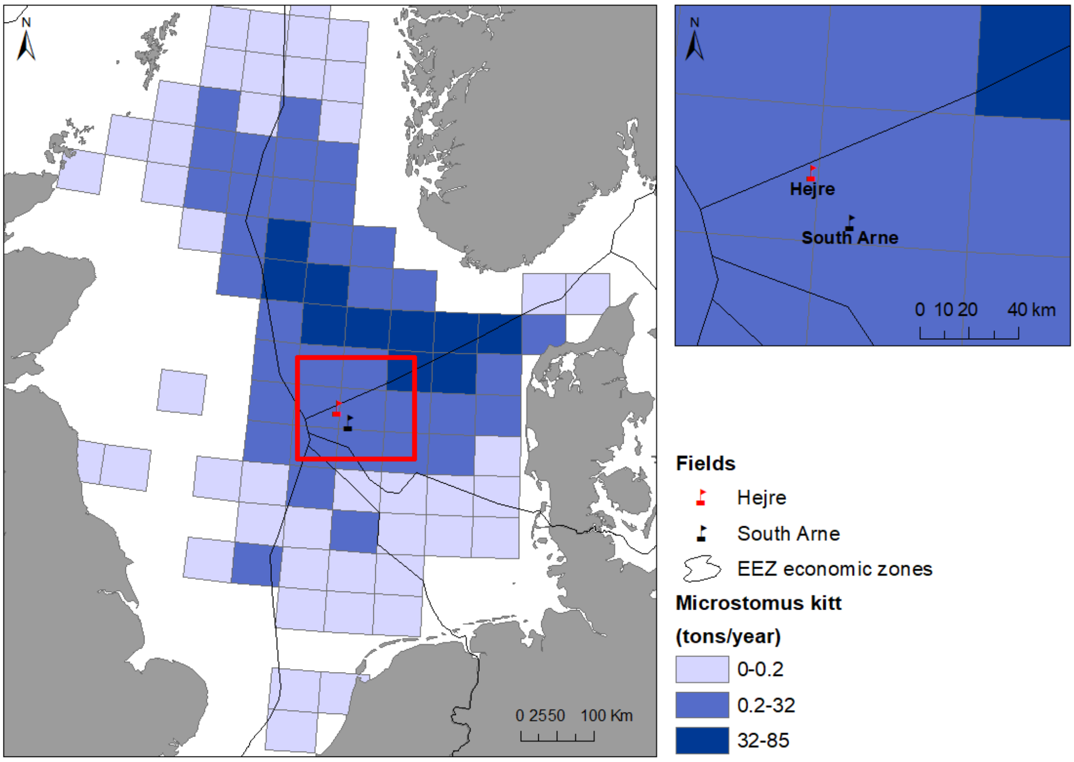


Figure 6-32 Mean Danish catches of lemon sole (Microstomus kitt) during the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

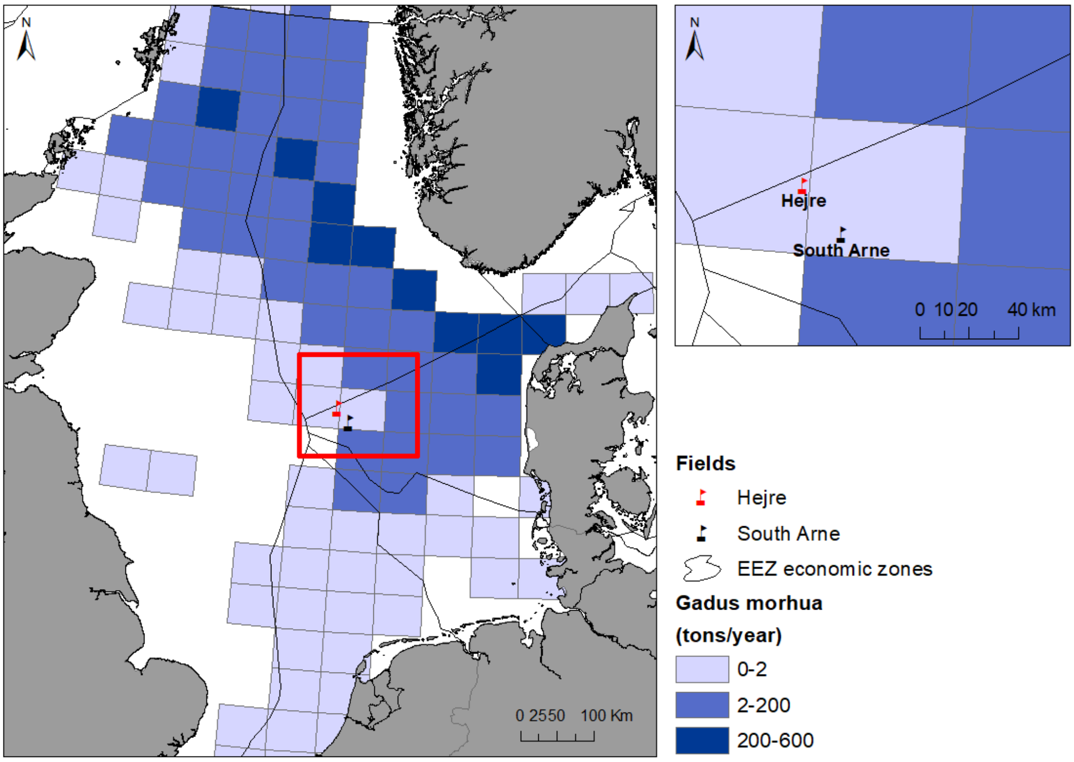


Figure 6-33 Mean Danish catches of cod (Gaudus morhua) during the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

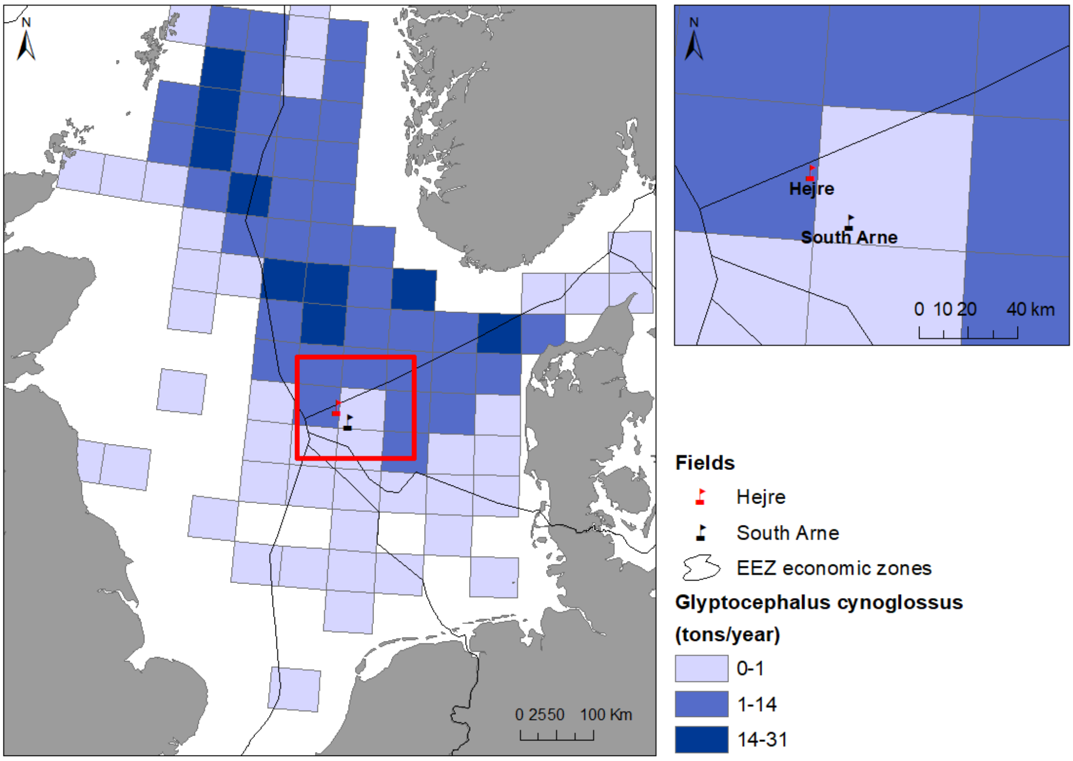


Figure 6-34 Mean Danish catches of witch flounder (Glyptocephalus cynoglossus) in the period 2014-2018. Mean catches are ranked in three percentile intervals: 0-50 (light blue), 50-90 (medium blue) and 90-100 percentile (dark blue). Based on data from the Danish AgriFish Agency (2019).

6.10.5 Cultural heritage

The only cultural heritage that potentially could exist in the project area is ship and plane wrecks. There are no registered wrecks in the project area (Palaces and Culture Agency, 2022). The closest registered wreck is located more than 10 km from Hejre and South Arne (Figure 6-35). The wreck is not protected.

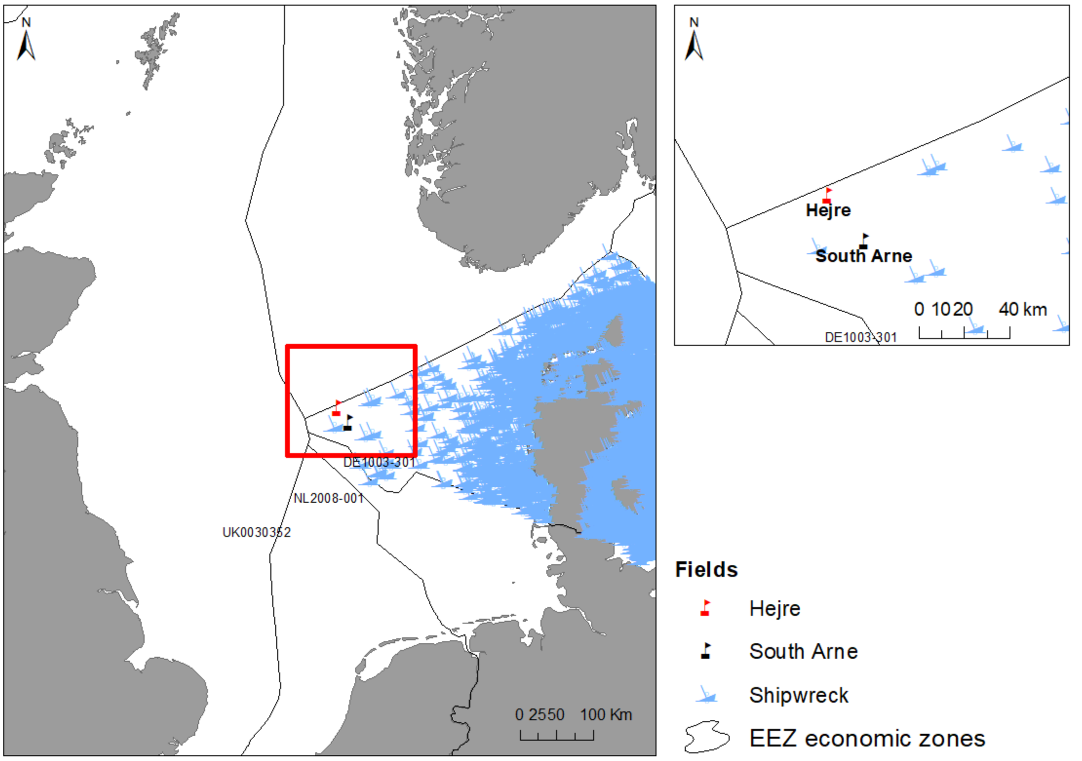


Figure 6-35 Registered wrecks in the project area (Palaces and Culture Agency2022).

7. Methodology

7.1 Methodology for evaluation of environmental severity and risk

The environmental significance (severity) and risk of impacts of the project on environmental and socioeconomic receptors has been evaluated using the following methodology.

7.1.1 Procedure for risk assessment

Environmental risk is the combination of the significance (severity) of an impact and the probability that an impact may arise. This implies for instance that an incidence that may cause severe impacts but is not very likely to occur has a low environmental risk.

For each operation or incidence, the assessment of environmental risk includes three steps:

- Assessment of environmental significance (severity) of an impact;
- Assessment of the probability that an impact will occur;
- Assessment of risk by combining severity and probability.

7.1.2 Assessment of environmental significance (severity) of an impact

Qualitative assessments of environmental severity of impacts of different operations and events will be carried out for both the EIA Addendum and the Natura 2000 assessment. The assessment of severity includes the following steps:

- Assessments of nature, extent, duration and magnitude of impacts using the criteria shown in Table 7-1 including whether the impact is positive or negative, temporary or permanent.
- Assessment of the severity of impacts combining the assessments of extent, duration and magnitude of the impacts using the criteria shown in Table 7-2.

Table 7-1 Criteria for assessment of nature, extent, duration and magnitude of impacts.

Criterion	Description
Nature	***Nature of the environmental change***
Positive	Beneficial environmental change
Negative	Adverse environmental change
Extent	***The geographical area that may be affected by the impact***
Local	Only the place where the activities directly related to construction may occur
Regional	Effects may occur in the Central North Sea
National	Effects may occur in Danish waters
International	Effects may occur in the entire North Sea
Duration	***Period along which the impact is expected to occur***
Short-term	Less than 8 (eight) months

Medium-term	Between 8 (eight) months and 5 (five) years
Long-term	More than 5 (five) years
Magnitude	***The magnitude of impacts on environmental and social processes***
Small Medium Large	If possible, the magnitude of an effect is assessed from results of environmental modelling. Otherwise, the magnitude of an effect is based on an expert assessment based on previous experience from other projects. The following factors are taken into consideration: • The extent to which potentially affected habitats and organisms are unaffected by human activity • The numbers/areas of an environmental feature that will be potentially affected • The uniqueness/rarity of potentially affected organism and habitats • The conservation status of habitats or organism (Natura 2000 areas, Annex IV species etc.) • The sensitivity of the habitat/organism • The robustness of the organism/habitats against impacts, i.e., and evaluation of the ability to adapt to the impact without affecting the conservation status, uniqueness or rarity The potential for replacement i.e., an assessment of to what extent the loss of habitats or populations of organisms can be replaced by others.
Frequency	***How often the impact will occur***
Low	The impact occurs rarely or as a single event
Medium	The impact happens regularly
High	The impact happens often or continuously
Reversibility	***Whether or not an impact is permanent***
Reversible	The impact is not permanent
Irreversible	The impact is permanent

Table 7-2 Criteria for assessment of severity of potential impacts of the project.

Severity rating	Relation with the criteria on nature, extent, duration and magnitude that describe the impact
Positive impact	The assessed ecological or socioeconomic feature or issue is improved compared to existing conditions
No impact	The assessed ecological or socioeconomic feature or issue is not affected
Insignificant impact	Small magnitude, with local extent, short-term duration, low frequency and reversible
Minor impact	1) Small magnitude, with any combination of other criteria (except for local extent and short-term duration, and long-term duration and national or international extent) or 2) Medium magnitude, with local extent and short-term duration 3) Reversible impact
Moderate impact	1) Small magnitude, with national or international extent and long-term duration; or 2) Medium magnitude, with any combination of other criteria (except for local extent and short-term duration; and national extent and long-term duration) 3) Large magnitude, with local extent and short-term duration 4) Some irreversible impact but at a local scale
Major impact	1) Medium magnitude, with national or international extent and long-term duration 2) Large magnitude, with any combination of other criteria (except for local extent and short-term duration) 3) No reversibility of impact (irreversible)

7.1.3 Assessment of the probability that an impact will occur

The probability that an impact will occur will be assessed using the criteria shown in Table 7-3.

Table 7-3 Criteria for assessment of the probability of that and impact will occur.

Probability criterion	Degree of possibility of impact occurrence
Very low	The possibility of occurrence is very low, either due to the project design or due to the project nature, or due to the characteristics of the project area
Low	The possibility of occurrence is low, either due to the project design or due to the project nature, or due to the characteristics of the project area
Probable	There is possibility of impact occurrence
Highly Probable	Possibility of impact occurrence is almost certain
Definite	There is certainty that the impact will occur

7.1.4 Risk assessment

The environmental risk of different operations and incidences will be assessed combining significance (severity) and probability of an impact according to a risk matrix as outlined below (Table 7-4).

Table 7-4 Qualitative risk assessment matrix.

	Significance (severity) of impact			
Probability	**Insignificant Impact**	**Minor impact**	**Moderate impact**	**Major impact**
Definite	Negligible risk	Low risk	Significant risk	High risk
Highly probable	Negligible risk	Low risk	Significant risk	High risk
Probable	Negligible risk	Negligible risk	Low risk	Significant risk
Low	Negligible risk	Negligible risk	Low risk	Low risk
Very low	Negligible risk	Negligible risk	Negligible risk	Low risk

8. Environmental impacts of planned activities during the construction phase

8.1 Potential impacts

The potential environmental impacts of the following operations during the construction phase assessed in this EIA comprise of:

- Impacts of discharges to the sea during completion of wells and pressure testing of pipelines
- Direct impacts in pipeline footprint and indirect impacts of dispersal of sediment during laying of pipelines
- Impacts of noise and disturbance during the construction phase
- Impacts of artificial light during the construction phase
- Impacts of emissions to the atmosphere during the construction phase
- Impact from waste and sewage
- Impacts of accidental spills
- Cultural heritage
- Hydrography

Figure 8-1 and Table 8-1 below provide overviews of potential effects during the construction phase assessed in the EIA. This chapter deals with environmental impacts of planned activities. Environmental impacts of accidental spills are dealt with in 0 and socioeconomic impacts are described and assessed in chapter 13 Socio-economic assessment.

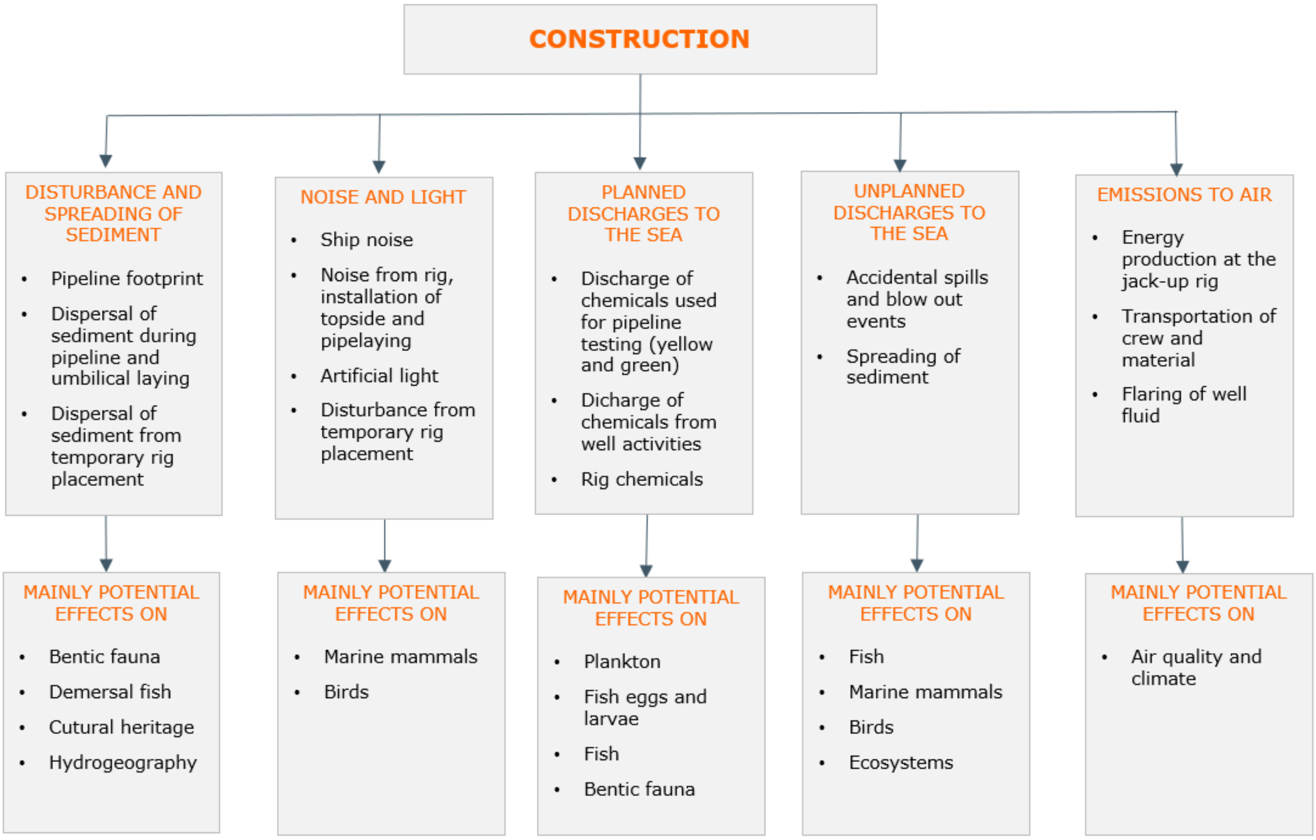


Figure 8-1 Overview of activities during construction that may have an impact on the environment and organisms that may primarily be affected by the different operations which will be assessed in the EIA.

Table 8-1 Overview of potential environmental and socioeconomic impacts of planned activities during construction which are assessed in the EIA.

Activity	Potential Impacts
Well completion and well repair	
Presence of jack-up rig	Physical disturbance benthic fauna and loss of sea floor integrity
Presence of rig during well completion and well repair	Discharges of utility chemicals can impact on water quality and marine fauna. However, only yellow and green chemicals are discharged.
Operation of jack-up rig and supporting vessels causing emissions to the air	Release of particles (PM_{10}) and gaseous emissions (SO_x, NO_x, VOC,) with potential mainly local effects on air quality Release of gaseous emissions (CO, CO_2, CH_4) with potential effects on global climate
Accidental spills and blowout	Mainly birds, marine mammals, fish, coastal ecosystems, fisheries, aquaculture and tourism may be affected. Blowouts are extremely rare events Economic loss to fisheries, aquaculture and tourism due to oiling
Pipelines and structures	
Laying of pipelines, including pre-installation survey, and installation of topside and other structures	Physical impact on the seabed and benthic fauna through placement and presence of pipelines or subsea structures Impact on fish eggs and larvae from suspended and settled sediment. Noise disturbance to marine mammals resulting in behavioural avoidance Release of particles (PM_{10}) and gaseous emissions (SOx, NOx, VOC, CO, CO_2, CH_4) from vessels with potential effects on air quality and climate Interference with shipping and fishing as a result of the presence of installation vessels outside the exclusion zone

8.2 Impacts of perforation and clean-up of Legacy wells and repair of HA-5

Perforation and clean-up of the three existing Legacy wells to be used for the production at Hejre (HA-1A, HA-2 and HA-4) will take place with only minimal discharge and, hence, the perforation and clean-up activities will not be associated with impacts on the marine environment.

During repair of the HA-5 well the cement plug will be partly drilled out and a new plug will be set. OBM will be used during the drilling activities. Afterwards the cement barrier will be repaired and during cementing the chemicals will likewise run through the OBM system. Thus, all mud and chemicals will be shipped to shore for reuse or disposal and thus no discharges.

It is expected that the utility chemicals used on the rig will be 100% discharged. Any surplus inhibited fluid not left in HA-5 for preservation will be sent for processing at South Arne and thus no discharge is expected.

The discharge of utility chemicals related to perforation, clean-up of wells and repair of HA-5, has been modelled and assessed below in Table 8-2. The chemicals for which the PEC/PNEC ratio exceed 1 is shown along with the distance where exceedance can be expected.

Table 8-2 Modelling of impact of discharge of chemicals used during perforation, clean-up of Legacy wells and repair of HA-5.

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 1000)	Duration of discharge
Utility chemicals	Rig wash	<1500	1 hour
	Jacking grease	<100	10 days
	Hydraulic oil	<100	10 days
	BOP control fluid	>5000	6 hours

From the above results it can be seen that effects are within a maximum of 1,500 m from the point of discharge. Furthermore, the discharges are short term batch discharges and thus the impact can be expected to be low.

8.2.1 Risk assessment – Perforation and clean-up and repair of HA-5

Based on the above and using the criteria described in chapter 7, it is assessed that the environmental risks related to the perforation and clean-up of the Hejre Legacy wells and repair of HA-5 is **Negligible** (Table 8-3).

Table 8-3 Environmental severity and risk of impacts of perforation and clean-up and repair of HA-5.

Impact	Extent of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of pre-installation survey– underwater noise	Local	Short term	Small	Insignificant impact	Probable	Negligible

8.3 Impacts of drilling of the Lunde well

Drilling mud contains several chemicals that are discharged during the drilling operation. In addition to drilling, establishment of the wells include several operations such as cementing and completion during which several chemicals are used and discharged (confer Chapter 5.4). When discharged, these chemicals may affect water quality and pelagic organisms.

The environmental assessment of the discharges of chemicals to sea in the different stages of the construction phase is based on the following:

- The amounts of materials and chemicals planned to be used and disposed at sea, as described in Section 5.4.2.
- The discharge patterns for the individual sub-operations
- The characteristics of the marine environment (in particular water depth and currents)
- The inherent environmental hazard properties of the chemicals.

The assessment of the latter is based on the data on environmental fate and ecotoxicological properties of each chemical and its components as documented by the suppliers of the chemicals in the so-called HOCNF

(Harmonised Offshore Chemicals Notification Format) documents. These are structured according to OSPAR's guidelines (OSPAR, 2010) and provide data based on accepted standard test methods on relevant physio-chemical properties, biodegradability and toxicity to aquatic organisms within the groups of fish, crustaceans, algae and, where relevant, sediment-dwelling organisms.

Dispersal modelling has been carried out using a model developed by COWI, based on the CHARM-model[3] developed by the oil and gas industry, chemical suppliers and members of OSPAR. The dilution part of the model is a slightly modified version of the CHARM model, and estimations of risk indicators of negative environmental effects (PNEC and PEC/PNEC ratios) are calculated according to OSPAR guidelines. They represent an assessment of the individual compounds potential effect on the environment.

Table 8-9 summarizes the main results for the discharged chemicals (except PLONOR chemicals) during the development phase (per well).

OSPAR does not regard chemicals on the OSPAR PLONOR list to be problematic and therefore no dispersal and risk indicator calculations have been performed for these compounds. Similarly, such calculations have not been performed for compounds and products, which by common use are not discharged to the marine environment. Model calculations are done for all relevant chemicals regarding dispersion and effects in the water phase. Individual assessments of the risk of effects on epi- and infauna, has been done on chemicals with an affinity towards sediments and a slow degradability in the marine environment.

No discharges in the construction phase are continuous over longer periods. PNEC's are determined according to OSPAR to protect the environment also to long term exposures. According to the current guidelines from the EU on assessment of discharges having a duration of 24 hours or shorter, these should be based on the PNEC's for acute effects. In some instances (e.g., cementing chemicals), such an assessment will lead to a PEC/PNEC ratio <1 within shorter distance of the platform than indicated by the results below. This is valid for the cementing additives and the rig wash chemical. In the case of the cementing chemicals the distance from the platform where PEC/PNEC >1 is already short (500 metres or less), while for the rig wash chemical, the use of a PNEC based on acute effects will give significantly different results (much lower distance to reach PEC/PNEC = 1).

Modelling has been performed on also short-term, batch-wise discharges as these in some cases contribute significantly to the total amount of chemicals being discharged during one particular sub-process in the development phase. The modelling has only comprised the yellow chemicals used, not any green chemicals. WBM, cement and completion fluid will be discharged during the drilling of the Lunde well. OBM will be shipped to shore for reuse or disposal.

A limited number of utility chemicals will be used at the rig during the completion of the Lunde well. It is assumed that 100% of the rig wash and other rig chemicals will be discharged to sea. All rig chemicals are discharged over a period of 6 hours per event, except for the jacking grease, which is discharged over a period of 12 hours, and the wireline fluid and the hydraulic fluid for well control, which will be directed to South Arne and continuously discharged with the produced water throughout the entire 159 days of the process.

The BOP control fluid, thread compound and dope chemicals are assumed to be discharged undiluted, while the cleaning agent is diluted 1:400.

The wireline fluid and the hydraulic fluid for well control are routed back to South Arne and discharged 100% with the produced water, with a flowrate of 1500 m^3/day.

[3] CHARM = Chemical Hazard Assessment and Risk Management.

The mud chemicals are discharged with the discharged volume of 5968 m³ for WBM. The WBM chemicals are expected to be discharged continuously throughout the 43 days in which WBM is used for drilling the upper sections.

The cementing chemicals are discharged with the discharged volume of 313 m³ for cement. The cementing chemicals are expected to be discharged continuously throughout the 133 days during cementing activities.

The completion chemicals are discharged with the volume of discharged completion fluid of 400 m³. The completion chemicals are expected to be discharged continuously throughout the 26 days during the top completion activity.

All discharges of yellow chemicals have been modelled. In Table 8-4 the chemicals where the PEC/PNEC ratio exceed 1 is shown along with the distance where exceedance can be expected.

Table 8-4 Modelling of impact of discharge of chemicals used during drilling of the Lunde well.

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 1000)	Duration of discharge
Rig chemicals	Rig wash	<250	6 hours
	Jacking grease	<500	12 hours
	BOP control fluid	>5000	6 hours
Completion chemical	Biocide	<250	26 days

Furthermore, a total amount of approx. 1,982 tonnes of cuttings will be discharged from the upper sections where WBM is used. Approx. 4,561 tonnes of cuttings from the lower sections will be shipped to shore and no OBM will be discharged as a base case.

In case a water treatment unit is used, treated slop water will be discharged to sea. The concentration of oil in the discharged water is expected to average 5-10 mg/l, which is well below the 30 mg/l limit allowed in produced water discharges according to OSPAR 2001/1.

In case a water treatment unit is used, also small amounts of water-soluble chemicals used during drilling with OBM will be discharged to sea. Exact volumes that will be discharged are difficult to estimate, but the modelling of a worst-case scenario with discharge of a concentration of 500 ppm of three water soluble red components in 20 m³ water during 1 hour showed an exceedance of PEC/PNEC = 1 (assessment factor 1000) at distances of <1780m, <1000m and <250m. Considering that this is expected to be an absolute worst case scenario, this is assessed to be a limited impact. Approximately 500 m³ of water from the OBM drilling and completion is expected to be discharged.

8.3.1 Fate of cuttings and WBM solids

When WBM solids and drill cuttings are discharged to the sea they form plumes that dilute rapidly as they drift away from the discharge point with the prevailing currents. Two separate plumes are generally formed (Sanzone et al 2016) (Figure 8-2):

- A plume of heavier larger particles and flocculated small particles that constitutes about 90% of the mass of the mud and cuttings solids. This plume settles quickly on the seafloor in close vicinity of the rig

- A plume formed in the upper water column, which constitutes the remaining 10% of the mass of the mud solids that consists of fine-grained clay-sized particles and soluble components. This plume drifts away from the platform with prevailing currents and is diluted downstream.

Several field studies have confirmed this pattern and have consistently shown that drilling waste solids are diluted by up to 30-fold in the discharge pipe and by an additional 1,000 - 3,000 fold within 30 meters from the rig, dependent on current speed (Neff 2010).

On the seabed material may be subject to erosion, dissolution, bioturbation as well as re-suspension and bed transport. Oxygen depletion may occur if the material contains large amounts of organic material especially in areas with low current speed on the seabed (Figure 8-2).

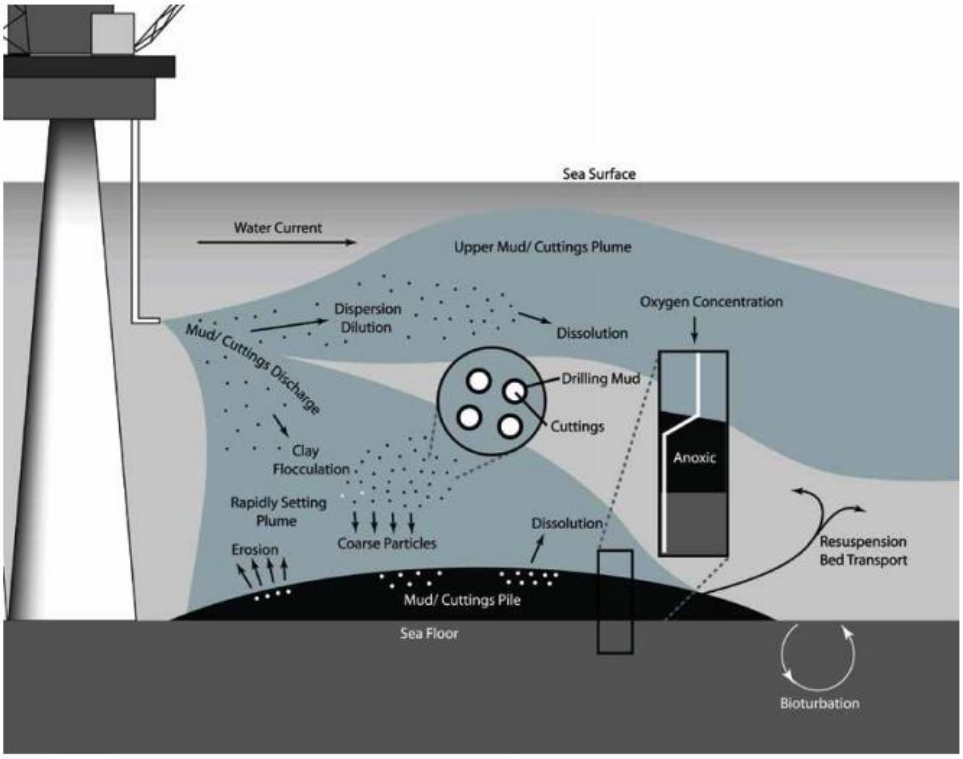


Figure 8-2 Dispersion and fates of cuttings and WBM components following discharge to the ocean (From Sanzone et al 2016).

8.3.2 Impacts of discharge

Ecological impacts of the discharge of WBM solids and cuttings, when detected, are predominantly physical effects of particles. Ecotoxicological studies, microcosms and mesocosm studies, as well as field surveys have consistently shown that WBM and WBM cuttings are non-toxic or practically non-toxic to marine plants and animals. Metals in WBM are associated almost exclusively with barite and bentonite and do not affect the environment because of their low bioavailability (Grant and Briggs 2002, Schaaning et al. 2002, Neff 2008). The metals have a low bioavailability because they are present as insoluble minerals in the nearly insoluble barite.

Once on the seabed, they do not dissolve in sediment pore water or overlying water even under anoxic conditions (Neff 2010). When toxicity of drilling muds and cuttings was identified in the past it was attributed to petroleum hydrocarbons or chrome lignosulfate in the mud, both now strictly limited in WBM destined for ocean disposal (Neff 2010).

8.3.3 Impacts in the water column

Modelling studies combined with data from laboratory tests as well as field studies have shown that offshore discharges of WBM and associated cuttings will cause little or no harmful effects on organisms in the water column (Sanzone et al 2016, Neff 2010).

A study in which measurements of the concentrations of suspended solids in the plume of drill cuttings showed a marked decrease in concentrations from 1,430,000 mg/l in the discharge point to 7-24 mg/l at distances of 250-375 m from the rig depending on rate of discharge (Ayers et al. 1980 Neff 2005). Smith et al. 2004 found that the concentration of bentonite clay in the discharge plume from a drilling rig was below 1000 mg/l at about 25 m down current from the discharge. Comparing these concentration levels with effect levels determined in the laboratory (cf. Table 8-5) it is assessed that impacts on plankton organisms, may only be expected in the immediate vicinity of the drilling rig i.e., within less than 100–200 meters from the rig.

This is substantiated by zooplankton monitoring around a rig drilling an exploratory well in the Canadian Beaufort Sea in December 2005 through March 2006. It was concluded that the discharge of water-based drilling mud had little or no effect on zooplankton communities dominated by copepods at and beyond 100 m from the rig (KAVIK-AXIS 2007, referred in Sanzone et al 2016) (samples were not collected closer to the rig than 100 m).

Local impact on plankton, including fish larvae in the immediate vicinity of the rig will not detectably affect the plankton populations and fish stocks in the Central North Sea. This is explained by the high abundance of plankton which naturally suffer very high levels of mortality and has an enormous regeneration capacity. Moreover, most fish species have extensive spawning grounds and produce vast numbers of eggs and larvae.

Fish may flee the plume of drilling mud and cuttings at larger distances. Laboratory experiments have shown that a sensitive specie like herring, may avoid concentrations of suspended matter ≥ 10 mg/l (Wildish & Power 1985, Johnston & Wildish 1981, Wildish et al. 1977).

Table 8-5 Lethal and sublethal effects of elevated concentration of WBM solids in the water column observed in the laboratory.

Observed effect	Effect concentrations	References
Average median lethal concentration of suspended barite to 12 to 15 species of pelagic animals (zooplankton and larvae of invertebrates and fish)	3010 mg/l	Smit et al. (2008)
Average median lethal concentration of suspended bentonite to 12 to 15 species of pelagic animals (zooplankton and larvae of invertebrates and fish).	1830 mg/l	Smit et al. (2008)
Barium (as barite) affected embryos of the crab *Cancer anthonyi* at concentrations greater than 1000 mg/l	> 1000 mg/l	MacDonald et al. 1988
Marine phytoplankton were adversely affected by exposure to more than about 1000 mg/l barite in suspension. Primary production was reduced due to shading effect of the suspended matter.	1000 mg/l	Smit et al. 2008
No observed effect concentration (NOEC) for marine phytoplankton exposed to bentonite for 72 hours was 1000 mg/l	1000 mg/l	Garcia et al. 2014
Early life stages of sea scallops *Placopecten magellanicus* exposed to 100 mg/l of used water-based drilling fluids for 96	100 mg/l	Cranford et al. 1988

Observed effect	Effect concentrations	References
hours were not affected in terms of fertilization success of eggs, survival of larvae and growth of the larvae		
Early life stages of lobsters *Homarus americanus* to 100 mg/l of used water-based drilling fluids for 96 hours had reduced survival	100 mg/l	Cranford et al. 1988
Early life stages of haddock *Melanogrammus aeglefinus* exposed to 100 mg/l of used water-based drilling fluids for 96 hours showed a slight reduction in survival of two of the four early life stages	100 mg/l	Cranford et al. 1988

8.3.4 Impacts on the seabed

Several monitoring studies have shown that the bulk of discharged cuttings and WBM components deposit in the immediate vicinity of the wellhead. Alterations to benthic infauna communities following the discharge of cuttings and WBM are generally restricted to within 100-200 m from the platform, if at all detected (Cf. Table 8-6). Effects may include a reduction in species diversity and increases in the abundance of a few opportunistic species. Functional changes have also been observed, including a loss of suspension feeding species and increases in deposit feeders (Ellis J.I, et al. 2012).

Table 8-6 Examples of field studies of impacts on benthic fauna around offshore platforms where WBM have been used for drilling.

Study	Result	References
Videosurveys with ROV was performed at three oil fields in the Faroe-Shetland Channel, where the top-hole section of three wells were drilled with WBM and where WBM and cuttings were discharged directly to the sea floor.	A thin layer of WBM cuttings completely covered the seabed within about 50 to 100 m of the three drilling rigs following the drilling operations. The abundance and diversity of benthic megafauna was much lower in the area where cuttings completely covered sediments	Jones et al. 2012
Sediments and benthic megafauna were monitored around a jack up rig in the Ragnarok field in Norway just before and a month after drilling the top-hole sections of the well and discharging WBM and cuttings directly to the seafloor.	The monitoring showed that the concentration of cuttings and WBM solids increased in sediments within 100 m down current of the drill site within one month of discharge of WBM and cuttings. The abundance of attached and less motile megafauna decreased within 50 m of the discharge site. The dominant species the sea urchin *Echinus acutus* was nearly eliminated from the immediate vicinity of the discharge site but was abundant at greater distances.	Hughes et al. 2010
Monitoring studies of impacts on benthic fauna of the drilling of six wells in about 25 m of water in the Gulf of Mexico off the Texas coast	Impacts on benthic fauna were observed within 75 m from the platform. Effects on benthic communities were probably caused by burial, changes in sediment texture and organic enrichment of sediment	Neff 2010
Monitoring study of impacts of the discharge of cuttings and WBM during the drilling of one exploratory well on 60 m depth	Decrease in abundance and loss of rare species of benthic fauna within 200 m from the platform	Currie & Isaacs 2005
Monitoring study of the effects on benthic fauna of the drilling of 39 wells using WBM off Point Arguello California	No effects were observed on the soft bottom benthic fauna	Hyland et al. 1994

Study	Result	References
Monitoring studies of fate and effects on benthos of exploratory drilling activities at two rigs on 80-140 m of water on Georges Bank off Massachusetts USA, where WBM was used for drilling. Approximately 20 million lbs. of WBM and 11 million lbs. of cuttings were discharged.	No changes were detected in benthic communities that could be attributed to drilling activities	Neff et al. 1989

In addition, studies have shown that:

- There is no evidence from field work of chemical toxicity of any WBM ingredients.
- There is no evidence of ecologically significant bioaccumulation of metals or petroleum hydrocarbons by marine animals residing or deployed in cages near WBM and cuttings discharges.

This strongly suggests that effects of WBM cuttings piles are highly localized to the immediate vicinity of the wellhead and are not being exported to the local food web (Neff 2010).

The marginal effects of drill cuttings and WBM on the benthos mainly result from sedimentation (Trannum et al. 2010). Possible mechanisms are:

- Burial of benthic fauna beneath accumulated cuttings and WBM components
- Changes in sediment grain size and texture, which render the sediments unsuitable for settling and growth of some species, while rendering the substrate more suitable for other species.

Under certain circumstances, effects may also be due to oxygen depletion in sediment resulting from biodegradation of organic material in the mud components. If the WBM contains biodegradable organic additives, it may stimulate growth of microbial communities in sediments, often leading to depletion of oxygen in the sediments. Anaerobic sulphate-reducing bacteria may further degrade the organic matter producing toxic hydrogen sulphide (Neff 2010). However, such effects are only likely on deeper waters with low current speeds at the seabed and not in a relatively shallow area (around 60 m depth) with relatively strong currents as that encountered at Hejre and South Arne field location.

Field and laboratory experiments have shown that benthic fauna affected by the discharge of cuttings and WBM components will rapidly recover to before drilling conditions. Recovery of the fauna may take 0.5-2 years, depending on the amounts discharge and the current speed in the area in question (Neff 2010).

Based on the above information, it is expected that the drilling of the Lunde well with water-based mud at the Hejre field will have limited effects on benthic fauna within a radius of no more than 200 m, if any detectable impacts occur. If impacts are observed, it is expected that recovery of impacted fauna will take place within 0.5-2 years after the drilling ends and probably nearer to 0.5 years than 2 years.

8.3.5 Other discharges

No other discharges are expected in the construction phase, except the temporary discharge of treated sewage from the residential quarters at the drilling rig. The impact of this discharge on the marine environment is considered negligible.

8.3.6 Risk assessment – Drilling of the Lunde well

Based on the above and using the criteria described in Chapter 7, it is assessed that the environmental risks related to drilling of the Lunde well, is **Negligible to Low** (Table 8-7).

Table 8-7 Environmental severity and risk of impacts of drilling the new well, Lunde.

Impact	Extent of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of the discharge of cuttings and drilling mud (WBM)	Local	Short term	Medium	Minor impact	Definite	Low
Impacts of the discharge of drilling chemicals	Local	Short term	Small	Insignificant impact	Probable	Negligible
Discharge of treated sewage from the residential quarters at the drilling rig.	Local	Short term	Small	Insignificant impact	Probable	Negligible
Discharge of oil and chemicals from water treatment unit	Local	Short term	Medium	Minor impact	Definite	Low

8.4 Impacts of the laying of pipelines

The construction of the Hejre tie-back to South Arne development project includes the laying of a 30 km multiphase pipeline from Hejre to South Arne, in addition to a power cable from South Arne with power and control from host. For the EIA for Hejre Legacy, the laying of two pipelines were included and pipelay has been conducted. Thus, new pipelay is assessed.

The pipeline will be buried by trenching, either through ploughing or jetting. The method to be used will be based on an evaluation of the seabed conditions by the pipe laying contractor.

8.4.1 Possible effects during laying of pipelines

Prior to the actual laying of the pipeline, a pre-installation survey and possibly a final survey of the expected route will be conducted, including seismic surveys. Potential impacts from underwater noise are discussed in Section 8.6. For completeness, the result from this overall impact assessment from underwater noise is included in Table 8-21.

The pipeline will be laid in the seabed consisting of sandy sediment. The seabed at Hejre and South Arne is characterised as fine sands. There will also be large areas with muddy sand (Figure 6-8). The laying of the pipeline will disturb the seabed and cause temporary turbidity of the water and subsequent settling of the suspended material on the seabed. This may affect organisms buried in the seabed (benthic infauna) and organisms living or immediately above the seabed in various ways.

The sediment may also contain contaminants which can be mobilised during the laying of pipelines. A baseline survey conducted at Hejre field in 2013 prior to drilling, showed that the concentrations of all investigated contaminants (PAH, THC, NPD and heavy metals) were low and generally well below the assessment criteria for sediment contamination provided by OSPAR. There was no difference between the concentrations of contaminants in samples from Hejre and from a reference station located 15 km north of

Hejre. An assessment of contaminants in the sediment around the South Arne platform was conducted in 2021. Concentrations of contaminants (PAHs and heavy metals) were generally low and below the HELCOM/Danish Targets. In general, there is no correlation between concentrations of contaminants and distance to the Syd Arne platform. The exception is Barium for which the average concentration was higher than the potential toxic concentrations (TEL) and concentrations decreased with the distance from the platform. Barium is associated with drilling activities but is not considered toxic, and therefore no assessment criteria are defined for Barium. Based on the relatively low concentrations of contaminants in the upper sediment surface and the limited expected dispersion of sediments (see below), impacts from the potential mobilisation of contaminants are not expected.

8.4.1.1 Dispersion of sediments

Two methods are considered for trenching: ploughing or water jetting. Of the two techniques water jetting result in the highest levels of suspended particles and a larger area will be affected.

Trenching of pipelines will create suspension of sediment to the water column which will gradually settle on the seabed again. Coarser particles will sediment in the vicinity of the laying track while finer particles will disperse further downstream before they settle. The disturbance period from dispersion of sediment is relatively short and local.

Calculations made in the Baltic Pipe EIA for the part of the 30" gas pipeline located in the North Sea indicated that most of the sediment suspended after jetting of the pipeline would settle close to the trench in a 75 mm thick layer. Hereafter the sediment layer would gradually decrease within a distance of 50 meters from the trench (Niras, 2019). Finer particles such as silt would disperse to a larger area (up to 500 meters from the trench), but settle in a very thin layer of max 0,6 mm.

8.4.1.2 Impacts on benthic fauna and fish

Most benthic fauna species in the direct footprint of the pipeline, will be damaged or killed during ploughing or jetting, either through direct contact with the installation device or due to burial. This footprint is expected to be narrow, generally restricted to 2-3m width. In addition, settled dispersed sediment beyond the footprint may affect organisms locally.

Findings of studies for a number of UK offshore wind farms indicate that the disturbance to seabed sediments during cable trenching is likely to be short term and relatively localised, especially if ploughing techniques are utilised (BERR 2008). During jetting of a cable in sandy sediment, the concentrations of suspended sediments were measured to a mean of 2 mg/l (max 18 mg/l) within a 200 m distance from the operation site (BERR 2008). Backfilling of the cable footprint resulted in a mean suspended sediment concentration of 5 mg/l. The study also indicated that the suspended sediment remains within a distance of 1-2 m from the seabed. Concentrations of similar magnitudes are expected during ploughing/jetting and backfilling of a pipeline between Hejre and South Arne.

Suspended particles may have negative impacts on aquatic organisms as shown in Table 8-8. Comparing these effect levels with the dispersal distance reported in BERR (2008), it is likely that zooplankton, fish eggs and fish larvae may be impacted within an area of ca. 200 m from the footprint and that sensitive pelagic fish species such as herring may avoid this area during the ploughing/jetting phase.

The area between Hejre and South Arne is spawning area for cod, plaice, lemon sole and mackerel, and potentially also for sandeel, whiting, dab and long rough dab (section 6.6). If the laying of pipeline takes place during the spawning season, eggs and larvae of these species may be negatively affected. However, it is argued that any such impact will be insignificant and will in no way affect the population size of these fish species. Firstly, the duration of elevated concentration particles above effect concentrations is limited to few hours at any site. Secondly, fish species produce vast numbers of eggs and larvae and have extensive spawning grounds. Based on the above arguments, spreading of sediment will not affect the spawning stock and stock recruitment of fish that spawn in the area including cod that is in a poor condition. Sandeels is a demersal spawner and vulnerable to physical disturbance of the seabed. However, since the area is not a core spawning area for sandeel, it is assessed that the environmental risk of an impact on spawning stock and recruitment of sandeel is negligible.

Table 8-8 Lethal and sublethal effects of elevated concentration of suspended particles in the water column observed in the laboratory.

Observed effect	Effect concentrations	References
Avoidance reactions. Herring and smelt may avoid the plume of suspended matter, if the concentration is sufficiently high to cause inconvenience.	≥ 10 mg/l	Wildish & Power 1985, Johnston & Wildish 1981, Wildish et al. 1977
Lethal effects. Increased mortality of juvenile copepods (*Calanus helgolandicus*)	≥ 6 mg/l	Paffenhöfer 1972
Lethal effects. Survival of cod eggs, cod larvae and herring larvae may be reduced because of elevated concentrations of suspended particles	Cod eggs ≥ 5 mg/l Cod larvae ≥ 10 mg/l Herring larvae ≥ 20 mg/l	Engell-Sørensen & Skyt 2000

Shortly after the backfilling of the footprint, benthic fauna will recolonize the affected areas. The organisms will immigrate from undisturbed areas and from larvae settlement (COWI/DHI Joint Venture 2001, Kiørboe & Møhlenberg 1982). The community will usually be re-established within 0.5-2 years after the disturbance (Kiørboe og Møhlenberg 1982). Recovery of the echinoderms including *Amphiura filiformis* may take a longer time, due to slow growth and late maturity.

Common fish species for the area such as haddock, dab and rough dabs, which stay on the seabed or within the bottom 1-2 m of the water column may temporarily avoid the area. Because the disturbance will be temporary, short term and confined to a small area compared to the potential available living space, measurable impacts on the fish population are not anticipated.

Sandeels may also be found in the affected area. Sandeel lay their eggs on the seabed. If pipe laying takes place during the spawning season (December – July), sandeel eggs may be destroyed. As each sand eel females lay thousands of eggs and as the potential area in which eggs may be destroyed is infinitely smaller than the total spawning area in the North Sea, this will not measurably affect the sandeel stocks.

8.4.2 Possible effects during testing of pipelines

The new pipeline to be tested comprise a 30 km multiphase pipeline from Hejre to South Arne.

The pipeline will be pressure tested using seawater that has been added a combined corrosion inhibitor, biocide and oxygen scavenger ("testing mixture") and a fluorescent tracer chemical. When testing of the Hejre tie-back to South Arne pipeline has been completed, the pressure-test water and chemicals will be discharged from the pipeline via South Arne and the discharge will have a duration of about 24 hours. The discharge has been modelled and assessed below.

Table 8-9 Modelling of impact of discharge of pipeline chemicals

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 1000)	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 100)	Duration of discharge
Pressure testing, pipeline Hejre to South Arne	Combined corrosion inhibitor, biocide and oxygen scavenger for preserving the pipe-line	>5000	<1000	24 hours
	Fluorescent tracer chemical	<100	<100	24 hours

As can be seen from the above table, the discharges leading to potential impact at distances of more than a few hundred metres occur only in connection with short term activities (max. one day), and thus the distance of impact is also modelled based on short-term PNEC values (derived based on acute L(E)C50 data and using an assessment factor of 100 in accordance with WFD Technical Guidance Document No. 27, 2018, Section 3.4.2). Thus, it can be seen that the distance where potential acute impact of a chemical might occur, is significantly shorter than the potential impact distance based on the corresponding long-term PNEC.

The PEC/PNEC-dispersal modelling results for pressure testing the pipeline shows that any impacts of discharging yellow chemicals may be toxic at larger distances. However, as the discharges take place over a very short period (24 hours), and it is assessed that toxic effects on any eggs or larvae of fish that may be spawning in the area and other plankton organisms will be local, marginal and without measurable impacts on the stocks.

8.4.3 Risk assessment - Laying of pipelines

Based on the above and using the criteria described in Chapter 7, it is assessed that the environmental risks related to the laying of pipelines is **Negligible** (Table 8-10).

Table 8-10 Environmental severity and risk of impacts of laying of pipelines.

Impact	Extent of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of the laying of pipelines – dispersion of sediments	Local	Short term	Small	Insignificant impact	Highly probable	Negligible
Impacts of the discharge of pipeline testing chemicals	Local	Short term	Small	Insignificant impact	Probable	Negligible

8.5 Impacts of air emissions

The emissions related to the planned activities during the construction phase are described in the following. The main activities causing emissions during construction are (including emissions during transport):

- Well completion activities and repair of well HA-05 including well clean-up
- Installation of the pipeline
- Installation of the topside at Hejre
- Modifications at South Arne and installation of tie-in module
- Emission factors and conversion factors used in the following are supplied by INEOS and cover burning of diesel in generators and emission factors for sea transport.

8.5.1 Emissions related to well perforation and clean-up activities and repair of well HA-5

In relation to the Hejre re-development well completion of three wells, repair of well HA-5 and clean-up of the wells will take place (INEOS Oil & Gas Denmark well and drilling data, 2019). Emissions to air from well service activities are related to:

- Energy production at the jack-up rig
- Transportation of crew and material by helicopter, standby boat, tugs and supply boat
- Flaring of well fluid during clean-up

Energy consumption at the rig will mainly be used for completion of 3 wells and repair of 1 well including power supply to pumps and compressors. Energy consumption for other purposes such as the accommodation module etc. is expected to be marginal. The energy is provided by generators powered by diesel engines. It is expected that the rig will be needed for 100 days in total.

A standby vessel is required, when rig activities are conducted, and thus the standby boat is operating 24 hours. The standard emission factors for rig and vessels are from The Norweigan Oil and Gas Association (NOGA, 2022).

All materials, supplies, waste etc. will be transported offshore/onshore by supply vessels. It is estimated that 1 vessel will be in operation approx. 11 hours per day, 2 times a week for 100 days, which will be 13 days in total for the well service activities. The standard emission factors for helicopters are from E&P Forum (E&P Forum, 1994).

Transportation of crew between shore and offshore is performed by helicopter. They are assumed to be in operation 3 hours per day for 100 days, which will be 13 days during completion and repair activities. The standard emission factors for helicopters are from E&P Forum (E&P Forum, 1994).

After the wells have been perforated, they will be cleaned up via rig-based test equipment until acceptable production fluid values are reached (expected duration of 12-24 hours per well). Well fluids will be produced to surface and the gas fraction will be burned via the rig-based burner. It is estimated that approx. 3,600,000 Sm^3 in total will be flared. The emissions are based on information from INEOS.

An estimate of the emissions related to the well activities is shown in Table 8-11.

Table 8-11 Estimated emissions related to the perforation, clean-up and repair activities.

Well completion and repair activities	Number of vessels	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]
Rig	1	100	10	2,700	50	4	0.1	2
Standby boat	1	100	3	810	15	1.5	0.05	0.5
Tugs	3	20	20	3,300	60	4	0.2	2
Supply vessel	1	13	10	360	6	0.5	0.02	0.2
Helicopters (kerozene)		13	1.2	40	0.2	0.05	0.001	0.01
Well clean-up and test		12-24 hrs	-	13,400	5.05	0.025	1	0.22
Total [ton]				**20,610**	**137**	**10**	**1.5**	**5**

This is primarily due to a shorter operation time and changes in fuel consumption by the vessels. The rig and the tugs although have a high emission of SO_X.

8.5.2 Emissions related to drilling of Lunde

In relation to the Hejre re-development a new well, Lunde will potentially be drilled. The emissions to air related to the drilling activities will include:

- Energy production at the jack-up rig
- Transportation of crew and material by helicopter, standby boat, tugs and supply boat
- Flaring of well fluid during clean-up and well test

Energy consumption at the rig will mainly be used for power supply for pumps and compressors used during drilling. Energy consumption for other purposes such as the accommodation module etc. is expected to be marginal. The energy is provided by generators powered by diesel engines. It is expected that the rig will be needed for 159 days in total.

A standby vessel is required, when rig activities are conducted, and thus the standby boat is operating 24 hours. The standard emission factors for rig and vessels are from The Norweigan Oil and Gas Association (NOGA, 2022).

All materials, supplies, waste etc. will be transported offshore/onshore by supply vessels. It is estimated that 1 vessel will be in operation approx. 60 hours per run, 1.5 times a week during the 43 days of drilling with WBM and 2.5 times a week during the 90 days of drilling with OBM, which will be 103 full days in total for the drilling activities. The standard emission factors for helicopters are from E&P Forum (E&P Forum, 1994).

Transportation of crew between shore and offshore is performed by helicopter. They are assumed to be in operation 3 hours per day for 159 days, which will be 20 days during drilling activities. The standard emission factors for helicopters are from E&P Forum (E&P Forum, 1994).

After the well has been perforated, it will be cleaned up via rig-based test equipment until acceptable production fluid values are reached (expected duration of 12-24 hours per well). Well fluids will be produced to surface and the gas fraction will be burned via the rig-based burner. It is estimated that 1,200,000 Sm^3 will be flared. The emissions are based on information from INEOS. An estimate of the emissions related to the well activities is shown in Table 8-12.

Table 8-12 Estimated emissions related to drilling activities.

Well completion and repair activities	Number of vessels	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_x [ton]	SO_x [ton]	CH_4 [ton]	nmVOC [ton]
Rig	1	159	10	4,300	72	5	0.2	3
Standby boat	1	159	3	1,290	21	2	0.1	1
Tugs	3	20	20	3,300	60	4	0.2	2
Supply vessel	1	103	10	2,800	50	4	0.15	2
Helicopters (kerozene)		20	1.2	62	0.2	0.1	0.002	0.02
Well clean-up		12-24 hrs	-	4,500	2	0.008	0.3	0.8
Total [ton]				**16,252**	**205**	**15**	**1**	**9**

8.5.3 Emissions related to pipeline installation

The Hejre tie-back to South Arne concept will include laying of pipelines connecting Hejre and South Arne.

Emissions to air during pipelay activities are related to:

- Transport activities and operation by the fleet used for pipelay (pipelay vessels and other special vessels)

The operation of the fleet includes transportation activities and operation activities such as pipelay, trenching, rock dumping etc. The standard emission factors for rig and vessels are from The Norweigan Oil and Gas Association (NOGA, 2022).

An estimation of the emissions related to the pipelay activities is carried out in Table 8-13.

Table 8-13 Estimated emissions related to the pipelay activities.

Pipelay activities	Number	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_x [ton]	SO_x [ton]	CH_4 [ton]	nmVOC [ton]
Pipelay vessel1)	1	30	20	1,650	30	2	0.1	2.5
Survey vessel (ROV)2)	1	35	5	500	10	1	0.02	1
Trenching/backfilling vessel3)	1	20	20	1,100	20	1	0.05	2
Guard vessel	1	30	0.5	40	1	0.05	0.002	0.06

Diving support vessel (DSV)[4)]	1	45	20	2,500	45	3	0.1	4
Total [ton]				**5,790**	**106**	**7**	**0,2**	**7**

[1)] Seven Navica (Subsea 7) or similar vessel
[2)] Seven Petrel (Subsea 7) or similar vessel
[3)] Skandi Skansen or similar vessel
[4)] Seven Atlantic (Subsea 7) or similar vessel

8.5.4 Emissions related to installation of the topside

Emissions to air during installation of the topside at Hejre related to:

- Transport activities and operation by the Heavy Lift Vessel (HLV)
- Special vessels used for installation of the topside at Hejre and South Arne tie-in module.

The emissions to air from fuel consumption in relation to the installation of the topside is mainly from the crane vessel, the barge and the tugboats, which shall transport and lift the topside and tie-in module into place.

The topside and tie-in module is transported on the same barge and thus only one barge and two tug boats are required. No fuel consumption is related to the barge, since the barge is towed by the tugboats. T The standard emission factors for rig and vessels are from The Norweigan Oil and Gas Association (NOGA, 2022).. An estimation of the emissions related to the topside installation activities is carried out in Table 8-14.

Table 8-14 Estimated emissions related to the topside and tie-in module installation activities.

Topside installation activities	Number	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]
Heavy lift vessel [1)]	1	9	47	1,150	20	1	0.1	1
Heavy lift vessel [2)]	1	18	35	1,730	30	2	0.1	1
Barge	1	35	-	0	0	0	0	0
Tug boats	2	35	20	3,800	65	5	0.2	2.5
Flotel for HUC [3)]	1	125	3.5	1,200	20	2	0.1	1
Total [ton]				**7,880**	**135**	**10**	**1.5**	**5.5**

[1)] HMC Balder or similar vessel

[2)] Seven Artic or similar vessel

[3)] Seafox Marinia or similar vessel

8.5.5 Environmental impacts from air emissions

In Table 8-15 a summary of the emissions from the different activities during the construction phase can be seen.

Table 8-15 Summary of the estimated emissions to air during the construction phase of the Hejre tie-back to South Arne concept

Construction phase	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]	CO_2-eq[1)] [ton]
Pipelay	5,790	106	7	0.2	7	5,796
Installation of the Hejre topside and tie-in module at South Arne	7,880	135	10	1.5	5.5	7,922
Completion and well repair activities	20,610	137	10	1.5	5	20,652
Drilling of Lunde	16,252	205	15	1	9	16,280
Total [ton]	**50,532**	**583**	**42**	**4**	**27**	**50,650**

[1)] CO_2-eq is the total emission of CO_2 and CH_4. The global warming potential for CH_4 is 28 (IPCC, 2014)

From the table it can be seen that well activities cover 73% of the total CO_2-eq emission related to the construction phase.

Compared to the total Danish CO_2-eq emission in 2020, the construction phase for the Hejre tie-back to South Arne concept constitute 0.11%.

Hejre is located offshore and emission of SO_X and NO_X are not expected to contribute to the onshore health effects.

8.5.6 Risk assessment - Air emissions during construction

Based on the above and using the criteria described in chapter 7, it is assessed that the environmental risks related to air emissions is negligible or low depending on the type of component emitted (Table 8-16). Due to the characteristics of the greenhouse gases, they will contribute to global warming if emitted, and thus the probability of the impact is assessed to be highly probable. The impacts related to NOX and SOX are determined by the surrounding environment and thus are assessed to be low.

Table 8-16 Environmental severity and risk of impacts of air emissions during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of air emissions (NO_X, SO_X)	Regional	Short term	Small	Minor impact	Low	Negligible
Impacts of air emissions (CO_2-eq)	International	Short term	Small	Minor impact	Highly probable	Low

8.6 Impacts of underwater noise

During the construction phase, the following operations may generate underwater noise:

- Noise from the rigs, installation of a new topside at Hejre, modifications to both Hejre and South Arne and pipe laying (including pre-installation survey).
- Machinery, propellers and thrusters of ships during the completion, modifications and installation operations.

- Noise from drilling activities of Lunde well, including noise from the rotating drill string, machinery and pumping systems

8.6.1 Impacts on marine mammals

Underwater noise may affect marine organisms in different ways. As cetaceans (whales, porpoises and dolphins) depend on the underwater acoustic environment for orientation and communication they are believed to be the marine organisms that are most sensitive to underwater noise. Seals and fish may, however, also be affected by underwater noise.

8.6.1.1 Potential impacts of underwater noise on marine mammals

The possible effects of underwater noise on cetaceans and seals include:

- **Hearing damage.** Intense underwater noise may damage hearing of cetaceans and seals. Loss of hearing is particularly serious for cetaceans because they use sound for communication, navigation and location of food. Seals may also loose hearing.

- **Behavioural reactions.** Underwater noise may cause avoidance reactions and other behavioural effects of cetaceans and seals, such as changes in surfacing, breathing and diving behaviour, cessation of feeding, aggression, aversion and panic (Däne et al 2013, Thompson et al. 2010, Tougaard et al 2009, Southall et al 2007, Stone 2003). Behavioural impacts to acoustic exposure are generally more variable, context-dependent, and less predictable than the effects of noise exposure on hearing.

- **Masking.** Because cetaceans depend on the underwater acoustic environment for orientation (echo location) and communication an emitted cetacean sound can be obscured or interfered with (masked) by manmade underwater noise (Tougaard 2014); and

- **Vocalisation.** There are examples of whales changing their vocalisation because of underwater noise (IWC 2007, Weilgart 2007).

The most used predictor for TTS and PTS is the sound exposure level (SEL), cumulated over a period of at least two hours. Guiding threshold values of sound exposure levels that may cause TTS or PTS or behavioural/avoidance reactions for harbour porpoise, white-beaked dolphin, minke whale and seals are presented in Table 8-17. These species have been assessed to be relevant for projects located in the North Sea (DCE 2021). In general, the harbour porpoise seems to be the most sensitive species and the seals the least sensitive species to underwater noise.

Table 8-17 Sound exposure levels, that are harmful to cetaceans and seals. 'I-type sounds' are characterised by having a very fast onset, short duration and with a large bandwidth. This is typically regarded as impulse sounds. Sounds that do not fulfil these three characteristics are 'Other sounds' (Based on DEA 2022).

Impact	I-type sounds SEL (cum) (dB re 1µPa2s)[2]	Other sounds SEL (cum) (dB re 1µPa2s)[3]	I-type and other sounds SPL dB re 1 µPa
Harbour porpoise (very high frequency cetacean)			
Sound exposure level causing permanent threshold shift (PTS)	155	173	
Sound exposure level causing temporary threshold shift (TTS)	140	153	

Impact	I-type sounds SEL (cum) (dB re 1µPa2s)[2]	Other sounds SEL (cum) (dB re 1µPa2s)[3]	I-type and other sounds SPL dB re 1 µPa
Behavioural reactions			103
White beaked dolphin (high frequency cetacean)			
Sound exposure level causing permanent threshold shift (PTS)	185	198	
Sound exposure level causing temporary threshold shift (TTS)	170	178	
Minke whale (low frequency cetacean)			
Sound exposure level causing permanent threshold shift (PTS)	183	199	
Sound exposure level causing temporary threshold shift (TTS)	168	199	
Seals (Harbour seal and grey seal)			
Sound exposure level causing permanent threshold shift (PTS)	185	201	
Sound exposure level causing temporary threshold shift (TTS)	170	181	

No major seismic surveys are expected, as the only seismic survey will be during the pre-installation survey of the pipeline route. The survey will be conducted according to the Danish guidelines for exploration at sea (DEA 2018) thus ensuring that only the equipment level of emitted sound required for the particular survey is utilised. This seismic survey may therefore be viewed as a 'light' seismic survey.

The pre-installation survey is expected to take place along two longitudinal lines along the proposed pipeline route (Figure 5-10). Each line is expected to be approximately 25-30 km long. With a survey speed of a maximum of 4 knots, the pre-installation survey is expected to be completed within 10 hours.

For the geophysical survey for the pre-installation survey of the pipeline route, a combination of different of equipment will be used, including a sub bottom profiler (pinger and sub/deep tow boomer), multibeam echosounder sonar, dual-channel side scan sonar, underwater positioning system and a magnetometer. Considering the sound emitted from the various equipment and the hearing range of the marine mammals, it has been assessed that the sub bottom profiler and the multibeam echosounder sonar are relevant for assessing potential impacts on the marine mammals (INEOS 2020).

Equipment expected to be used during the pre-installation survey is listed above. Most of the equipment has been assessed as having no significant environmental impact, based on the frequency range, which is either too high or too low for marine mammals to hear, compared to their hearing threshold according to the report "Environmental assessment of pipeline route survey" prepared by Rambøll on behalf of INEOS (INEOS 2020). Noise propagation has been calculated for three of the listed instruments, which has been assessed as having the largest noise impact. The three instruments are:

- Surface-towed Low-frequency SBP GeoSpark 200TIP. Source level is estimated to be 188 dB re 1 µPa2s at 1 meter SEL.
- High Res. Sub-bottom profiler (CHIRP, Innomar SES2000 Medium). Source level is estimated to be 243 dB re 1 µPa2s at 1 meter SEL, corrected for beam directivity.

- Singlebeam Echosounder (Kongsberg EA 400). Source level is estimated to be 147 dB re 1 µPa2s at 1 meter SEL

Noise propagation for the relevant equipment has been calculated and compared to threshold levels for the marine mammals, although based on Tougaard 2016 and NOAA 2018 so slightly different than the threshold levels in Table 8-17, and based on this, calculated a distance from the equipment where marine mammals may be impacted.

For the equipment generating the most noise relevant for the marina mammals, the sub-bottom profiler, and for the most sensitive marine mammal, the harbour porpoise, the calculated distance for PTS was 120 m, for TTS 205 m and for behavioural change 3.400 m (INEOS 2020). This is thus the most conservative distances for potential impacts on the marine mammals. These distances are based on underwater noise in the higher part of the range, thus the assessment in this EIA represents a conservative approach.

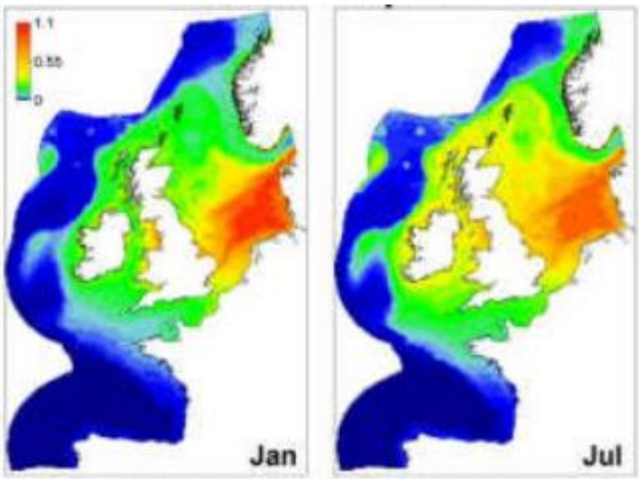
The noise levels may typically be in the range of 188-243 dB re. 1 µPa2 s, depending on the equipment used (INEOS 2020). It is not expected that the pre-installation survey of the pipeline route will use a method that results in underwater noise in the higher range.

Based on the above considerations, the potential impacts from the pre-installation survey of the pipeline route are assessed to be temporary and short term. Only mammals within very short distances to the survey boat and equipment will risk TTS and PTS. The project will implement the Danish guidelines for exploration at sea (DEA 2018), thus initiate the survey with a ‘slow start’ and engage a marine mammal observer (MMO) and deploy passive acoustic monitoring (PAM) equipment. By these measures the risk of impacts on marine mammals are assessed to be reduced significantly.

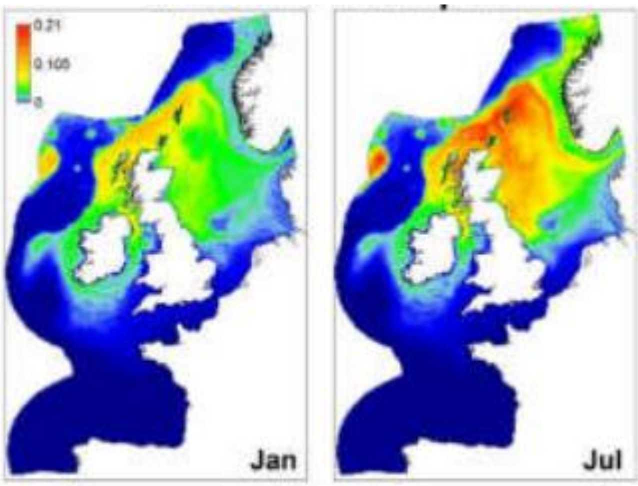
Annex IV-species have specific protection requirements including prohibition of all forms of deliberate capture or killing of these species in the wild, deliberate disturbance of these species particularly during the period of breeding, rearing and migration and deterioration or destruction of breeding sites and resting places. Marine Annex IV-species of relevance in the Danish North Sea include the harbour porpoise, the white-beaked dolphin and the minke whale (DCE 2021).

The harbour porpoise and white-beaked dolphin are very high frequency and high frequency cetaceans respectively. Based on the threshold levels the harbour porpoise tends to be more sensitive to underwater noise compared to the white-beaked dolphin. The minke whale is a low frequency cetacean (Table 8-17).

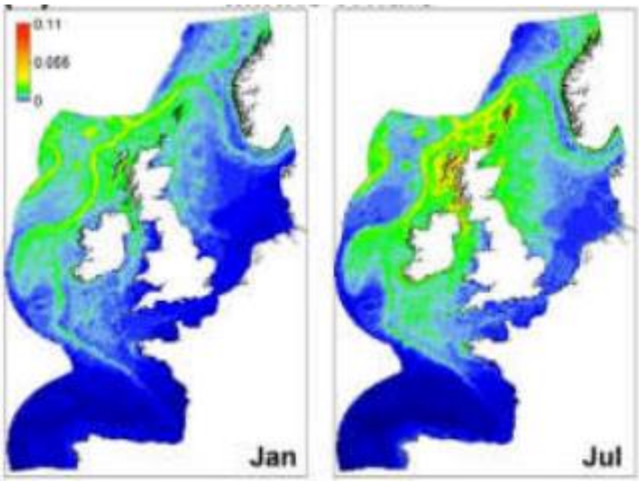
The distribution of the harbour porpoise, the white-beaked dolphin and the minke whale in the North Sea has been modelled (Figure 8-3). The harbour porpoise is the most common marine mammal in Danish waters and harbour porpoises in the project area are expected to belong to the North Sea Population. The white-beaked dolphin is typically found in the northern part of the North Sea, while the minke whale is found in both the central and northern part of the North Sea, particularly during the summer (Figure 8-3). The populations of harbour porpoises, white-beaked dolphins and minke whale are all assessed to be in favourable conservation status (DCE 2021).



Harbour Porpoise



White-Beaked Dolphin



Minke Whale

Figure 8-3 Modelled spatial distribution in animals per km² in January and July in the North-East Atlantic. Note a different colour gradient used for each species. From Waggit et al. 2019.

The offshore activities at Hejre are expected to take place within the weather window from April to September during 2026 and 2027. The noise from the rigs, machinery, etc. will take place approximately during 5 months in 2026 and 6 weeks during 2027. The pipeline activities, including pipeline route survey, trenching and pipelay are expected to take place during 50 days in 2026 and 80 days for pipeline installation activities during 2027. Drilling of the Lunde well will either take place in the fall of 2027 after the other activities have been completed, or alternatively at a later stage. The drilling of Lunde will thus not cause any cumulative impacts from underwater noise.

Cetaceans are probably most sensitive to potential impacts from underwater noise during the period where they mate, deliver the calf and the initial nursing. Harbour porpoises mate during July-September, deliver during the spring and summer with a peak in June. White-beaked dolphins mate during May-August and give birth during the summer. Minke whales mate and deliver during late winter to early spring.

The harbour porpoise and white-beaked dolphin breed during part of the weather window for the activities from April to September. No breeding areas have been established for either the harbour porpoise or the white-beaked dolphin. It may be expected that for example the harbour porpoises will breed in more protected and shallower waters closer to the shore. From a precautionary approach breeding may take place in the vicinity of the project area, The impulse noise creating activities that have impacts for the longest distance is for high frequency cetaceans non-impulse sounds and for low frequency cetaceans impulse noise. The potential impacts are thus dependent on the various equipment and sound type the equipment emits. It is noted, that according to the guidelines from DEA, the implementation of soft start and utilization of a marine mammal observer (MMO) and passive acoustic monitoring (PAM) will allow the cetaceans to flee the area and thus reduce the potential for permanent and temporary threshold shifts significantly. Behavioural reactions cannot be ruled out completely, however as the activities take place during a relative short period and for a limited impacted area in combination with implementation of a soft start, MMO and PAM, it is assessed that the ecological functionality of the area for these two species will not be impacted.

For the minke whales, as they are low frequency cetaceans, it is expected that they potentially will be impacted at the furthest distance due to the propagation of low frequency sounds. However, they are mostly observed during May-July and there have been no observations of minke whales in Danish waters during February-April. As they mate and deliver during late winter to early spring, and mostly are observed in the northern part of the North Sea, it is not likely, that minke whales will be impacted by the activities during their most sensitive periods.

It is assessed that the project activities will not cause a deterioration or destruction of breeding or resting sites for the Annex IV-species.

Noisy activities during completion, repair of well, installation of topside and laying of pipelines are not expected to exceed the threshold for triggering avoidance and other behavioural impacts of habour porpoise (Southall et al. 2007). Field studies around the drilling rig *Noble Koskaya* and its support vessel *Northern Seeker* in the German sector of the Doggerbank have shown that activities at the rig and noise from shipping do not affect the behaviour of harbour porpoise. Porpoise activity appeared to be independent of rig activity except for rig-docking/rig departure manoeuvres (Todd et al. 2007, Todd et al. 2009). The drilling noise at the well was measured at 120 dB re 1µPa, i.e., above the threshold for triggering potential change in behaviour 103 dB re 1µPa (Table 8-17).

Bach et al (2010) also monitored "click" activity around two platforms in the North Sea using T-PODs. They concluded that drilling activities in general do not affect porpoise and other small cetaceans and that behavioural effects are only expected during the ramming of conductors (ramming of conductors produces the highest levels of underwater noise and is not part of this project).

For potential cumulative impacts, it is not a simple assessment as it is not possible to just add the different noise levels. It is noted that the threshold levels presented in Table 8-17 for PTS and TTS are presented for cumulative sound exposure levels for I-type sounds and other sounds. However, cumulative impacts may arise by a combination of different project activities and the underwater noise levels for these different activities. It is expected that underwater noise will be generated during the good weather window by for example ship activities and from platform modification in addition to short term activities e.g. from the pre-installation pipeline survey. It is expected that it will be the most noisy activity in addition to the specific frequencies that will determine the distance from which the cetaceans may experience TTS and PTS. Potential impacts from cumulative impacts among others depend on the hearing group of the cetacean (very high, high or low frequency) and the noise level frequencies. As the above assessments are based on a worst case scenario, additional impacts from cumulative impacts are not expected.

To current knowledge, data from field studies on impacts on seals of underwater noise during drilling are not available. However, based on a comparison of measured underwater noise levels from different drilling rigs (Table 8-18) and that seals do not react to sound pressures up to 160 dB re 1µPa (Tougaard 2014), it is assessed that drilling noise will not affect seals beyond a distance of 100 m from the rig if at all.

Table 8-18 Underwater noise level at different distances from drilling rigs.

Source	Sound levels at different distances from the source (dB re 1µPa)				References
	At the Source	100 m	125 m	400-500 m	
Underwater noise from drilling rig	120	-	-	-	Todd et al., 2007
Underwater noise from jack-up drilling rig	163	123			Richardson et al., 1995
Underwater noise from drilling rig	145-190				Thomsen, 2009
Underwater noise from drilling rig	-	-	117	115	McCauley, 1998

It is concluded that the project activities at Hejre and South Arne is not expected to exceed the sound exposure levels that are harmful to cetaceans and seals (Table 8-17). The project activities are expected to have a local impact only due to the described activities. The impact is assessed to result in potential avoidance by marine mammals of the area in the immediate vicinity of the activities. The site is not assessed to be an important area for marine mammals, although marine mammals may be present and utilise the area, and as the impact is expected to be temporary and local the overall impact is assessed to be insignificant.

The project activities are expected to take place within the weather window from April to September. The project area is not expected to be important for either harbour porpoises, white-beaked dolphins or minke whales. Similarly, no breeding areas are identified in the area. Based on this and on the general negligible impacts, this impact assessment is expected to be valid no matter when the project activities take place during the weather window.

8.6.2 Impacts on fish

It has been demonstrated that fish, fish eggs and fish larvae may be injured by sudden exposure to loud underwater noise. It has for instance been observed that swim bladder damage occurred in adult anchovies at high sound levels (OSPAR Commission 2009). Noise levels from ramming activities and the potential effects on fish has been assessed and the noise levels that may cause effects are shown in Table 8-19. Note however, that these levels should serve as a guideline only, as they are based on ramming activities, which are not part of this project.

Table 8-19 Levels of underwater noise that have been reported to harm fish, fish eggs and fish larvae (Andersson et al. 2017). These levels are based on ramming activities.

Effect	$SPL_{(peak)}$	$SEL_{(ss)}$	$SEL_{(cum)}$

	(dB re 1μPa)[1]	(dB re 1μPa^2s)[2]	(dB re 1μPa^2s)[3]
Risk of serious injuries of inner organs or risk of death	≥ 207	≥ 174	≥ 204
Damage of fish eggs and fish larvae	≥ 217	≥ 187	≥ 207

1) $SPL_{(peak)}$ = Sound Pressure Level= Maximum overpressure generated by ramming.
2) $SEL_{(ss)}$ = Sound Exposure Level (Single Strike) = Sound energy level emitted during a single ramming strike.
3) $SEL_{(cum)}$ = Sound Exposure Level (Cumulative) = Cumulative sound energy level emitted during several ramming strikes over a certain period.

Fish has also been observed to flee from underwater noise (avoidance reaction) or to alter behaviour such as changing of swimming speed and/or swimming direction or to show “freeze” reaction (i.e., a reaction in which the fish suddenly stops swimming) (Mueller-Blenke et al. 2010).

However, the literature provides an ambiguous picture of the reaction of fish to underwater noise (Table 8-20). Some species flee from noise and others do not react to noise. There is even evidence that some species are attracted to noise (Nedwell et al. 2004). Field studies have shown that several species of fish may be disturbed by noise from passing vessels and they may flee from the vessel while other species are not affected (Freon et al. 1993). It has also been demonstrated that species, which normally would flee from vessel noise can adapt to frequent noise and become unaffected (Steward, 2003). Some studies also indicate that fish which are exposed to high levels of noise may stay in an area, if it is an important feeding or spawning ground (Wardle et al. 2001, Pena et al. 2013).

Table 8-20 Levels of underwater noise that has affected the behaviour of fish in laboratory experiments.

Effect	SPL (dB re 1μPa)	$SPL_{(peak)}$ (dB re 1μPa)[2)]	$SEL_{(ss)}$ (dB re 1μPa^2s)[3)]	Ref.
Changes of behaviour [1)] observed for cod		140 - 161		Mueller –Blenke et al. 2010
Changes of behaviour [1)] observed for sole		144 - 156		Mueller –Blenke et al. 2010
Changes of behaviour observed for sprat			≥ 135	Hawkins et al 2014
Avoidance reactions of herring	122 - 138			Blaxter, and Hoss 1981

1) Changing of swimming speed and/or swimming direction or “freeze” reaction, in which the fish suddenly stops swimming.
2) $SPL_{(peak)}$ = Sound Pressure Level= Sound Pressure Level= Maximum overpressure generated by ramming.
3) $SEL_{(ss)}$ = Sound Exposure Level (Single Strike) = Sound energy level emitted during a single ramming strike.

The fact that offshore drilling rigs and platforms in general attracts fish and that the abundance and diversity of fish may be higher than the surrounding waters indicate that noise from the rig generally do not disturb fish (Løkkeborg et al., 2002, Soldal et al., 2002, Fabi et al., 2002, Stanley & Wilson 1997, Love et al., 2000).

Potential impacts are only expected in the immediate vicinity of the project activities. As the noisy activities are insignificant, local, and temporary and will not affect fish populations, the impact is assessed to be insignificant. The project activities are expected to take place within the weather window from April to September. According to Table 6-8 several fish species may spawn during this period, which is especially relevant for the species that exhibit high spawning activities within the project area, e.g. lemon sole (*Microstomus kitt*) and mackerel (*Scomber scombrus*). However, no impacts are expected due to the overall negligible impact caused by the expected local impact during a short period of time.

8.6.3 Risk assessment - Underwater noise

Based on the above and using the criteria described in Chapter 7.1, it is assessed that the environmental risks related to underwater noise generated during installation of a new topside at Hejre, modifications to both Hejre and South Arne and pipe laying including pre-installation survey. in addition to noise from support vessel activity is **Negligible** (Table 8-21).

Table 8-21 Environmental severity and risk of impacts of underwater noise generated from the activities at the rigs, pipe laying and support vessel activities.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of noise from rig including drilling	Local	Short term	Small	Insignificant impact	Probable	Negligible
Impacts of pre-installation survey– underwater noise	Local	Short term	Small	Insignificant impact	Probable	Negligible
Impacts of underwater noise from support vessels	Local	Short term	Small	Insignificant impact	Probable	Negligible

8.7 Impacts of noise and artificial light

The installation of a new topside at Hejre and the modifications to both Hejre and South Arne will increase the artificial light and noise emissions compared to the production phase. However, the majority of the potential impacts from the artificial light and noise emissions will already be dealt with in the Hejre Legacy EIA so for this EIA Addendum for Hejre to South Arne tie-back it is only the minor addition that is assessed. In addition, the optional drilling of the Lunde well will add to the artificial light and noise emissions as it requires a drilling rig, which also will be included in the assessment.

It is expected that the artificial light and noise emissions will take place 24 hours a day and the project sites will be illuminated during the dark hours. The rigs must be continuously lit to enable work to be carried out properly and to ensure the safety of the crew. The platforms must also be properly equipped with navigation lights to alert ships and aircraft. Furthermore, flaring during clean-up of wells produces a horizontal flame, that causes substantial light emissions. In clear weather, this flame may be visual from up to 10 km from the platform. Naturally, this effect is stronger at night than during the day.

Artificial light may affect seabirds and migration of land birds in different ways, both positively and negatively.

8.7.1 Positive effects of artificial light

At night lights and flares may be beneficial for foraging gulls because they attract prey to the surface waters (zooplankton and/or small fishes). Lights from offshore platforms may thus create additional foraging opportunities for gulls that normally forage by daylight, thus supplementing their diets and, potentially, increasing their survival and reproductive success (Ronconi, Allard and Taylor 2015, Tasker et al., 1986).

8.7.2 Negative effects of artificial light

Artificial light at sea may attract certain species of birds especially during bad weather and overcast nights. There are examples that illumination from offshore platforms under such circumstances can attract and disorient the birds and have a trapping effect that leads birds to circle around the light source. In particular, this is the case for migratory songbirds, waders, ducks, and geese, not so much by the light source's intensity, but by specific spectra within the light source (Deda et al. 2006, Van De Laar 2007). The circling behaviour may reduce their energy reserves and especially for migrating songbirds making them unable to cross the North Sea.

Reports of attracted birds, which collide with the platform and are killed or incinerated in the flare are also known. For migrating land birds, early reports highlighted rare events where hundreds or thousands of birds were incinerated in flares, though dedicated "flare watches" at other platforms observed no direct mortality. Information on mortality rates associated with collision and incineration of seabirds remains uncertain. One study has estimated annual rates of mortality in flares to be in the range of "a few hundred birds per platform per year" (Ronconi, Allard and Taylor 2015). Another study concluded that although incineration of birds in flares occur in the North Sea, such incidences are probably infrequent and are ultimately the result of weather phenomena driving migratory birds off course to begin with (Bourne 1979).

8.7.3 Impacts of airborne noise on birds

It is expected that additional noise will be generated during the construction phase. This has the potential to temporarily disturb seabirds locally. However, as this potential impact is expected for a limited number of birds, it is expected that this will in no way impact seabird population.

8.7.4 Risk assessment - Artificial light and airborne noise during construction

Based on the above and using the criteria described in Chapter 7, it is assessed that the environmental risks related to artificial light during construction will have a **positive** effect in terms of improving foraging opportunities for seabirds. Impacts related to collision of birds is **negligible** (Table 8-22). Some loud noise will be generated during the construction phase that will temporarily disturb seabirds locally. The environmental risk is **negligible**.

Table 8-22 Environmental severity and risk of impacts of artificial light during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Improvement of night foraging opportunities for seabirds	-	-	-	-	-	Positive effect
Risk of bird collision due to light attraction	Local	Short term	Medium	Minor impact	Low	Negligible
Risk of disturbance of birds due to noise	Local	Short term	Very low	Insignificant	Medium	Negligible

8.8 Impacts of waste

All waste generated during all project phases at Hejre and South Arne will be transported to Esbjerg by vessel. The waste will be further sorted out to improve recycling, sent for further treatment at approved waste treatment plants, for combustion or for final disposal.

Obm cuttings from the drilling of the Lunde well is expected to be shipped for treatment and final disposal at approved sites in either Norway or UK, as no sites in Denmark currently offer this service, whereas the OBM mud will be shipped to Esbjerg for treatment at an approved site.

The main impact related to the waste is associated with the air emissions for transporting it to sites onshore. This is accounted for in Section 8.5. The waste treatment onshore will not have an impact on the marine environment. Risk related to waste is shown in Table 8-23.

Table 8-23 Risk related to waste from both Hejre and South Arne during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of waste	Regional	Long term	Small	Minor impact	Very low	Negligible

8.9 Impacts on cultural heritage

The laying of the pipeline (described in Chapter 5) may potentially damage cultural heritage. The only cultural heritage that potentially could be affected in the project area are ship and plane wrecks. There are no registered wrecks in the project area and the area is generally not a hot spot for shipwrecks. Potential findings of wrecks or other historical artifacts identified during site investigations will be reported to the Palace and Culture Agency. The pre-installation survey on the pipeline route may also pick up wrecks if present.

Based on the arguments above the environmental risk related to cultural heritage is assessed to be negligible.

Table 8-24 Risk related to damage of cultural heritage during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Damage of wrecks	Local	Permanent	Small	Minor impact	Very low	Negligible

8.10 Impacts on hydrography

The substructure of the rig for the well perforation and clean-up activities will be temporary located in the water column. The legs are placed in an open structure and are considered too small to have any impact on the hydrography of the North Sea. In addition to that the rig will placed in the location temporary as it is expected the rig will operate 70 days per well.

Based on the arguments above the environmental risk related to cultural heritage is assessed to be negligible.

Table 8-25 Risk related to damage of cultural heritage during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts on seabed	Local	Short term	Small	Insignificant impact	Low	Negligible
Impacts on water column	Local	Short term	Small	Insignificant impact	Low	Negligible
Impacts on benthic fauna	Local	Short term	Small	Insignificant impact	Low	Negligible

9. Environmental impacts of planned activities during the production phase

9.1 Potential impacts

Figure 9-1 and Table 9-1 provide an overview of the potential effects during the production phase, which are assessed in the present impact assessment. Effects from discharges and emissions related to host platform concerns only the increase caused by the production at Hejre.

This chapter deals with environmental impacts of planned activities during the operation phase. Environmental impacts of accidental spills during the operation phase are dealt with in 0 and socioeconomic impacts are described and assessed in Chapter 13.

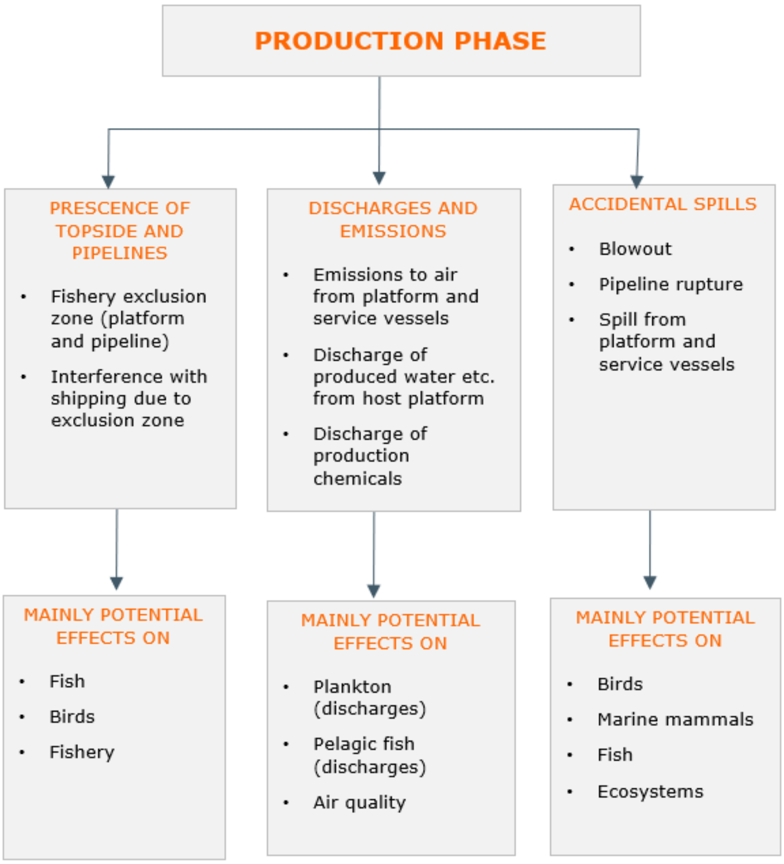


Figure 9-1 Overview of impacts during the production phase assessed in the EIA.

Table 9-1 Overview of impacts during the production phase assessed in the EIA

Activity	Potential Impacts
Presence of structures Rig, including 500 m safety zone and pipeline including 200 m exclusion zone	Interference with shipping due to safety zone
Discharges and emissions Discharge of produced water from Hejre (at discharge point on South Arne)	The discharge may affect marine organisms, particularly pelagic organisms such as plankton including fish eggs and larvae

Activity	Potential Impacts
Emissions to air	Release of particulates and gaseous compounds (SOx, NOx, VOC, CO, CO_2, CH4) from generators, compressors and other machinery on the production platform and due to flaring operations
Accidental spills	
Blowout	Extremely rare events. Experience from previous blow outs and oil spills at sea have shown that it is mainly birds, marine mammals, fish, coastal ecosystems, fisheries, aquaculture and tourism that may be affected Economic loss to fisheries, aquaculture and tourism due to oiling
Accidental spills from platforms and ships	Mainly birds, plankton, fish eggs and larvae may be affected.

9.2 Impacts of the presence of the rig, topside and pipelines

The environmental impact from the presence of the rig and pipelines will be restricted to loss of access to fishing grounds and interference with shipping due to exclusion and safety zones. The potential impacts are described further in Chapter 13. The changes to Hejre topsides will not give an impact on the surrounding environment.

9.3 Impact of planned discharges from Hejre

The maximum daily flow of produced water at Hejre is estimated to be 2,000 BPD, which is a conservative estimate based on no restrictions in the production capacity at South Arne. No produced water will be discharged from the Hejre platform. Residues of Hejre oil and chemicals will be included in discharges of produced water from South Arne only whenever water reinjection at South Arne is not possible for other reasons. During normal operation there is a target to inject more than 80% of the produced water at South Arne.

The production chemicals to be used at Hejre will be the same as the ones used at South Arne (i.e. they serve the same purposes, e.g. inhibition of scale etc.). The additional discharges at South Arne caused by use of chemicals at Hejre is further assessed in Chapter 9.4 below. An updated RBA modelling will be conducted for South Arne after production at Hejre starts.

Through the 20 years of design life facility maintenance and well service will be conducted at Hejre and chemical discharges can be expected. The facility and well service chemicals will be discharged typically over a few hours per job and thus no continuous discharge will happen during operation. Thus, the discharges will only occur over a short time and an assessment of the distance of impact based on acute criteria should be taken into consideration. Thus, as for the pipeline chemicals the distance of impact is modelled based on long-term PNEC values based on an assessment factor of 1000 and also modelled based on short-term PNEC values (derived based on acute L(E)C50 data and using an assessment factor of 100 in accordance with WFD Technical Guidance Document No. 27, 2018). The results can be seen in Table 9-2.

Table 9-2 Modelling of impact of discharge of facility and well service chemicals at Hejre.

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 1000)	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 100)	Duration of discharge
Facility	Wash of installation	<4500	<2000	2 hours
Facility	Wash of turbine	<5000	<4500	2 hours
Well service (Acid job)	Frac additive	<2000	<500	2 hours
Well service (Acid job)	Corrosion inhibitor	>5000	<5000	2 hours
Well service (Acid job)	Iron stabilizer	<1000	<250	2 hours
Well service (Wireline job)	Brine lubricant	<4200	<1000	2 hours
Well service (Coil tubing)	Lubricant	<5000	<3000	2 hours

As can be seen in the table above, the max. distance of impact is 5000 m but all well service discharges can be expected to be short-term and will only occur few times over the 20 years except for the wash of the installation. The facility chemicals are likewise discharged over short-term period.

Based on the experience from the RBA calculations for South Arne it is estimated that the natural occurring substances from Hejre produced water will contribute with around 55% to the total environmental risk from discharge of produced water (NORCE, 2022).

9.4 Impacts of planned discharges from South Arne

An updated modelling for production at South Arne after tie-in of Hejre has been conducted and the results can be seen in Table 9-3 and Table 9-4. Only the chemicals where Hejre tie-in will have an impact on discharged amounts are modelled. The oxygen scavenger and hydrate dissolver are not modelled as they are PLONOR chemicals and thus not expected to pose any risk.

The modelling shows that chemicals are disposed to up to 5000 meters from the platform. Discharge of chemicals will affect pelagic species consisting of fish, fish larvae, zooplankton and phytoplankton in the affected area. Since the duration of the impact is short term and the magnitude of the impact is small, it is assessed that the impact of discharge on pelagic organisms including pelagic fish stocks, is negligible.

Table 9-3 Modelling of impact of discharge of production at South Arne.

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC = 1	Discharge scenario for produced water discharge per day [m³/day]
Production	Corrosion inhibitor	<300	2,781
Production	Demulsifier	<100	2,781
Production	Antifoam (process)	<100	2,781
Production	Scale inhibitor (topside)	<100	2,781
Production	Wax inhibitor	<5000	2,781

Table 9-4 Risk related to discharges from Hejre toe-back project (will be discharged from South Arne).

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environ-mental risk
Impacts on discharge on pelagic organisms (Production South Arne)	Local	Short-term	Small	Minor im-pact	Probable	Negligible

9.5 Impacts of air emissions from Hejre during the production phase

In relation to the operation of the Hejre field, emissions to air will be generated from

- Fuel gas and diesel combustion for power generation
- Transportation of crew and material by helicopter, standby boat, tugs and supply boat
- Flaring of gas

Fuel consumption in relation to transportation by vessel and helicopter is based on the conduction of 12 facility maintenance visits a year, covering both planned and emergency maintenance. Transport is divided between ship and helicopter evenly. Trips by ship are expected to last 18 hours each way and include 2 days of standby at the rig per maintenance visit. Furthermore, a yearly campaign by ship is included with a return trip and 15 days of standby. In total ships are expected to operate for a duration equivalent to 37.5 full days. Trips by helicopter are expected to last 1.5 hours each way and to consist of two return-trips per maintenance visit equivalent to 1.5 full days in total.

An estimate of the emissions related to the transportation activities is shown in Table 9-5.

Table 9-5 Estimated emissions related to the transportation activities.

Transpor-tation ac-tivities	Number of vessels	Days	Fuel con-sumption [m^3/day]	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]
Helicop-ters (kero-sene)	1	1.5	1.2	4.7	0.02	0.006	0.0001	0,001
Supply vessel (to-tal)	1	37.5	10	1010	17	1	0	1

All power at Hejre will be supplied from the host South Arne by existing gas turbine generator using gas as fuel and with a possibility to use diesel as fuel in case of no gas is available. The need for power supply at Hejre will be minimal as the platform is an unmanned platform.

No flaring will take place at Hejre, Flaring will take place at South Arne where all processing of the multi-phase from Hejre takes place. The general level of flaring at South Arne is expected to remain unchanged (~1,800,000 Sm^3 in 2021), however, a slightly higher flaring rate can be expected during shut downs of the Hejre wells than the South Arne wells, since the system contains more gas in general.

The annual emissions related to the power generation and flaring at South Arne are approx. 180,000 tons CO_2/year and 200 tons NO_X/year (OSPAR report 2021). It is expected that level of emissions will remain approximately at the same level after Hejre tie-in. In all events, emissions will remain below the limits given in in the South Arne EIA (2006), 300,000 tons CO_2/year and 1,000 tons NO_X/year.

The Hejre platform is envisaged to be developed as a normally unmanned installation, controlled from Syd Arne. Similar to other tie-back satellite facilities operated by INEOS (such as Cecilie, Nini, Nini East), the overpressure protection philosophy is based on an inherently safe design with hydrocarbon containing process piping designed to withstand shut-in pressure. This approach eliminates the need for a flare system. Limited safety venting will take place, e.g., for routine maintenance of certain equipment and material for safety reasons prior to accessing the equipment.Due to the characteristics of the greenhouse gases, they will contribute to global warming if emitted, and thus the probability of the impact is assessed to be highly probable. The impacts related to NO_X and SO_X are determined by the surrounding environment and thus are assessed to be low.

Table 9-6 Risk related to emissions from Hejre.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of air emissions (NO_X, SO_X)	Regional	Long term	Small	Minor impact	Low	Negligible
Impacts of air emissions (CO_2-eq)	International	Long term	Small	Minor impact	Highly probable	Low

9.6 Impacts of waste

Due to the Hejre being an unmanned platform the waste production will be very limited. The majority of the waste will be produced during maintenance campaigns. All waste from Hejre will be transported to Esbjerg by vessel. The waste will be further sorted out to improve recycling, sent for further treatment at approved waste treatment plants, sent for combustion or for final disposal.

The waste treatment onshore will not have an impact on the marine environment. Risk related to waste is shown in Table 9-7. NORM contaminated equipment will be sent onshore for cleaning and the NORM waste will be sent to temporary disposal at approved disposal sites.

Table 9-7 Risk related to waste from both Hejre.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of waste	Regional	Long term	Small	Minor impact	Very low	Negligible

9.7 Impacts of noise and light emissions during the production phase

No significant noise will be generated at the Hejre platform during the production phase.

As previously described, light from platforms may disturb bird's sense of direction. However, during the production phase light is limited to navigational purposes (i.e., signalling to vessels and aircrafts) and incidentally to light the platform to perform work safely. The extent of light disturbance will be similar as today.

Noise and light are therefore not expected to impact marine organisms or birds during the production phase. It is therefore assessed that there is no environmental risk (Table 9-8).

Table 9-8 Environmental severity and risk of impacts of artificial light during construction.

Impact	**Extension of impact**	**Duration of impact**	**Magnitude of impact**	**Severity of impact**	**Probability of impact**	**Environ-mental risk**
Improvement of night foraging opportunities for seabirds	Local	Long-term	Very low	No impact	High Probabil-ity	No risk

10. Environmental impacts from planned activities during decommissioning

10.1 Potential impacts

Figure 10-1 provides an overview of the potential effects during the decommission phase, which are assessed in the present impact assessment.

The expected lifetime of the installation is approximately 20 years. The decommissioning of the platform, wells and export pipeline will be conducted in accordance with Danish legislation and international agreements in force at that time. The assessment of potential impacts during the decommissioning is made based on vessels and technology available today. However, it is expected that the technological advancements over the lifetime of the project will improve and hereby reduce the impact.

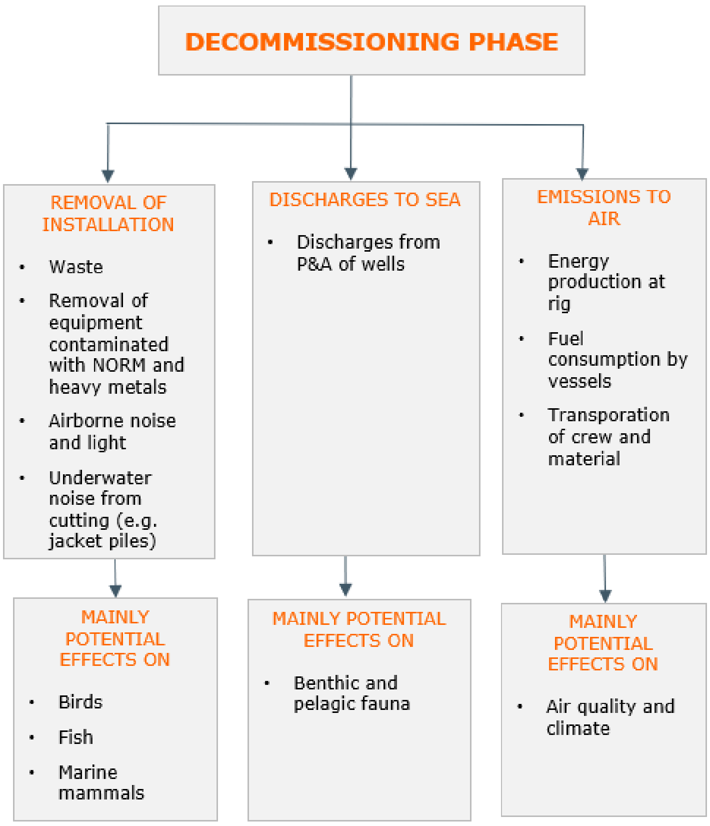


Figure 10-1 Overview of potential impacts during the decommissioning phase assessed in the EIA.

10.2 Impacts of discharges to sea

Discharges from the decommissioning activities will primarily be related to plug and abandonment (P&A) of wells. This will be done by a rig and thus constitute of rig chemicals and discharges from the well P&A.

Modelling has been performed on also short-term, batch-wise discharges as these in some cases contribute significantly to the total amount of chemicals being discharged during one particular sub-process in the development phase. The modelling has only comprised the yellow chemicals used, not any green chemicals. Wash train chemicals, cementing chemicals and slop chemicals will be discharged during the P&A of the Hejre wells. OBM will be shipped to shore for reuse or disposal.

A limited number of utility chemicals will be used at the rig during the P&A of the Hejre wells. It is assumed that 100% of the rig wash and other rig chemicals will be discharged to sea. All rig chemicals are discharged over a period of 6 hours, except for the jacking grease, which is discharged over a period of 12 hours.

The pipe dope and jacking grease are assumed to be discharged undiluted, while the cleaning agent is diluted 1:400.

The slop chemicals are discharged undiluted.

The wash train chemicals are expected to be discharged over a period of 12 hours and diluted in 90 m³.

The cementing chemicals are discharged with the discharged volume of 4.1 m³ for cement. The cementing chemicals are expected to be discharged continuously throughout the 154 days during cementing activities.

The completion chemicals are discharged with the volume of discharged completion fluid of 400 m³. The completion chemicals are expected to be discharged continuously throughout the 26 days during the top completion activity.

All discharges of yellow and red chemicals have been modelled. In Table 10-1 the chemicals where the PEC/PNEC ratio exceed 1 is shown along with the distance where exceedance can be expected.

Table 10-1 Modelling of impact of discharge of chemicals used during P&A of the Hejre wells.

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC = 1 (assessment factor = 1000)	Duration of discharge
Rig chemicals	Rig wash	<250	6 hours
	Jacking grease	<1000	12 hours
Wash train chemicals	Base oil	<1000	12 hours
	Surfactant	<5000	12 hours
	Solvent	<5000	12 hours
Slop chemicals	H_2S scavenger	<2000	1 hour
	Biocide	<2500	1 hour

It can be seen that especially the wash train chemicals will exceed the PEC/PNEC ratio on longer distances of up to 5000 m. Discharge of chemicals will potentially affect pelagic species consisting of fish, fish larvae, zooplankton and phytoplankton in the affected area. Since the duration of the impact is short term (within hours) and the magnitude of the impact is marginal, it is assessed that the impact of discharge on pelagic organisms is negligible.

The impact from P&A can only be preliminary assessed given that the activities and used chemicals can change when the specific decommissioning programme is completed. But from the initial modelling the impact can be described as stated in Table 10-2.

Table 10-2 Environmental severity and risk of impacts of discharges to sea during decommissioning (P&A of wells)

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of discharge to sea during decommissioning	Local	Short term	Small	Minor impact	Probable	Negligible

10.3 Impacts of emissions to air

Emissions to air from decommissioning activities are related to:

- Energy production at the jack-up rig
- Fuel consumption by special vessels such as heavy lifting vessels, rock dumping vessels, offshore construction vessels etc.
- Transportation of crew and material by helicopter, standby boat, tugs and supply boat

Energy consumption at the rig will mainly be used for plugging and abandoning of wells and including power supply for pumps and compressors. Energy consumption for other purposes such as the accommodation module etc. is expected to be marginal. The energy is provided by generators powered by diesel engines.

A standby vessel is required when rig activities are conducted, and thus the standby boat is operating 24 hours for 255 days.

All materials, supplies, waste etc. will be transported offshore/onshore by supply vessels. It is estimated that 1 vessel will be in operation for 10 days.

An estimation of the emissions related to the decommissioning activities is carried out in Table 10-3. All estimated days include weather delays and unforeseen events.

Table 10-3 Estimated emissions related to the total decommissioning phase.

Decommissioning	Number of vessels	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]
Rig	1	255	10	6,900	115	9	0.3	4.1
Heavy lift vessel	1	83	47	10,510	180	14	0.5	6.5
Supply vessel	1	97	7	1,830	30	2.5	0.1	1.1
Survey vessel (ROV)	1	70	4	755	15	1	0.03	0.5
Pipe Trench/Jet Skid	1	5	30	405	10	0.5	0.02	0.2
Rock dumping vessel	1	8	27	590	10	1	0.03	0.3
Offshore construction vessel	1	28	20	1,510	25	2	0.1	0.9
Diving support vessel	1	320	24	20,700	350	26	1	13
Standby boat	1	255	10	6,900	115	9	0	4
Tugs	3	20	20	3,250	55	4	0	2
Helicopters (kerosene)	1	109	1.2	360	1	0	0	0
Total [ton]				**53,710**	**906**	**69**	**2**	**33**

[1)] The SO_X emission factor is field specific and thus not provided by Norsk Olje og gass (2019), but is based on information from INEOS

Compared to the total Danish CO_2-eq emission in 2020 the decommissioning phase for the Hejre tie-back to South Arne concept constitute 0.12%.

Due to the characteristics of the greenhouse gases, they will contribute to global warming if emitted, and thus the probability of the impact is assessed to be highly probable. The impacts related to NO_X and SO_X are determined by the surrounding environment and thus are assessed to be low.

Table 10-4 Environmental severity and risk of impacts of air emissions during decommissioning.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of air emissions (NO_X, SO_X)	Regional	Short term	Small	Minor impact	Low	Negligible
Impacts of air emissions (CO_2-eq)	International	Short term	Small	Minor impact	Highly probable	Low

10.4 Impacts of waste

The process fluids, fuels and lubricants will be drained from the Hejre platform and transported ashore for controlled disposal at a decommissioning yard.

After cleaning, the topsides will be transported to shore for further cleaning and recycling. First priority is direct reuse of process equipment after cleaning. The jacket will also be transported to shore and be cleaned for marine growth. Both the topside structure and the jacket structure is expected to be recycled.

In total, around 11,000 ton of material is planned to be taken onshore for cleaning and reuse/recycling. Referring to two decommissioning reports from UK the % of reuse and recycling is expected to be above 95% and the amount for landfill is in the area of 2.5% and the remainder is burned for energy production.

NORM may occur as for example in the water treatment systems and the wells. NORM contaminated equipment will be cleaned, and the NORM waste will be sent to temporary deposit at approved disposal sites.

Heavy metals, as for example mercury, can also occur and will need to be cleaned at the onshore plant to where the installation will be transported for controlled dismantling.

INEOS will ensure that the onshore decommissioning yard will have the environmental approval in place for handling the different types of contaminants on the Hejre topsides, which are not possible to remove during the offshore cleaning of the topsides.

Details about management of waste during decommissioning will be described in a decommissioning plan and a waste management plan.

Table 10-5 Environmental severity and risk of impacts of waste handling during decommissioning.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Waste handling	Local	Short term	Small	Minor impact	Low	Negligible

10.5 Impacts of noise and light emissions

As previously described, light from platforms may disturb bird's sense of direction (Section 8.7). However, during the production phase light is limited to navigational purposes (i.e. signalling to vessels and aircrafts) and incidentally to light the platform to perform work safely. The extent of light disturbance will be similar as today. There will be some loud noise during decommissioning that will scare seabirds away. The noise will be local and will not harm sea birds. Noise and light are therefore not expected to impact marine organisms or birds during the decommissioning phase.

10.6 Impacts from underwater noise

During the decommissioning there will be generated underwater noise from vessels and cuttings of underwater structures. Underwater noise may affect marine organisms in different ways. As cetaceans (i.e. whales, porpoises and dolphins) depend on the underwater acoustic environment for orientation and communication, they are believed to be the marine organisms that are most sensitive to underwater noise (NOAA, 2018). Seals and fish may, however, also be affected by underwater noise.

Noisy activities during decommissioning include broad band noise from heavy lift vessels and service vessels. It has been found that the sound exposure level (SEL_{cum}) of passing vessels during a 30-second- window reached values between 105–145 dB re 1 µPa2s and that harbour porpoises react to this noise level (Dyndo et al. 2015). However, underwater noise from vessels is not expected to exceed the threshold for hearing damage (Tougaard et al. 2016, NOAA 2018).

In addition to the noise from vessels there will potentially be underwater noise from diamond wire cuttings (Pangerc et al. 2016). It has been shown that underwater noise from decommissioning of a platform at 80 m depth increase the background underwater noise with 4-15 dB which will not lead to hearing damage of marine mammals.

Field studies have shown that several species of fish may be disturbed by noise from passing vessels and they may flee from the vessel while other species are not affected (Freon et al. 1993). Noisy activities are marginal, local, and temporary and will not affect fish populations.

Based on the above and using the criteria described in Chapter 8.6.3 it is assessed that the environmental risks related to decommissioning on marine mammals and fish is **Negligible** (Table 10-6).

Table 10-6: Environmental severity and risk of impacts of activities during decommissioning.

Impact	Extent of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of underwater noise on marine mammals	Local	Short-term	Small	Insignificant impact	Highly probable	Negligible
Impacts of underwater noise on fish	Local	Short-term	Small	Insignificant impact	Highly probable	Negligible

11. Environmental impact of accidental oil and chemical spills

The original oil spill modelling from Hejre Legacy was updated in 2020 as the Hejre has been developed and data on reservoir pressure, flow rates from wells etc. is available, see DNV (2020). The following section is based on the updated oil spill modelling.

The impacts of the following types of accidental spills have been assessed in this chapter:

- Spill of oil and emission of gas during an accidental blowout at Hejre
- Accidental spill due to rupture of the new pipeline

Blow out and rupture of pipelines causing discharge and dispersal of oil are extremely rare events. However, in case of blowout and rupture the environmental impacts may be severe. Experience from previous blowouts and oil spills at sea have shown that it is mainly birds, marine mammals, fish and coastal ecosystems that may be affected by large oil spills.

11.1 Environmental impacts of an oil release during a blowout incident

The worst-case scenario in terms of accidental oil spill is an uncontrolled blow out during production. A blowout is the uncontrolled release of crude oil and/or natural gas from a well after pressure control systems have failed. The probability of a blowout occurring is very low but in case a blowout occurs, wide reaching and severe impacts on the marine environment may occur.

11.1.1 Risk of a blowout

Blowout is an extremely rare event and extensive preventative/control measures are implemented to reduce the likelihood of such events. It has been estimated that the risk (frequency) of a blowout occurring at Hejre is 9×10^{-6} per year (INEOS Oil & Gas 2019).

A blowout will last until the well is under control again. This may take anywhere from a few hours if control can be regained using the safety systems present, up to several months if a so-called relief well needs to be drilled to regain control over the original well. History shows that most wells can be brought back under control within one to a few days.

11.1.2 Fate and effects of oil

During a blowout the oil is spread with the surface currents, simultaneous undergoing a wide array of processes including evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation and biodegradation. Oil components and their breakdown product may affect marine and coastal habitats and species. In general, the most severe impacts of an oil spill will occur if the oil slick passes concentrations of seabirds or if the oil ends up in near coastal waters and on shorelines. For a more detailed description of the fate and effects of an oil spill reference is made to Appendix A.

11.1.3 Methodology

DNV GL Norway carried out oil spill modelling of topside blowouts at Hejre using the OSCAR statistical oil drift model developed by SINTEF, Norway. OSCAR is a 3D modelling tool used to predict the movement and fate of oil on the sea surface and throughout the water column.

The modelled blowout case represents a variety of 3 release rates Table 11-1 and 4 duration combinations with an individual distribution Table 11-2. The probability of a blowout is extremely low. Furthermore, in the unlikely event that a blowout should occur, the duration will in most cases be short-term (<15 days), whereas the probability of a long-lasting blowout of 100 days is only 6.5 %. A long-lasting blowout (100 days) is the expected duration for mobilizing a drilling rig and drill a relief well.

Table 11-1 Oil spill drift modelling matrix. Release rates as well as the probability distributions of release rates based on information from Lloyds (2019) and blowout statistics (for further information reference is made to Appendix A).

Scenario variations			
Release rates (Sm^3/day)	2077	2525	7328
Probability distribution (%)	34	33	33
Number of simulations (trajectories/year)	36	24	12

Table 11-2 Oil spill drift modelling matrix. Release duration as well as the probability distributions of release durations based on information from Lloyds (2019) and blowout statistics (for further information reference is made to Appendix A).

Scenario variations				
Release duration (days)	2	15	35	100
Probability distribution (%)	52.7	35.2	5.6	6.5

The assessment of the environmental impacts of accidental blowout is based on a matrix using all four scenarios representing a worst-case scenario in which no mitigating oil spill response measures are taken. The simulations have been made using both stochastic and deterministic modelling.

Stochastic modelling possesses some inherent randomness versus a deterministic model where the output is fully determined by the parameter values and the initial conditions.

The use of a stochastic model means that the blowout can be analysed statistically. However, the prediction represents the gross area that may potentially be affected by a spill as it combines the impact area of several single spill events and therefore does not represent how a blowout will look in reality (see number of simulation events in Table 11-1).

In contrast, the deterministic model simulates a single spill at a chosen date under the weather conditions at that point in time. Thus, it predicts the actual trajectory of a single spill event, but it does not consider the statistical uncertainty of the fact that the spill trajectory will be different under different weather conditions.

Efficient oil spill response measures will reduce the spreading of spills significantly and thereby the extent and magnitude of environmental damage is most likely smaller than the model results indicate.

Table 11-3 provides a list of the threshold used in the impact assessment.

Table 11-3 Sea surface, water column and shoreline thresholds for impact scoring

Species/habitat exposed to oil	Threshold	Justification
Seabirds, emulsion on water surface	1 µm	The 1 µm threshold is considered below levels which would cause harm to seabirds from exposure of oil. Exposure above threshold will lead to effects such as transferring oil to eggs reducing hatching success (French-McCay 2009).
	10 µm	The 10 µm threshold for oil on water surface has been observed to lead to 100% mortality of impacted seabirds and other wildlife associated with the water surface (French-McCay 2009).
Seabirds, shoreline	"Light oiling" or above on shoreline	Light oiling of shoreline may result in mortal impact on seabirds.
Marine mammals (fur-bearing), oil emulsion water surface	10 µm	The 10 µm threshold for oil on water surface has been observed to mortally affect fur-bearing marine mammals such as seals (French-McCay 2009).
Marine mammals (fur-bearing), oil emulsion on shoreline	"Light oiling" or above on shoreline	Light oiling impacting shoreline may result in mortal impact on fur-bearing marine mammals such as seals, if they get impacted when hauling onto or resting at beaches.
Marine mammals (cetaceans), oil emulsion on water surface	100 µm	Cetaceans are less sensitive to oil compared to seals, as it does not stick to their skin. Cetaceans can inhale oil and oil vapour when surfacing to breathe leading to internal injuries (French-McCay 2009).
Fish, THC in water column	25 ppb	Following guidelines from the Norwegian Oil Industry Association effects of acute oil pollution on fish eggs and larvae will be seen in THC concentrations >25 ppb
	70.5 ppb	According to OSPAR 2014/5 concentrations >70.5 ppb are considered as having potential for chronic impacts to juvenile fish and larvae that might be entrained within the oil plumes
	500 ppb	The 500 ppb threshold is considered conservative high exposure level in terms of potential for toxic effects leading to mortality of 50% of all marine life if impacted by an acute oil spill
Seabed habitat	25 ppb	Seabed habitats considered are protected reefs and areas with protected cold-water corals; areas with a high ecological production. This threshold is used to identify when the most sensitive marine life (fish eggs and larvae) begins to be affected by acute oil pollution on. Based on guidelines from the Norwegian Oil Industry Association.
Shoreline habitats	"Light oiling" or above on shoreline	The Environmental Sensitivity Index (ESI) is used for assessing the sensitivity of various types of shoreline to acute oil pollution.

11.1.4 Modelled dispersion of oil from an unmitigated blowout

Figure 11-1 shows the modelled stochastic probability that the sea surface in 10x10 km grid cells could be hit by more than 1 tonnes of oil released at Hejre during March-August) and September-February, respectively. It is seen that released oil during blowout will be transported towards northeast with the prevailing currents, but may also be transported to UK, German and Dutch waters including Natura 2000 areas (SACs).

Figure 11-2 shows the seasonal resolution of arrival times (since start of the release) within the influence area to 10 x 10 km grid cells (drift time). It is seen that it will take approximately 2 weeks for oil to reach shore. However, it should be noted that although all shores are statistically affected by oil in case of a blowout according to Figure 11-1, it also shows that the amount of oil that hits the shore are below the detection level of 4 tonnes pr. 100 km² (0.04 µm thickness).

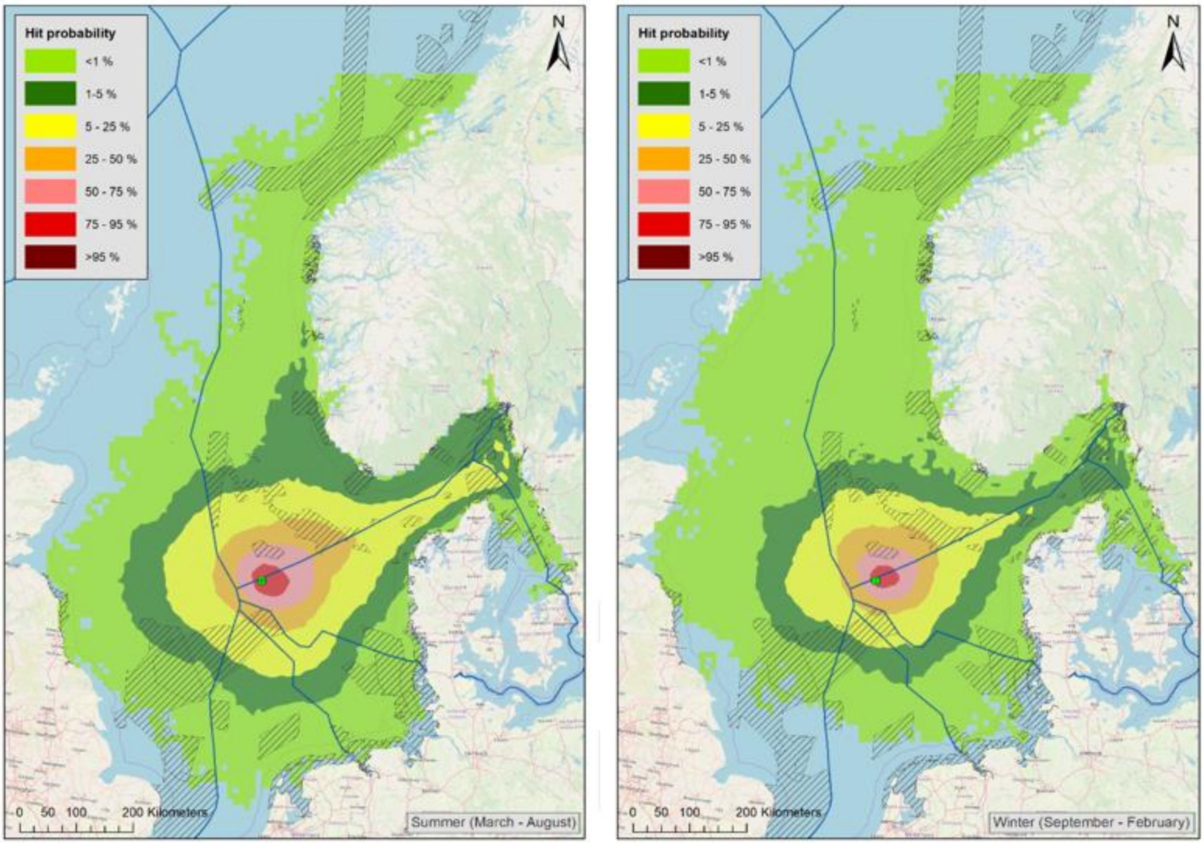


Figure 11-1 Result of stochastic oil spill modelling of a worst case, unmitigated surface release of oil during a blowout at Hejre during March-August (left) and September-February (right). The figures show the modelled probability that the sea surface in 10x10 km grid cells could be hit by more than 1 tonnes of oil released at Hejre. The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

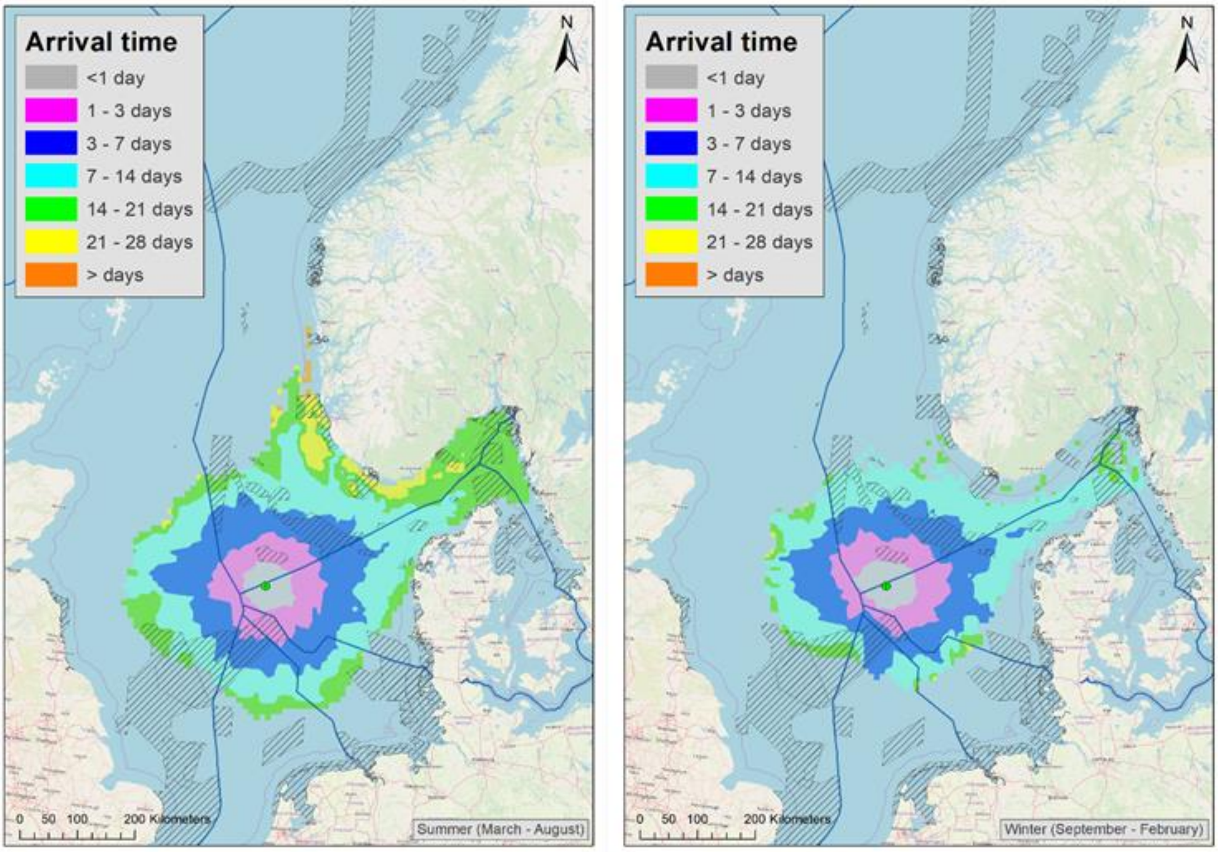


Figure 11-2 Result of stochastic oil spill modelling of a worst case, unmitigated surface release of oil during a blowout at Hejre during March-August (left) and September-February (right). The figures show the seasonal resolution of arrival times (since start of the release) within the influence area to 10 x 10 km grid cells; The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

The seasonal resolution of oil mass within the influence area is shown in Figure 11-3. The figure shows that there will be up to 50 tonnes of oil per 100 km^2 in the North-eastern part of the closest SAC during summer and up to 25 tonnes per 100 km^2 during winter.

Table 11-4 shows the expected surface oil layer thickness corresponding to the oil mass according to the Bonn Agreement (2016). Five levels of oil appearances are distinguished in the Bonn Agreement.

Birds are generally considered to be affected by surface oil when the emulsion thickness exceeds 1 µm whereas seals and cetaceans (incl. harbour porpoise) are more tolerant to surface oil. Latter being affected when emulsion thickness exceeds 10 µm and 100 µm for seals and cetaceans respectively (French-McCay 2009).

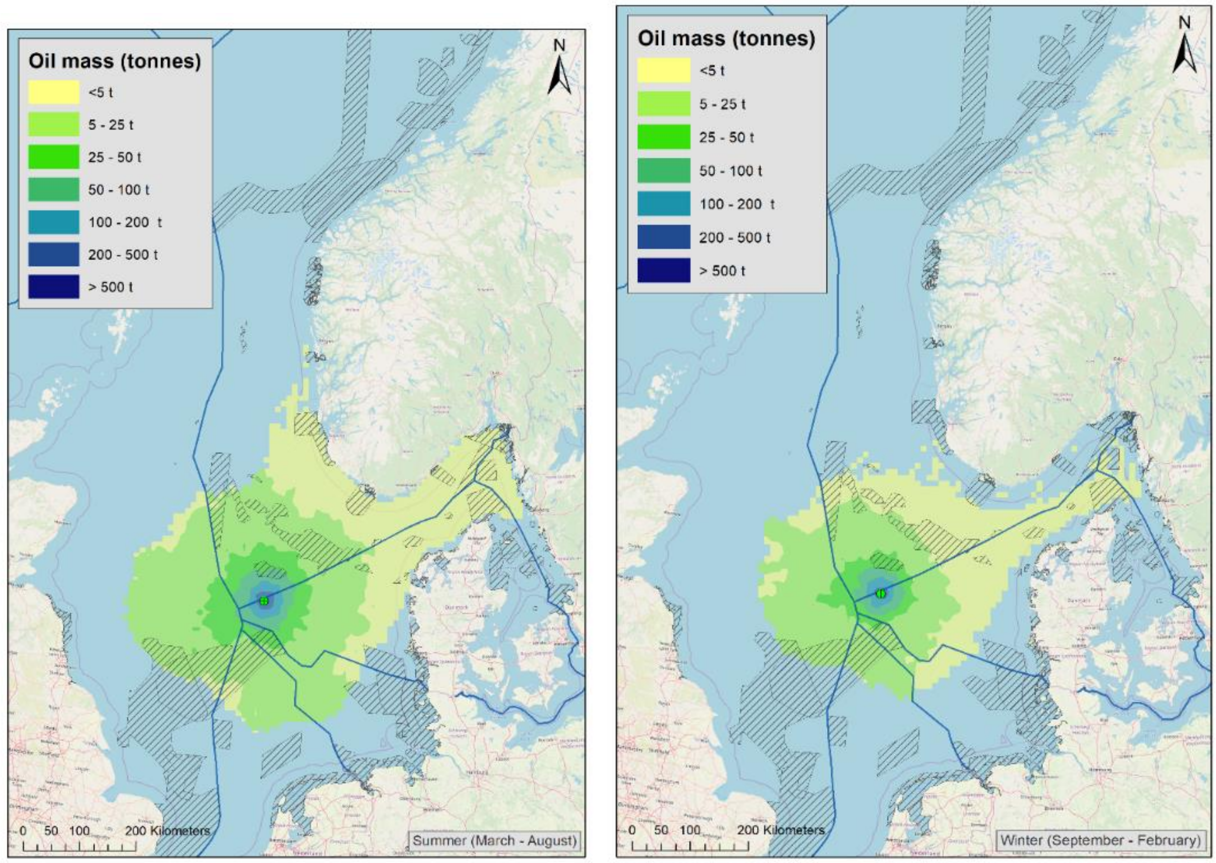


Figure 11-3 Seasonal resolution of oil mass within the influence area in 10 x 10 km grid cells; Summer left and winter right, including marine protected areas, SVO areas and country border lines.

Table 11-4 Levels of oil appearances distinguished according to the Bonn Agreement (2016).

Code	Description/Appearance	Layer thickness (µm)	Tonnes per 100 km2
1	Silver/gray	0.04 - 0.30	4 - 30
2	Rainbow	0.30 - 5.0	30 - 500
3	Metalic	5.0 - 50	500 - 5,000
4	Discontinuous true oil colour	50 - 200	5,000 - 20,000
5	Continuous true oil colour	> 200	> 20.000

11.1.5 Impacts on seabirds of oil from a blowout incident

It is well-documented that seabirds are extremely vulnerable to oil spills and that large amounts of seabirds are often killed in connection with an oil spill in areas where seabirds are concentrated. The reason for seabirds being especially vulnerable is that they are often in contact with surface water and that the oil destroys the buoyancy and the isolating quality of the plumage.

Birds smothered in oil will usually die of cold or starvation or drown. Even very small spots of oil may be fatal, especially during winter. Mainly seabirds that stay on the sea surface for longer periods are at risk, but all types of seabirds may be affected (Trosi et al 2016). The threshold for emulsion thickness considered as harmful for birds is 1 µm (French-McCay 2009) (roughly 100 t per 10 x 10 km, Table 11-3, Table

11-4). Exposure above this threshold will lead to effects such as transferring oil to eggs reducing hatching success. Emulsion thickness of more than 10 µm will lead to immediate killings.

In the unlikely event of a blowout incident at Hejre the oil will most likely be transported towards northeast with the prevailing currents and pass the internationally important bird areas in the Norwegian part of the North Sea. The probability that this area will be impacted by a blowout is extremely low. However, in the unlikely case of a long-lasting unmitigated blowout, the probability that the area will be affected is high (i.e. 50-75 % in the eastern part of the area, decreasing to 25-50 % further away). The drift time to these areas are 1-3 and 3-7 days, respectively (Figure 11-1 and Figure 11-2). The area is important for gulls and auks (i.e. mainly little auk, but also guillemot and razorbill (Skov et al. 1995, Skov et al. 2007). The auks are particularly vulnerable to oil spills as they spend most of their time on the sea surface. The birds are particularly vulnerable during winter where most species are clustering. It is estimated that around 1 million birds are present in the North Sea during winter (Skov et al. 2007). The northern part of the Danish EEZ in the North Sea is considered an intermediate important conservation area for seabirds (Skov et al. 2007). Consequently, there is a high risk of oiling and killing of birds in this area in the unlikely event of a blowout. On the other hand, the important bird areas in and immediately off the Wadden Sea will not be affected.

11.1.6 Impacts on marine mammals of oil from a blowout incident

The modelling shows that oil from a blowout may hit areas where harbour porpoise, grey seals or harbour seal may be encountered. Harbour porpoises and seals are generally less vulnerable to oil spill than birds (i.e. threshold for seals is estimated to 10 µm while the threshold for cetaceans is 100 µm, French-McCay 2009) (10 µm corresponds to ca.10 t oil per 10x10 km (Table 11-4). As their heat insulation is due to their layer of blubber a porpoise or seal smothered in oil will not be fatal as is the case with a bird.

11.1.6.1 Harbour porpoise

Comparative little is known about the effects of oil on cetaceans (whales, dolphins and porpoises), but based on scant records of cetacean mortality associated with oil spills, it has been suggested that an oil spill may only affect small numbers of cetaceans. Several authors suggest that the threat of most immediate concern is inhalation of evaporated volatile toxic components from the oil slick on the sea surface if they emerge at the surface to breathe in the middle of an oil slick. This risk is greatest near the source of a fresh spill because volatile toxic vapours evaporate and disperse relatively quickly. When concentrated vapours are inhaled, mucus membranes may become inflamed, lungs can become congested, and pneumonia may ensue. Inhaled fumes from oil may accumulate in blood and other tissues, leading to possible liver damage and neurological disorders. As porpoises rely on blubber for insulation their thermoregulatory ability does not seem seriously hampered by contact with oil (Helm et. al. 2015).

Harbour porpoises in the Central North Sea may be affected in the unlikely incidence of a blowout at Hejre. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and as the density of porpoises is relatively low (0.01-8 individuals/km²) only a tiny fraction of the populations of harbour porpoise in the North Sea is likely to be affected (Geelhoed et al 2014). It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the harbour porpoises in the North Sea.

11.1.6.2 Seals

Seals may be affected by direct contact with oil in a variety of ways. Oil can coat all or portions of their body surface and they may inhale toxic fumes of hydrocarbons, which affects their lungs. In addition, they may ingest oil directly or ingest oil-contaminated prey. As seals rely on blubber for insulation their thermoregulatory ability does not generally seem seriously to be hampered by contact with oil. However, observations suggest that some individuals have become so encased in oil that they were not able to swim and subsequently drowned. In addition, observation also suggest that eyes, oral cavity, respiratory surfaces and uro-genital surfaces are particularly sensitive to contact with oil (Helm et al. 2015). It cannot be excluded that seals in the Central North Sea may be affected. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the surface currents and as seals are relatively rare in the Central North Sea only a tiny fraction of the populations of seals is likely to be affected. It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the seals.

11.1.7 Impacts on fish eggs- and larvae of oil from a blowout incident

Eggs and larvae are considered the most sensitive life stages of fish in terms of acute impacts of spilled oil. The Norwegian Oil Industry Association use 25 ppb as the concentration at which fish eggs- and larvae and other sensitive marine life begin to be affected by oil components. A literature review conducted by BP suggested that oil content greater than 500 ppb will cause acute toxicity to over 50 % of the marine life in the area (DONG E&P 2015).

For oil in the water column, the modelling shows that concentrations above 25 ppb is limited to a tiny area around Hejre which constitutes a negligible fraction of the entire spawning areas for fish in the North Sea (Figure 11-4). In addition, the important nursery areas for larvae of cod, whiting, Norway pout, haddock and sandeel at the productive hydrographical front in the north-eastern part of the North Sea will not be affected by an oil blowout. It is therefore concluded that an oil blowout at Hejre will not measurably affect the amount of fish eggs and larvae in the North Sea.

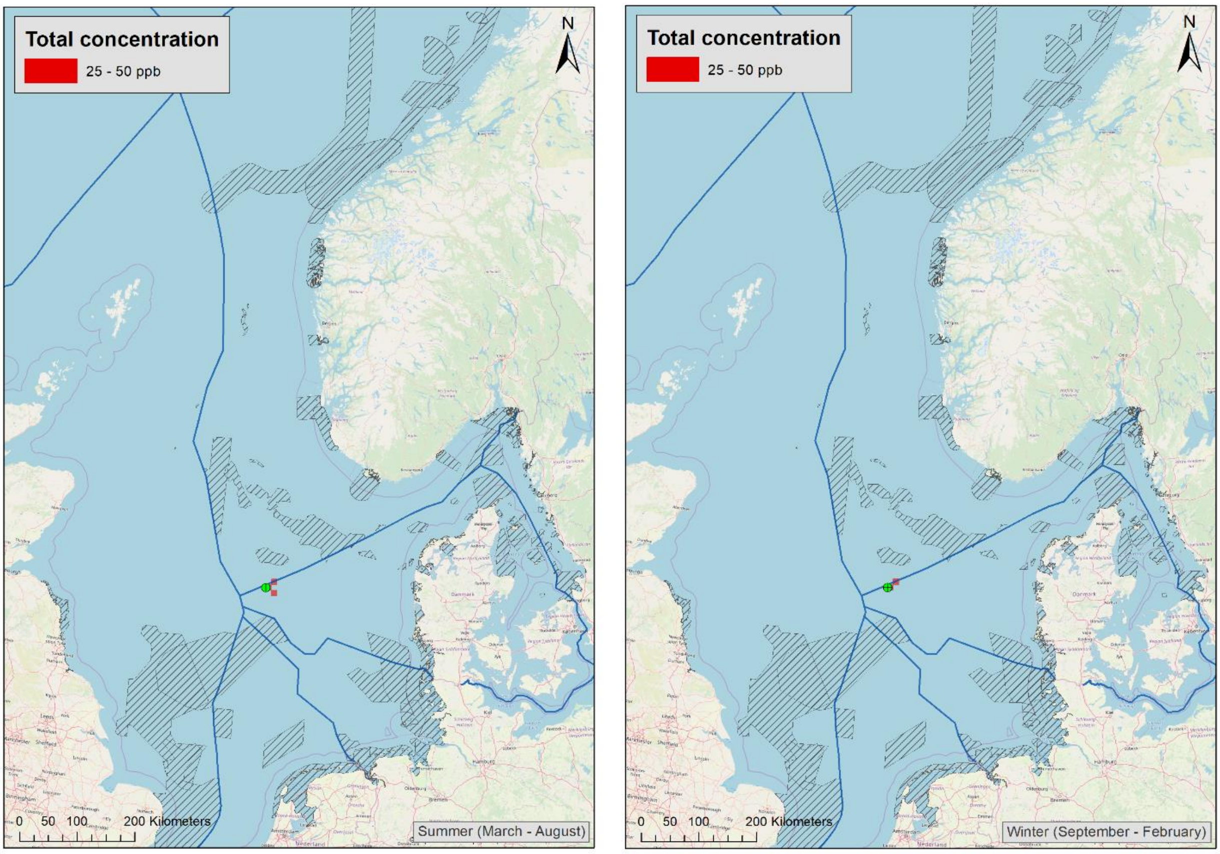


Figure 11-4 Result of oil spill modelling of a worst case, unmitigated surface release of oil during a blowout at Hejre during March-August (left) and September-February (right). The figures show seasonal resolution of total concentration of dissolved oil components within the influence area in 10 x 10 km grid cells. Oil in the water column is only within detection level (>25 ppm) in the coloured squares. The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

11.1.8 Impacts of oil stranded on shorelines from a blowout incident

Shorelines, more than any other part of the coastal environment, are exposed to the effects of floating oil. Oil stranded on beaches often gives rise to concern because it may affect sensitive coastal habitats and important socioeconomic conditions. Further, the cleaning of oiled beaches may be costly. The vulnerability of shorelines to oil spills differs considerably depending on the type of habitat and with respect to how easy they are to clean up after an oil spill.

The modelling shows that the risk of oil stranding on coasts is negligible, the probability generally being < 1%, see Figure 11-6. In some areas, especially along the Norwegian coast, the probability has however, been calculated at 1-5 %. The modelling shows that the drift time to the coast in these areas is at least 14-28 days.

The reason for the low risk of stranding is that oil components will have undergone a wide array of processes including evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation and biodegradation before reaching the shorelines.

The Danish coastlines, which may be hit by stranded oil are generally exposed, gently sloping sandy beaches. These types of beaches are not particularly vulnerable to oil as they are not very productive ecologically. In addition, the oil does not penetrate the sand readily, facilitating mechanical removal (IPIECA 1996).

It is expected that the drift time from Hejre to the shoreline will be in the range 14-21 days (DNV, 2020), thus the stranded oil will mostly be in the form of tar balls. This can be seen from Figure 11-5, which illustrates the breakdown processes of oil over time. The most volatile components have evaporated, and emulsification and dispersion have almost terminated after approximately a week, leaving only hard degradable oil components that can form tar balls by wave impacts. Tar balls are even easier to remove on sandy beaches compared to less weathered oil. However, the stranded oil in the summer period may be a nuisance to holidaymakers bathing from the beach.

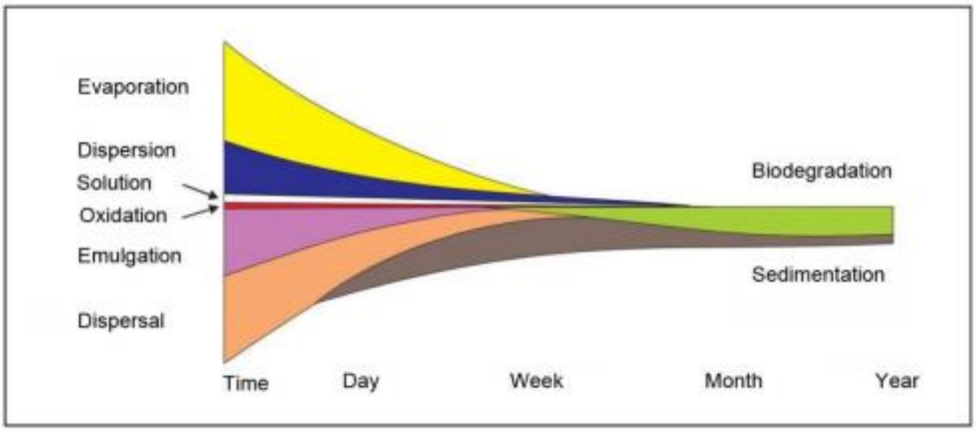


Figure 11-5 Overview of the relative significance of the different physical and chemical processes that affects spilled oil at sea as a function of time (after ITOPF 2002).

The biologically highly productive tidal flats and saltmarshes in the Wadden Sea in the southern part of the Danish coast will not be affected. The Norwegian and Swedish coastlines that may be hit by oil are rocky shores that are more sensitive to oil spills compared to the Danish sandy shores. However, with a drift time of 14-21 days (DNV, 2020) most of the oil will be in the form of tar balls, which are considerably less damaging as they are no longer sticky or toxic.

Shoreline oiling is likely to range between very light and moderate, as defined by ITOPF's recognition of shoreline oiling guidelines. Under the worst-case metocean conditions, the quickest impact on the shoreline in Denmark will be between 14-21 days. Shoreline impact may also happen in Norway (after 14-28 days) and Sweden (after 14-21 days). There will be no shoreline impact in UK, Germany or the Netherlands. In case of a blow-out with surface release during winter, the extent of affected shorelines will be considerably smaller than for a release during summer.

Along the Danish coast, only the stretch on the west coast of Vendsyssel between Hirtshals and Skagen may be hit by oil. Model results indicate that for more than 95% of the simulations only marginal amounts of oil will reach the Danish shoreline, that is <1 tonnes (DNV 2020). Along the Danish coast, only the stretch on the north-west coast of Jutland may be hit by oil. The shortest arrival time during the summer period to the northwest of Jutland is 11,3 days and 13,4 days during the winter period (DNV 2020).

Similarly, only marginal amounts of oil will potentially reach the Swedish coast, that is <1 tonnes during the winter period and 1 tonnes during the summer period. For Norway this pattern is similar for the winter period, that is 1 tonnes, however during the summer the model results indicate that 31 tonnes of oil may reach the Norwegian coastline, which is considered to be a limited amount (DNV 2020). The modelling showed that the risk, the extent and the degree of oiling of shorelines during a seabed release of oil is quite similar to a surface release (DNV 2020).

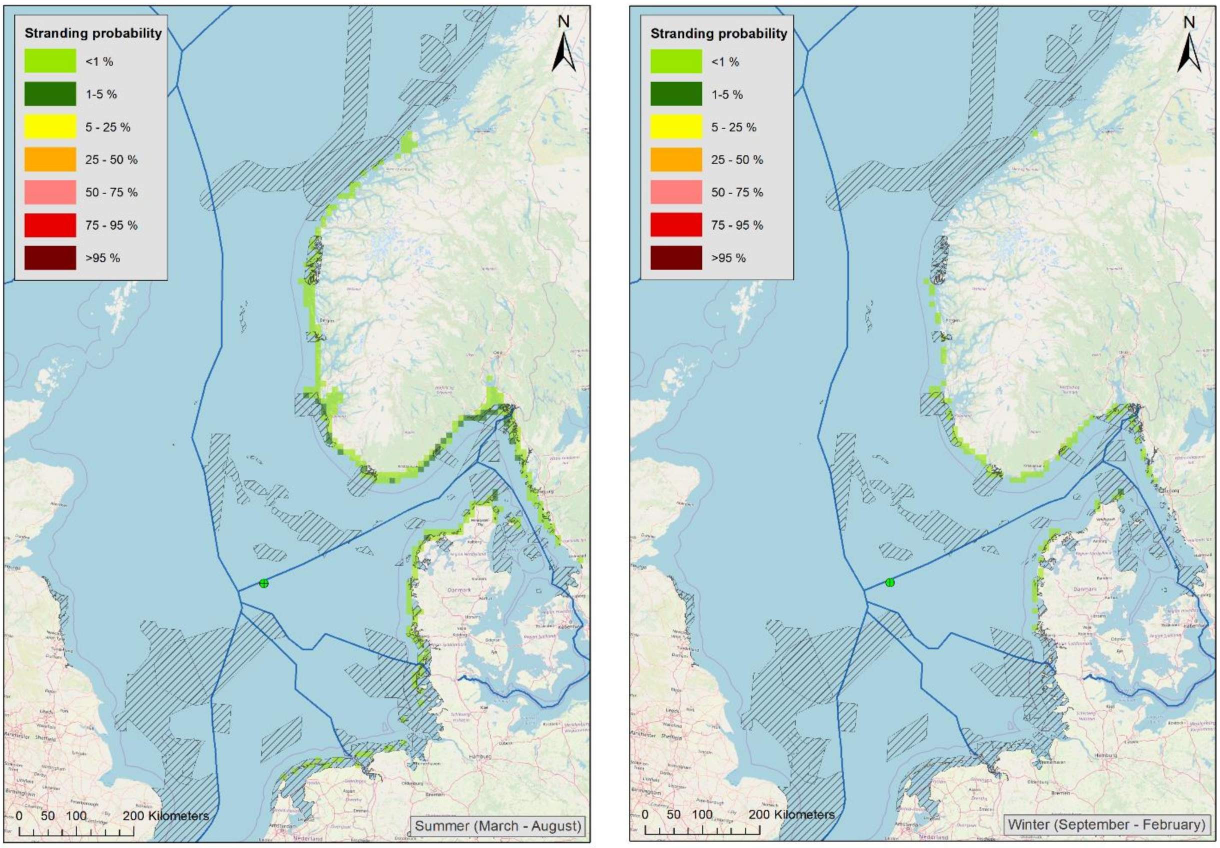


Figure 11-6 Result of oil spill modelling of a worst case, unmitigated surface release of oil during a blowout at Hejre during March-August (left) and September-February (right). The figures show seasonal resolution of shoreline oil hit probabilities of oil in 10 x 10 km grid cells. The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

11.1.9 Impacts on Norwegian SVOs

The modelling shows that Norwegian SVOs may be hit by oil in case of an unmitigated blowout (Figure 11-1 and Figure 11-2) i.e.:

- There is a probability of 5-25% probability that SVO "*Makrellfelt*", which is a spawning area for mackerel from May to July will be hit by oil. The calculated drift time from Hejre is 3-7 days.

- Sandeel field south may also be hit (probability 50-75%; drift time 1-3 days. The sandeel field south is spawning and foraging areas for sandeel (*Ammodytes* sp.). Furthermore, the Sandeel field south is a valuable habitat for common guillemot (*Uria aalge*) and northern fulmar (*Fulmaris glacialis*) from April to December. The model results show that the concentration of oil in these areas are less than 25 ppb, which is below concentrations that are harmful to fish eggs and larvae (cf. 11.1.2) so spawning in this area is not at risk.

On the other hand, there is a risk of oiling and killing of birds on the Sandeel field South (cf. 11.1.5).

11.1.10 Impacts on SACs (Natura 2000 sites) and Annex IV species

Assessments of the impacts on SACs (Natura 2000 sites) of oil release during a blowout incident is summarised in the following based on the modelling performed by DNV (2020).

11.1.10.1 Impacts on German, Dutch and UK Natura 2000 areas south of Hejre

In the unlikely event of a blowout, the German, Dutch and UK Natura 2000 (SAC) areas south of Hejre may be affected by an unmitigated spill, especially the German area i.e. (cf. Table 11-5):

- There is a 25-50 % probability that oil hits the German DE 1003301 *Doggerbank* in March-August and the drift time of oil to this area is 1-3 days. During September-February the probability is lower (5-25%) for the vast majority of the area and the drift time is also 1-3 days

- The probability that the Dutch NL 2008001 *Doggerbank* may be hit, is 5-25 % for both seasons and with a drift time of 1-3 days during March-August and 3-7 days during September-February

- The probability that the UK SAC, UK0030352 *Doggerbank* will be hit is 5-25% March-August and the drift time to this area is drift time 3-7 days. In September-February the probability is only 1-5% and the drift time 7-14 days for the vast majority of the area.

Table 11-5 Results of oil OSCAR spill modelling of an unmitigated oil spill following a blow out at Hejre. Probabilities that the German, Dutch and UK Natura 2000 (SAC) sites south of Hejre are hit by oil and drift time of oil to site (the modelled drift time is shown in Figure 11-1).

Season	Site	Probability that the area may be hit by oil	Drift time from blow out to site
March-August	DE 1003301 Doggerbank	25-50 %	1-3 days
	NL 2008001 Doggerbank	5-25 %	1-3 days
	UK0030352 Doggerbank	5-25 %	3-7 days
September-February	DE 1003301 Doggerbank	25-50 %	1-3 days
	NL 2008001 Doggerbank	5-25 %	3-7 days
	UK0030352 Doggerbank	1-5 %	3-7 days

The basis for the designation of the three areas are the habitat type 1110 *Sandbanks* and the habitat species 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1364 *Grey seal*.

Impacts on harbour porpoise

Comparatively little is known about the effects of oil on cetaceans (whales, dolphins and porpoises), but based on scant records of cetacean mortality associated with oil spills, it has been suggested that an oil spill may only affect small numbers of cetaceans. Several authors suggest that the threat of most immediate concern is inhalation of evaporated volatile toxic components from the oil slick on the sea surface if they emerge at the surface to breathe in the middle of an oil slick.

This risk is greatest near the source of a fresh spill because volatile toxic vapours evaporate and disperse relatively quickly. When concentrated vapours are inhaled, mucus membranes may become inflamed, lungs can become congested, and pneumonia may ensue. Inhaled fumes from oil may accumulate in blood and other tissues, leading to possible liver damage and neurological disorders. As porpoises rely on blubber for insulation, their thermoregulatory ability does not seem seriously hampered by contact with oil. (Helm et al. 2015).

It cannot be excluded that harbour porpoises in the Central North Sea may be affected in the unlikely incidence of a blowout at Hejre. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and as the density of porpoises is relatively low (0.01-8 individuals/km^2 (cf. Figure 18-2), only a tiny fraction of the populations of harbour porpoise in the North Sea is likely to be affected. It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the harbour porpoises in the North Sea.

Impacts on seals

Seals may be affected by direct contact with oil in a variety of ways. Oil can coat all or portions of their body surface and they may inhale toxic fumes of hydrocarbons, which affects their lungs. In addition, they may ingest oil directly or ingest oil-contaminated prey. As seals rely on blubber for insulation their thermoregulatory ability does not generally seem seriously to be hampered by contact with oil. However, observations suggest that some individuals have become so encased in oil that they were not able to swim and subsequently drowned. In addition, observation also suggest that eyes, oral cavity, respiratory surfaces and urogenital surfaces are particularly sensitive to contact with oil (Helm et al. 2015).

It cannot be excluded that seals in the German, Dutch and UK Natura 2000 areas may be affected. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and as seals are relatively rare in the Central North Sea only a tiny fraction of the populations of seals is likely to be affected. It is therefore unlikely that a potential oil contamination from a blowout will significantly affect the population sizes of the seals.

Impacts on habitat type 1110 sandbanks

Oil may be incorporated in plankton or aggregate with marine snow and thus settle on the habitat type 1110 *Sandbanks which are slightly covered by sea water all the time*, especially in the German area, thereby affecting the benthic infauna community that has been characterised as a Bathyporeia-Fabulina (Amphipod-Tellina) community, with the crustacean *Bathyporeia elegans* and the bristle worms *Spiophanes bombyx* and *Spio decorata* as characterising species. However, given that fact that the risk of a blowout occurring is extremely low and that 60 % of the oil will have evaporated by the time it hits the area the risk is negligible.

11.1.10.2 Impacts on Danish Natura 2000 areas

In case of a blowout, Danish Natura 2000 areas east and north-east of Hejre may be hit by oil to a larger and lesser extent dependent on distance from the blowout and the position in relation to the axis of the prevailing direction of the oil slick drift.

The different sites can be grouped in terms of risk of being hit by oil and drift time as follows (Table 11-6):

- DK00VA257 *Jyske Rev Lille Fiskebanke*, K00VA259 *Gule Rev,* DK00VA258 *Store Rev* and DK00FX112 *Skagens Gren og Skagerrak* are situated with increasing distance from Hejre in the prevailing direction of the oil slick drift. There is a modelled probability of 5-25 % that these areas will be hit by oil during March-August and the drift time from Hejre to *Jyske Rev Lille Fiskebanke* will be 3-7 days, 7-14 days from Hejre to *Gule Rev* and *Store Rev* and 14-21 days to *Skagens Gren og Skagerrak*

- DK00VA301 *Lønstrup Rødgrund*, DK00VA348 *Thyborøn Stenvolde,* DK00EX023 *Agger Tange* and DK00VA340 *Sandbanker ud for Thyborøn* are located outside the axis of the prevailing drift direction at quite large distances from Hejre. The risk that these areas are hit by oil is very small (i.e. 1-5 % probability) and the drift time from Hejre in the range 14-21 days.

- Oil will basically not enter DK00VA347 *Sydlige Nordsø* (probability <1%). However, there is a 1-5 % probability, that oil may enter in two very small areas in the westernmost part of the area.

The probability that the Natura 2000- areas are being hit by oil is smaller during September-February (the modelled drift time is shown in Table 11-6).

Table 11-6 Results of OSCAR oil spill modelling following an unmitigated blow out at Hejre. Probabilities that Danish Natura 2000 sites are hit by oil and drift time of oil during March-August and September-February in case of seabed release. Surface release is identical in terms of probability and drift time. (the modelled drift time is shown in Figure 11-1).

Season	Site	Probability that the area will be hit by oil	Drift time from blow out to site
March-August	DK00VA257 Jyske rev, Lille Fiskebanke	5-25 %	3-7 days
	DK00VA259 Gule Rev	5-25 %	7-14 days
	DK00VA258 Store Rev	5-25 %	7-14 days
	DK00FX112 Skagens Gren og Skagerrak	5-25 %	14-21 days
	DK00VA301 Lønstrup Rødgrund	1-5 %	14-21 days
	DK00VA348 Thyborøn Stenvolde	1-5 %	14-21 days
	DK00EX023 Agger Tange	1-5 %	14-21 days
	DK00VA340 Sandbanker ud for Thyborøn	1-5 %	14-21 days
	DK00VA347 Sydlige Nordsø	< 1 %*	
September-February	DK00VA257 Jyske rev Lille Fiskebanke	5-25 %	3-7 days
	DK00VA259 Gule rev	1-5 %	7-14 days
	DK00VA258 Store Rev	1-5 %	7-14 days
	DK00FX112 Skagens Gren og Skagerrak	1-5 %	7-14 days
	DK00VA301 Lønstrup Rødgrund	< 1 %	
	DK00VA348 Thyborøn stenvolde	< 1 %	
	DK00EX023 Agger Tange	< 1 %	
	DK00VA340 Sandbanker ud for Thyborøn	< 1 %	
	DK00VA347 Sydlige Nordsø	< 1 %	

*There is a 1-5 % probability, that oil may enter in two very small areas in the westernmost part of the area

The basis of the designation of these Natura 2000 areas are listed in Table 11-7. The table also provides an overview of the assessments of impacts on the habitat types and habitat species in the areas.

Table 11-7 Assessment of impact on habitats and species that are basis for the designation of Danish Natura 2000 that may be affected by oil spill, in the unlikely event of a blow out at Hejre.

Natura 2000 area	Basis for designation	Assessment of impacts resulting from an un-mitigated blowout at Hejre
DK00VA257 *Jyske Rev Lille Fiske-banke*	1170 Reef 1351 Harbour porpoise	Negligible risk of impacts on reef Negligible risk of harmful effects on Harbour por-poise (cf. text above)
DK00VA259 *Gule rev*	1170 Reef 1351 Harbour porpoise	Negligible risk of impacts on reef Negligible risk of harmful effects on Harbour por-poise (cf. text above)
DK00VA258 *Store rev*	1170 Reef 1351 Harbour porpoise	Negligible risk of impacts on reef Negligible risk of harmful effects on Harbour por-poise (cf. text above)
DK00FX112 *Skagens Gren og Skagerrak*	1110 Sandbanks which are slightly covered by sea water all the time 1180 Submarine structures made by leaking gases 1351 Harbour porpoise 1365 Harbour seal	Negligible risk of impacts on sandbanks and submarine structures Negligible risk of harmful effects on Harbour por-poise and Harbour seal (cf. text above)
DK00VA301 *Lønstrup Rødgrund*	1170 Reef 1351 Harbour porpoise	Negligible risk of harmful effects on reef Negligible risk of harmful effects on Harbour por-poise (cf. text above)
DK00VA348 *Thyborøn Stenvolde*	1170 Reef 1351 Harbour porpoise	Negligible risk of harmful effects on reef Negligible risk of harmful effects on Harbour por-poise (cf. text above)
DK00EX023 *Agger Tange*	19 different species of seabirds including species of terns, ducks and wading birds.	Negligible risk of harmful effects on birds (cf. text above)
DK00VA340 *Sandbanker ud for Thyborøn*	1110 Sandbanks which are slightly covered by sea water all the time 1351 Harbour porpoise	Negligible risk of harmful effects on sandbanks Negligible risk of harmful effects on Harbour por-poise (cf. text above)
DK00VA347 *Sydlige Nordsø*	1110 Sandbanks, which are slightly covered by sea water all the time 1351 Harbour porpoise 1365 Harbour seal 1364 Grey seal Red-throated diver, Black-throated diver and Lit-tle gull	Will not be affected

Impacts on marine mammals

Harbour porpoise and seals are included in the basis for designation in eight of the nine potentially affected Danish Natura 2000 areas. As described above, impacts on harbour porpoise may primarily be caused by toxic fumes from the oil slick on the surface.

Except for DK00VA257 *Jyske rev, Lille Fiskebanke* the oil will have drifted a week or more upon arrival to the potentially Danish affected Natura 2000 areas (Table 11-7). Within a week, the toxic fumes will have evaporated.

The drift time to Jyske Rev has been estimated at 3-7 days, so most toxic fumes have probably evaporated especially during March-August. In addition, the oil slick is transported in a relatively narrow band in the direction of the surface currents, hence the risk that a porpoise encountering an oil slick is low.

Seals are included in the basis for the designations of the Danish Natura 2000 areas DK00FX112 *Skagens Gren og Skagerrak.*

The drift time to DK00FX112 *Skagens Gren og Skagerrak* is 14-24 days at which time the oil will mostly be in the form of tar balls, which are unlikely to harm seals. The risk that oil is reaching DK00VA347 *Sydlige Nordsø* is low (probability 1-5 %) and with a drift time of 7-14 days any toxic oil components would have evaporated.

It is therefore assessed that the risk of harmful impacts of an unmitigated oil blowout at Hejre on harbour porpoises and seals within the Danish Natura-2000 areas is negligible.

Impacts on seabed habitats

The basis for designation at all sites except DK00EX023 *Agger Tange*, includes a seabed habitat (either 1170 Reef or 1110 Sandbanks). The drift times to DK00VA *Jyske Rev Lille Fiskebanke,* DK00VA259 *Gule Rev*, DK00VA *Store Rev* are in the range 3-14 days (Table 11-6). The sedimentation of oil components is at its maximum after a drift time of a week (Cf. Table 11-6). Consequently, there may be a risk that the seabed habitats in these areas to some extent may be affected by settled oil. However, the risk is relatively low (probability 5-25%).

The probability that DK00FX112 *Skagens Gren og Skagerrak* is hit by oil is also 5-25 %, but the drift time is larger (14-21 days), so any sedimentation of oil will be less.

The probability of oil entering the remaining areas are even lower i.e. 1-5 % (5-25 %, so the risk of impacts on seabird is therefore assessed to be negligible.

Impacts on birds

Species of seabirds are included in the basis for designation of DK00EX023 *Agger Tange.*

Seabirds are very vulnerable to oil spill because they often are in contact with surface water and exposure to the sticky oil destroys the buoyancy and the isolating quality of the plumage. Birds smothered in oil will usually die of cold, starvation or drowning. Seabirds that stay on the sea surface for longer periods are mainly at risk, but all types of seabirds may be affected.

However, the probability of an oil slick entering the area is low (1-5 %) and the drift time has been modelled to 14-21 days (Table 11-6). By this time the oil will be weathered so much that it is not sticky or toxic and therefore much less damaging to birds than fresher oil. Risk of impacts on seabird is therefore assessed to be negligible.

11.1.11 Conclusion

It is concluded that the Hejre tie-back to South Arne development will not negatively affect the conservation status of habitats and species, for which potentially affected Natura 2000- sites have been designated as well as species listed on Annex IV of the EU Habitats directive (Directive 98/43EEC of 21 May 1992). Nor will the re-development affect the integrity of the areas negatively.

The conclusion in based on following arguments:

- The risk that a blowout occur is extremely low since all safety systems and measures are in place on the platform.
- The oil slick is transported in a relatively narrow band in the direction of the surface currents.
- The INEOS Energy Denmark's oil spill contingency plan (INEOS Oil and Gas, 2022) will be activated, and oil spill combat will be carried out, which will reduce the spreading of oil and mitigate impacts of any spill,, se section 11.4 below.

11.2 Environmental impacts of gas released during a blowout

In the unlikely event of a blowout at Hejre, gas may also escape from the formation.

In general, the extent of environmental impacts of escaped gas is not comparable to the impact of oil blowouts. The bulk of the gas, bubbles to the surface and escape to the atmosphere within a relatively small area around the platform and does not disperse in the water to the same extent as oil. On the other hand, field and laboratory investigations have demonstrated that severe environmental impacts may be observed in the immediate vicinity of the platform. The investigations clearly proved that severe damages and mass mortality on zooplankton, benthic fauna and fish might occur within the small gas affected area (Table 11-8).

Although gas blowout has smaller environmental impacts than oil blowouts, the gas may pose a severe safety risk for personnel on rig, platform and vessels. If the gas ignites and causes fires or explosions, installations and equipment will be damaged and in case personnel is not evacuated in due time, injuries or loss of life of personnel may occur. However, the risk of this is minor due to technical safety features on the platform that prevent blowout from happening. During an unlikely situation, the existing contingency arrangements involving evacuations of personnel from platforms will minimise the risk even further.

Table 11-8 Field-and laboratory studies on impacts of methane gas in the marine environment.

Study	Observations	References
Field survey in connection with a gas blowout at drilling rigs in the Azov Sea summer/autumn 1982 and in 1985	95 % of the escaped gas was methane. The concentration of methane in the vicinity of the well was 4-6 mg/l. The concentration had decreased to 0.07-1.4 mg/l 200 m from the well. In areas with a high concentration of methane, the biomass of benthos declined. Some declining of the zooplankton biomass also occurred in the vicinity of the accidental well Fish in the vicinity of the well clearly developed significant intoxication symptoms such as impaired movement coordination, weakened muscle tone, pathologies of organs and tissues, damaged cell membranes, disturbed blood for-	Glabrybvod 1983 AzNIRKH 1986

Study	Observations	References
	mation, modifications of protein synthesis, radically increased total peroxidase activity, and some other anomalies typical for acute poisoning of fish.	
Laboratory investigations of impacts of natural gas on fish	Fish clearly avoided concentrations of dissolved gas of 0.1-0.5 mg/l	Sokolov and Vinogradov 1991
Laboratory investigations of acute toxicity of natural gas on fish and zooplankton	48h LC_{50} for fish = 1-3 mg/l 96h LC_{50} for zooplankton = 5.5 mg/l	Umorin et al 1991
Laboratory investigations of acute toxicity of natural gas on zooplankton, benthic fauna and fish fry	96h LC_{50} for zooplankton, benthic fauna and fish fry = 0.6-1.8 mg/l	Borisov et al 1995
Laboratory investigations of impacts of natural gas on fish	Exposure to 1 mg/L and above induced intoxication symptoms (Impaired movement coordination, impaired oxygen absorption. disorientation. Lethal effects were observed after two days.	Patin 1993

11.3 Environmental impacts of pipeline rupture

Rupture of pipelines may occur as a result of corrosion or damage caused by trawlers. This applies for the new pipeline as well as the pipelines previously covered in the Hejre Legacy EIA. Still however, the risk of spills of larger amounts of oil or gas in case of rupture is minor.

Pipeline pressure is continuously monitored from the production platform. In case of pressure drop, the system closes. In addition, any spills are dealt with in accordance with the oil spill contingency plan for INEOS Energy Denmark's offshore operations, recent version from March 2022 (INEOS Oil & Gas DK 2022).

11.3.1 Modelled dispersion of oil during pipeline rupture

11.3.1.1 Spreading of oil

The unlikely event of subsea leakage from rupture of the longest pipeline has been modelled for Hejre to Siri tie-back (HESI-DNVI-S-RA-00002). This modelling is viewed as a conservative scenario, as the Hejre to South Arne will have a shorter pipeline with potentially fewer leakage points and thus overall lower risk for leakage. Figure 11-7 shows the modelled probability that a subsea leakage from pipeline rupture will be hit by ≥1 % of 1 tonne of oil per 10 x 10 km grid cells during March-August) and September-February, respectively.

It is seen that released oil during pipeline rupture will be transported with the prevailing current towards the North-eastern part of the Norwegian and Danish part of the North Sea. In the unlikely case of unmitigated pipeline rupture, the hit probability in Danish waters is above 94 % in the vicinity of the release location. In Norwegian waters the hit probability is 75-95 % during summer and 50-75 % during winter. For all other neighbouring countries including Natura 2000 areas (SACs) the hit probability is 0-50 %. The model shows that even for an unmitigated spill, the risk of oil stranding on coasts is 0 %. This means that there will be no stranding of oil in coastal areas such as the Wadden Sea in Germany, the west coast of Jutland or the Norwegian coast.

Figure 11-7 shows the seasonal resolution of arrival times from pipeline rupture within the influence area to 10 x 10 km grid cells (drift time).

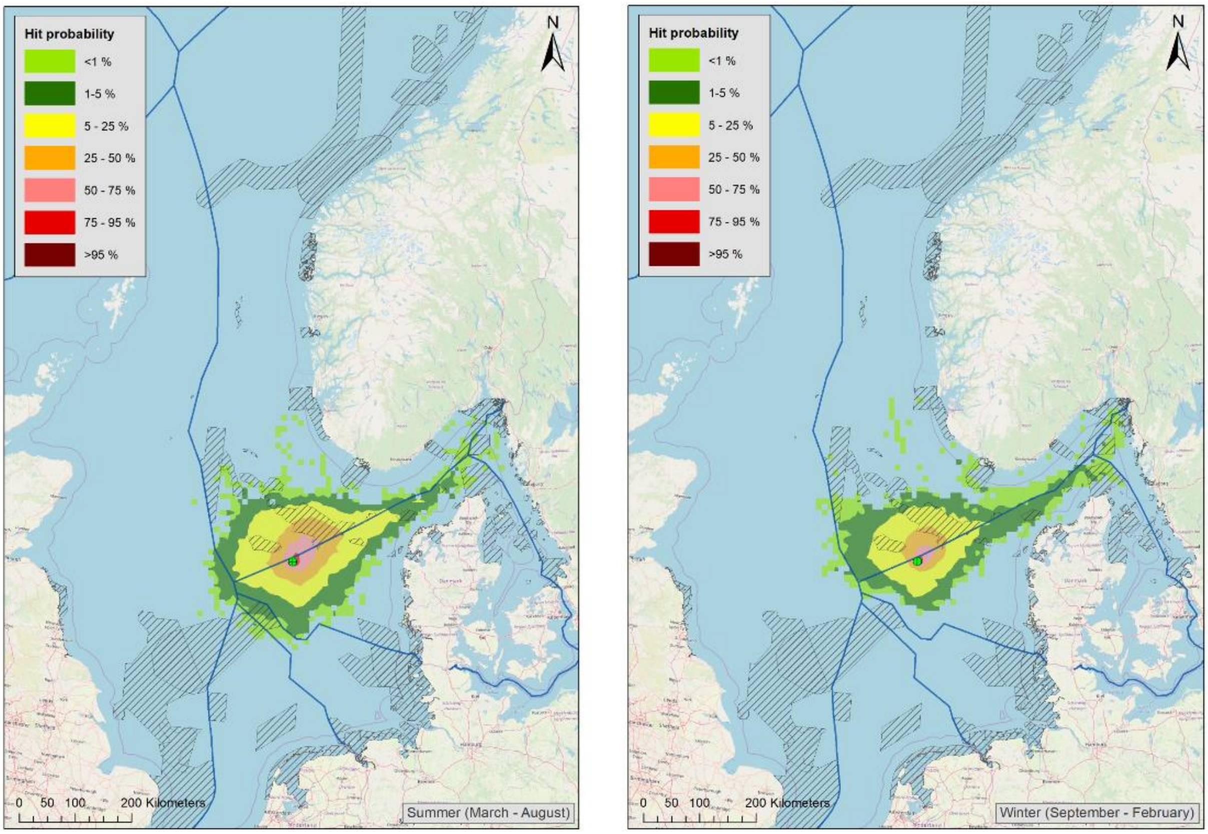


Figure 11-7 Result of stochastic oil spill modelling of a worst case, unmitigated release of oil during a full pipeline rupture at Siri during March-August (left) and September-February (right). The figures show the modelled probability that the sea surface in 10x10 km grid cells will be hit by more than 1 tonnes of oil. The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

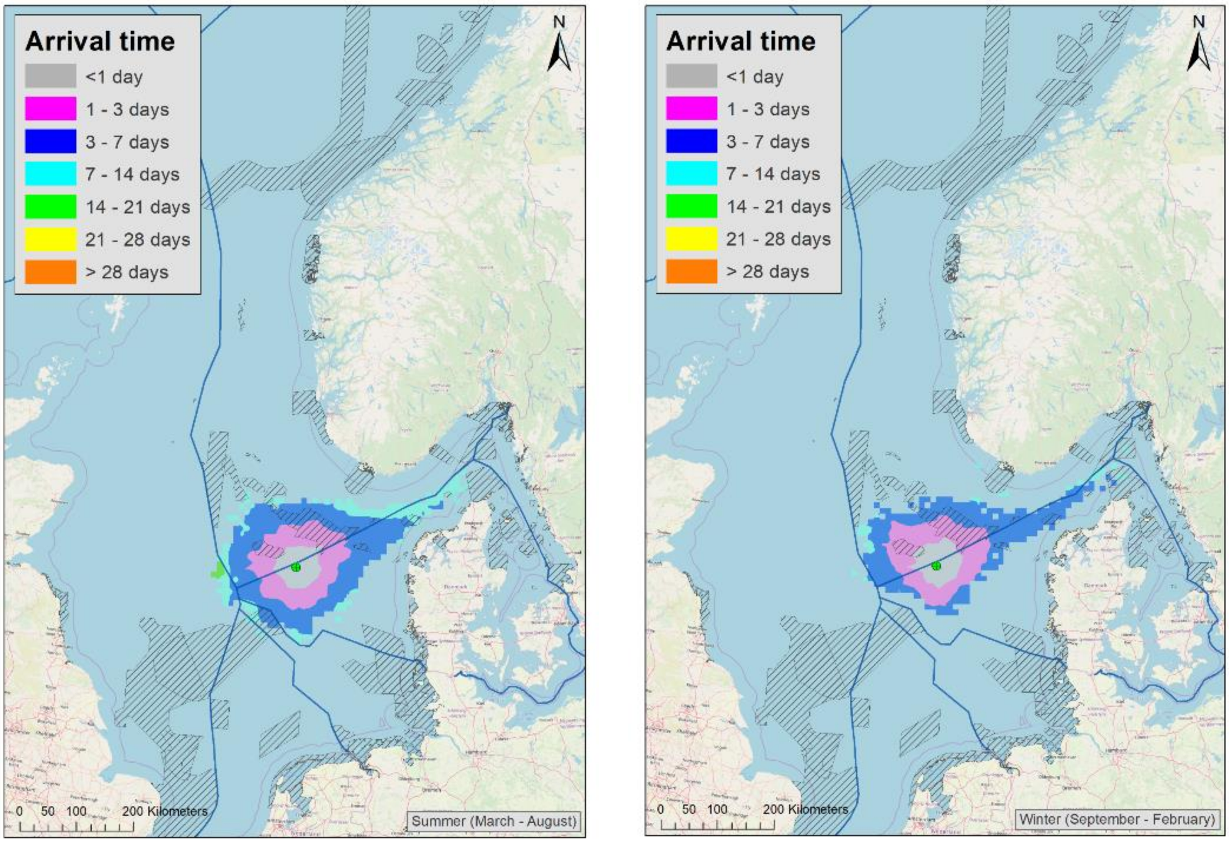


Figure 11-8 Result of stochastic oil spill modelling of a worst case, unmitigated release of oil during a pipeline rupture of the Hejre tie-back to Siri development during March-August (left) and September-February (right). The figures show the shortest arrival times (since start of the release) within the influence area to 10 x 10 km grid cells. The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

Figure 11-9 shows that there will be <5 tonnes of oil per 100 km^2 in the North-eastern part of the closest SAC during summer and no detectable oil during winter.

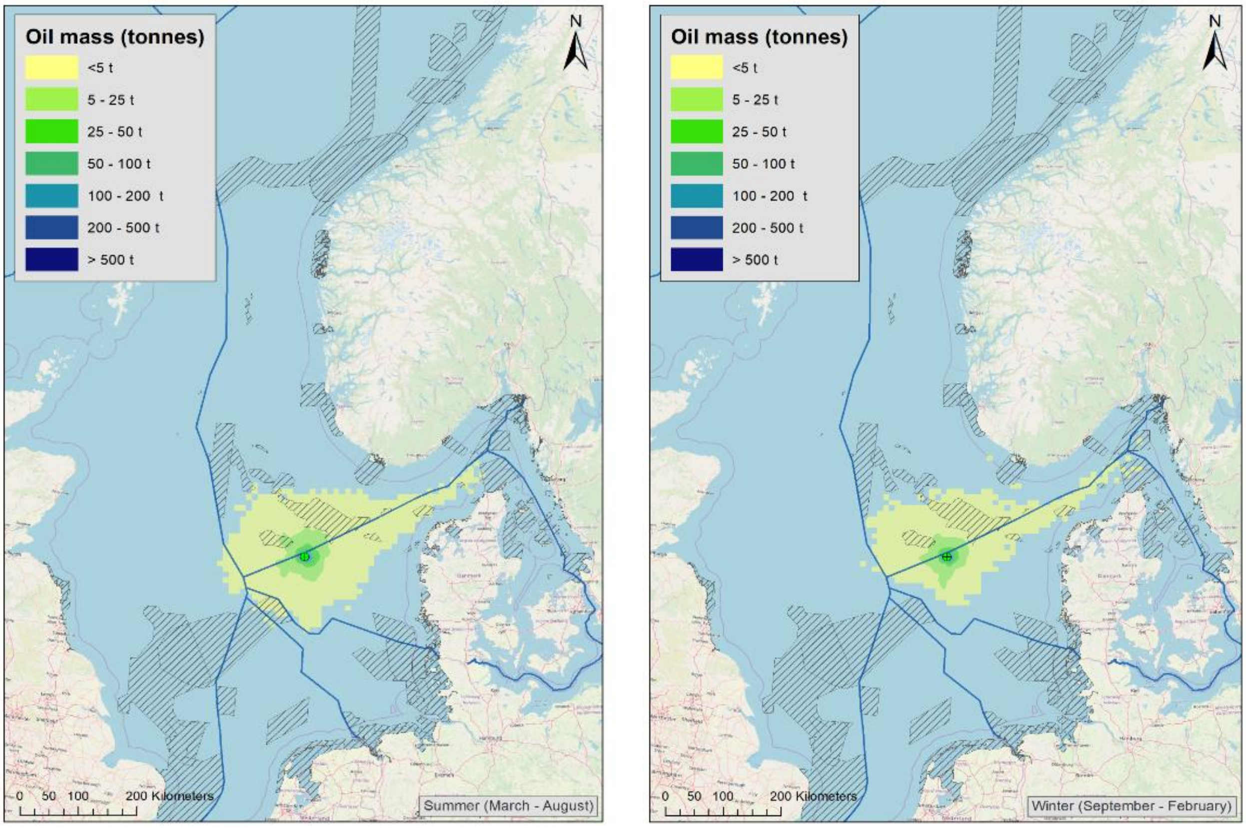


Figure 11-9 Seasonal oil mass within the influence area in 10 x 10 km grid cells during a pipeline rupture of the Hejre tie-back to Siri development during March-August (left) and September-February (right). The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

11.3.2 Impact on seabirds of oil during pipeline rupture

As addressed in section 11.1.5 birds are extremely vulnerable to oil spills, and they are often killed if occurring within the area of an oil spill. Oil spill from pipeline rupture impact a much smaller area than an oil blowout (green area on Figure 11-9). In the unlikely event of an unmitigated pipeline rupture, seabirds occurring in the vicinity of the pipeline will be affected. The oil will be transported with the current towards the internationally important bird area in the Norwegian part of the North Sea. However, most of the oil will have evaporated at the time of arrival and the oil sheen thickness will most likely be so thin that birds will survive.

Marine habitat areas off and along the coast of Denmark, Norway, Sweden, Germany, The Netherlands and United Kingdom will not be affected by a pipeline rupture.

11.3.3 Impact on marine mammals of oil during pipeline rupture

The modelling shows that oil spill from pipeline rupture may hit areas where harbour porpoise, grey seals or harbour seal may be encountered. However, since the influence area is limited to a relatively small area in the vicinity of the pipeline and since marine mammals in general are robust to oil spills (threshold is ca. 10 µm for seals and 100 µm for cetaceans, French-McCay 2009) only a small number of the North Sea populations of cetaceans and seals is expected to be negatively affected. Based on this is assessed that the impact of an unmitigated oil spill from pipeline rupture on harbour porpoise and seals is negligible. The effect of oil spill on marine mammals is described in more details in section 11.1.6.

11.3.4 Impact on fish eggs- and larvae of oil during pipeline rupture

Eggs and larvae are considered the most sensitive life stages of fish in terms of acute impacts of spilled oil. The Norwegian Oil Industry Association use 25 ppb as the THC concentration at which fish eggs- and larvae and other sensitive marine life begin to be affected by oil components (see also section 11.1.7). THC concentration does not exceed 25 ppb given a 10 x 10 km grid cell resolution and therefore fish eggs and larvae are not expected to be affected by oil during pipeline rupture.

Figure 11-10 shows the probability of oil released during pipeline rupture will strand. The calculations show no hit probability during summer season. During winter there is <1 % stranding probability at the south coast of Norway. There is no hit probability elsewhere.

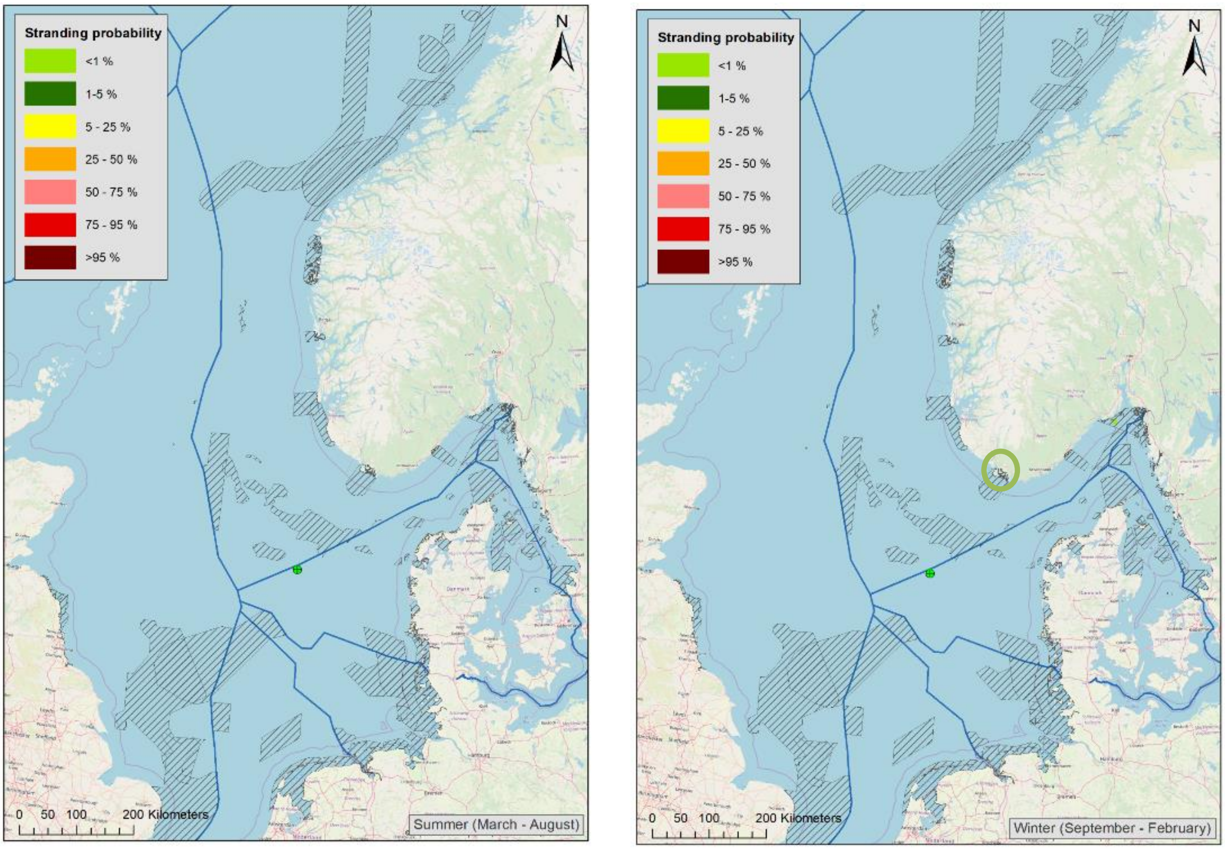


Figure 11-10 Result of stochastic oil spill modelling of a worst case, unmitigated release of oil during full pipeline rupture at the Hejre tie-back to Siri development during March-August (left) and September-February (right). There is a stranding probability of <1% in Norway (light green area in red circle). The figure shows the shortest arrival times (since start of the release) within the influence area to 10 x 10 km grid cells. The hatched areas show Natura 2000 areas (SACs) in territorial waters of EU countries and SVO areas (valuable and vulnerable areas) in Norwegian waters.

11.3.5 Impact on Norwegian SVOs

The modelling shows that Norwegian SVOs may be hit by oil in case of an unmitigated pipeline rupture (Figure 11-1 and Figure 11-2) i.e.:

- Sandeel field south may be hit by oil from pipeline rupture. The hit probability has been estimated to 25-50% during summer; drift time <1 day. The Sandeel field South is spawning and foraging areas for sandeel (*Ammodytes* sp.). Furthermore, the Sandeel fields South is a valuable habitat for common guillemot (*Uria aalge*) and northern fulmar (*Fulmaris glacialis*) from April to December. The model results show that the concentration of oil in these areas are less than 25 ppb, which is below concentrations that are harmful to fish eggs and larvae (cf. 11.1.7) so spawning in this area is not at risk.

- The SVO "*Makrellfelt*", which is a spawning area for mackerel from May to July has no hit probability.

11.3.6 Impact on SACs (Natura 2000 sites)

The oil spill modelling of a pipeline rupture shows it is very unlikely that Natura 2000 areas will be hit by oil. The hit probability within the German SAC DE 1003301 Doggerbank is thus < 1 %. DE 1003301 is designated to protect sandbanks, reefs and different species of fish and marine mammals (see further description in section 11.1.10). SACs in the Netherlands, UK and Denmark show no hit probability. Based on the low hit probabilities in neighbouring SACs it is assessed that that pipeline rupture will not significantly impact the basis of the designation of these areas.

11.4 Oil spill contingency plan

The modelling and assessments described above, are made under the assumption that all safety systems on the platform fail and that oil spill combat actions are not taken. In case of an uncontrolled blowout or other types of spill INEOS's oil spill contingency plan will be activated, which will significantly mitigate the impacts of spills (INEOS Oil & Gas 2022).

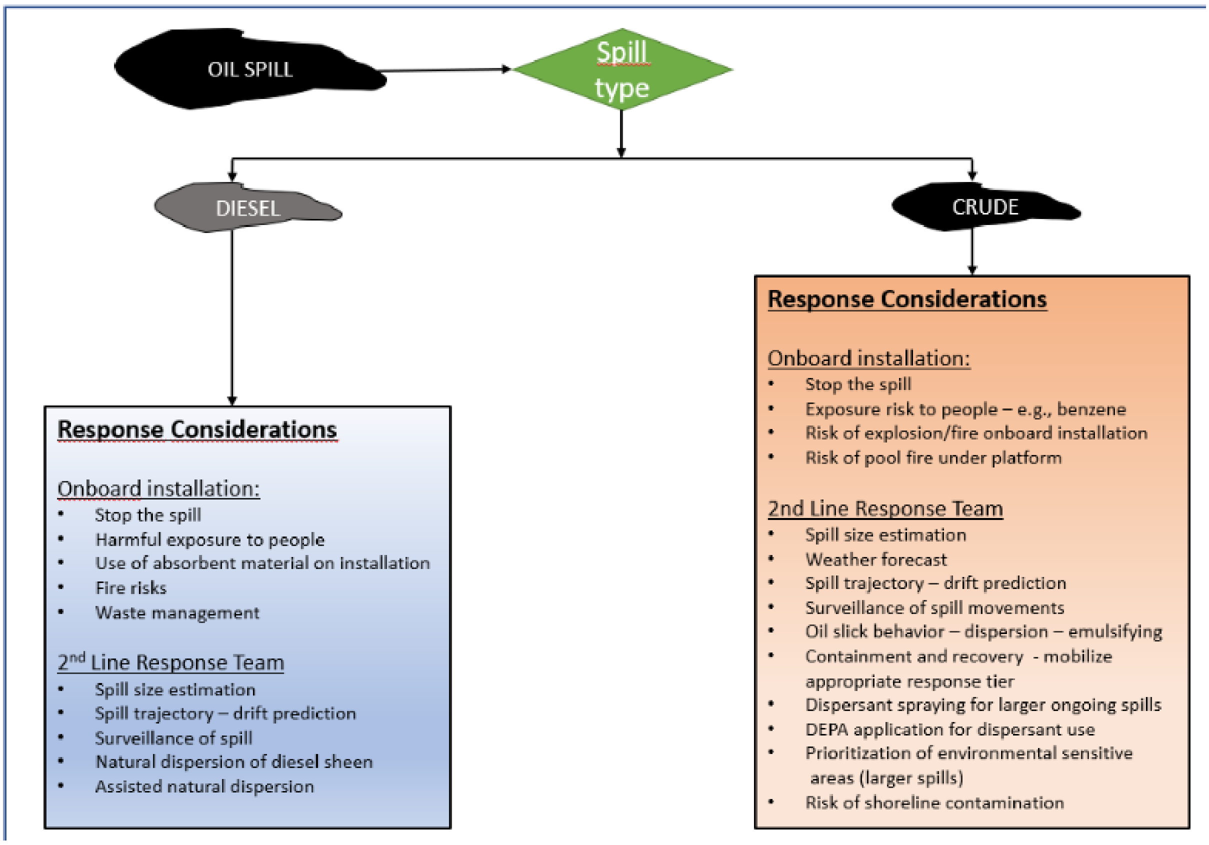


Figure 11-11 General response techniques consideration and strategy options (from INEOS Oil spill contingency plan, 2022).

INEOS Energy Denmark has established a legally binding cooperation arrangement with Total E&P Denmark for mutual assistance in case of an oil spill incident from one of the operator's production installations. This arrangement ensures that four containerized DESMI (provider of pumps and systems for oil spill) fast sweep oil collection systems will be available for containing and collecting spilled oil, depending on the magnitude of the spill. In case of a blowout further oil spill mitigation resources will be provided by Oil Spill Response Ltd (OSRL).

Oil spill contingency plan are thus in place and implemented. The plans are forwarded to Authorities for approval. In Denmark, the preferred response strategy is containment and recovery of spilled oil. Dispersant spraying may be used, subject to a case-by-case approval from the DEPA. Details on the specific equipment available for the preferred response strategy (mechanical containment and recovery) for the three tier responses are outlined in Figure 11-12 and Table 11-9.

TIER 1	TIER 2	TIER 3
Oil spills are likely to be small and effect a localized area. The spill can be managed by using INEOS pre-arranged PSV resources.	A spill incident in which TOTAL response resources and support are required to control the spill	An incident where assistance is required from international (OSRL) and national resource (other operators based on OCES agreement).
Characteristics of a Tier 1 oil spill Spill occurs within immediate site proximity and is likely above 5 m3 Spill can be easily managed using response resources available on site. The spill source has been secured	**Characteristics of a Tier 2 oil spill** Spill extends beyond the immediate site proximity Tier 1 resources are overwhelmed Spill source cannot be immediately secured	**Characteristics of a Tier 3 oil spill** Uncontrolled Well blowout/ loss of control / risk of total GBS inventory loss. Spill has crossed international maritime boundaries Tier 1 and Tier 2 resources are overwhelmed

Figure 11-12 Characteristics of the Tier 1, Tiers 2 and Tier 3 oil spills (INEOS Oil & Gas 2022)

Table 11-9 Characteristics of the Tier 1, Tiers 2 and Tier 3 oil spills and available resources for combatting the three types of spill (INEOS Oil & Gas 2022)

Tier	Resources for each Tier
Tier1	One containerized DESMI Speed Sweep 1500 system (swath width 25 m) with an in-built Ro-Skim 1500 skimmer connected to a DOP 250 pump system (nameplate capacity: 100-125 m^3/hour). The sweep system is operated along with a DESMI Ro-Kite 1500 allowing operation of the sweep system by one vessel. The system is stored permanently on Esvagt Innovator - ready for immediate deployment. Esvagt Innovator liquid storage capacity for recovered oil: 1200 m^3. System is owned by INEOS

Tier 2	One containerized DESMI Speed Sweep 1500 system with in-built skimmer (as described for Tier 1). The system is stored permanently on TOTAL PSV – ready for immediate deployment. Esvagt Dee liquid storage capacity: 510 m³. One containerized DESMI Speed Sweep 1500 system with in-built skimmer (as described for Tier 1). The system is stored on the TOTAL offshore installation crossway Eagle – in case of mobilization the system – ready for deployment within 8 hours onto a support vessel nominated on the day. Preferably Hvila Fanø with a 1150 m³ liquid storage capacity for recovered oil. One containerized DESMI Speed Sweep 1500 system with in-built skimmer (as described for Tier 1). The system is stored onshore in Port of Esbjerg ready for deployment onto a vessel of opportunity. The timeline for this will be dependent on vessel availability and location. All three systems are owned and operated by TOTAL
Tier 3	OSRL Tier 3 Provider OSRL has a variety of booms and skimmer systems including fast sweep systems that can be operated by one vessel. Provision of personnel to operate and manage the incident is a part of the service. INEOS will hire suitable vessels of opportunity on the day.

11.5 Risk assessment of accidental spills

Based on the above and using the criteria described in section 7, it is assessed that the environmental risks related to accidental spills during construction and operation of Hejre is **Low** to **Negligible** (Table 11-10).

Table 11-10 Environmental risk of accidental spills during operation of Hejre.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Likelihood of impact	Environmental Risk
Impacts of oil release during blowout	International	Medium term	Large	Major impact	Very low	Low risk
Impacts of gas release during blowout	Local	Short term	Large	Moderate impact	Very low	Negligible risk
Impacts of rupture of pipeline	Local	Short term	Moderate	Minor impact	Low	Negligible risk

12. Environmental risk of non-indigenous species

The term non-indigenous species means that the species is introduced outside its natural, past or present range (Ministry of Environment and Food 2019). The Vessels used for construction, production and decommissioning activities can potentially introduce non-indigenous species to the North Sea area through marine fouling on vessels or through discharge of ballast water from the vessels.

The Ballast Water Management Convention implemented in Danish law through the Statutory Law on Protection of the Marine Environment (LBK 1165 of 25/11/2019) and regulated through the Executive Order on treatment of ballast water and sediments from ships' ballast water tanks (BEK 733 of 19/05/2022) stipulate the requirements for the vessels management of their ballast water. Vessels solely operating in the Danish sea-territory and exclusive economic zone are exempted from the requirements in the Ballast Water Management Convention. Smaller vessels (<400GT) are until 8 September 2024 also exempted.

If the vessel must fulfil the requirements in the Ballast Water Management Convention, it will either be by exchange of their ballast water (D1 exchange standard) or discharge of treated ballast water (D2 discharge standard). Whether the vessel must comply with the D1 or D2 standard depends on the vessels' renewal date of the IOPP certificate. These vessels must comply with the D2 standard on 8 September 2024 at the latest.

Management of biofouling is currently not regulated in the national Danish legislation. However, there may be some regulation and requirements in specific ports when performing in-water cleaning of the vessels. All vessels are expected to be coated with antifouling to reduce marine fouling. In addition, there is an economic incitement to remove marine fouling from the vessels regularly to minimize use of fuels. This incitement does generally not extend to cleaning of the so-called niche area. There will therefore be a risk, although minor risk, for introducing non-indigenous species by the vessels biofouling. This risk is reduced as it is expected the majority of the vessels generally will be operating within the North Sea. It is further expected that the vessels are guided by the non-mandatory "IMO Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species" (Resolution MEPC.207(62)) from 2011, which is currently under review in the IMO.

The presence of oil and gas platforms may also represent at pathway for non-indigenous species. at the platforms may be used as steppingstones during a secondary dispersal. However, as the structures at Hejre and South Arne are already present, there is no additional risk to be evaluated for this EIA Addendum.

The severity of a potential impact is theoretically major if the non-indigenous species become established and subsequently invasive. However, based on the arguments above the environmental risk of introduction of invasive species is assessed to be low Table 12-1.

Table 12-1 Risk related to non-indigenous species vessels under construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of non-indigenous species	Regional/ national	Long term	Moderate	Major impact	Very low	Low

13. Socio-economic assessment

This chapter consists of an assessment of the potential derived socio-economic consequences for the population or the society in the surrounding area, which could arise from the environmental impact of the project. The surrounding area is defined as the entire west coast of Jutland.

13.1 Method

The assessment in this chapter is a general assessment of the derived socio-economic consequences without detailed impact assessments. The analysis does not consider the consequences of the environmental impacts on the staff who visit the platform in connection with operational tasks either.

The assessment of the derived socio-economic consequences is primarily based on the following sources:

- The descriptions of environmental effects in chapter 8, 9 and 11.
- Statistics from the Danish Fisheries Agency and Statistics Denmark concerning the socio-economic importance of fisheries, and the tourist sector in the surrounding area.

13.2 The scope

The proposed project potentially results in several environmental impacts which can bring on either negative or positive changes experienced by local businesses and societal groups or the society. Some of these environmental impacts can potentially lead to socio-economic consequences. The socio-economic consequences considered in this chapter are:

- Changes in fish catches and tourism due to prohibited zones
- Changes in fishing industry and tourism due to accidental oil spill and gas escape
- Changes in employment and tax revenue

The focus of the socio-economic analysis is thus primarily on prohibited zones and accidental oil spills, since these (if they occur) are expected to lead to economic consequences for the local area, such as a decrease in the revenue of the local fishing industry and tourism businesses along the coast. Additionally, the socio-economic analysis will include potential positive impacts related to increase in employment and tax revenues.

13.3 The importance of the commercial fishery and tourism industries today

13.3.1 Extent of commercial fishery in the Hejre re-development area

The Danish AgriFish Agency collects information about the Danish fishing industry using a system defined by The International Council for the Exploration of the Seas (ICES), which divides the north-eastern Atlantic Ocean into geographical rectangles of 60 times 60 nautical miles. Fish catch data to the level of species are collected for each rectangle in the Danish sector. To assess the implications of the Hejre field re-development on the commercial fisheries, fisheries statistics from ICES squares 41F3, 41F4 and 40F4, as shown in Figure 13-1, has been used.

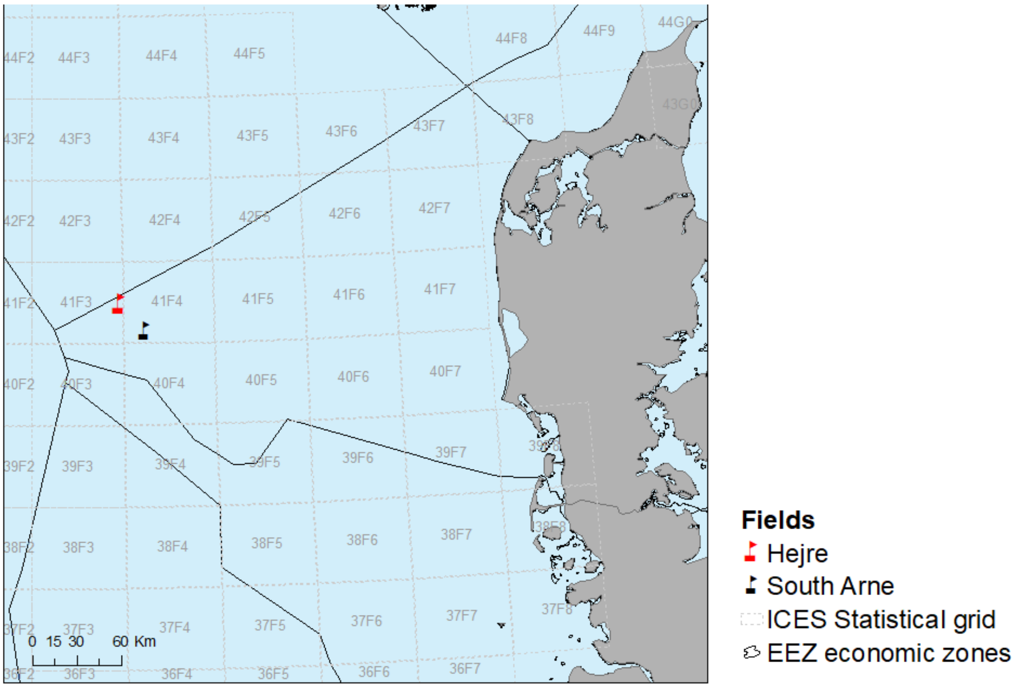


Figure 13-1 Location of the Hejre field in ICES 41F3 and the new pipelines from Hejre to South Arne (marked with flags) in ICES 41F4 and 41F3.

This method was also used in connection with the assessment of the impacts on commercial fisheries of the Hejre Legacy EIA using data from 2010. The assessment is redone to include newer data and to include the route corridors for the new pipelines. In this connection it should be mentioned that the assessment of the impact on the commercial fisheries around the Hejre field in the Hejre Legacy EIA included a broader area than in this EIA. The focus is here only on the catches in ICES 41F3 and 41F4, whereas the Hejre Legacy EIA included both ICES 41F3,41F4 and 40F4..

In the period 2014-2018, the annual Danish commercial fishery in the Central North Sea amounted to approximately 500,000 tons with an average value of 1,900 million DKK per year in average. In 2011, when the Hejre Legacy EIA was prepared, the annual Danish fishery in the Central North Sea amounted to approximately 477,000 tons with a value of 1,400 million DKK (Fiskeridirektoratet 2010). The extent of annual Danish commercial fishery has thus been fairly constant. As mentioned in Chapter 6, the area around Hejre is of minor importance compared to the total fish catch in the North Sea. Thus, the average value of fish catches around Hejre (ICES square 41F3) is 2.1 million DDK/year, corresponding to 0,1% of the value of the total fish catch in the Central North Sea per year in the period 2014-2018 (See Table 13-1).

Table 13-1 Average annual catch and value of Danish catches in the project area registered by ICES. Based on data 2014-2018. Source: Danish Fisheries Agency 2019.

ICES	Tons/year	Million DKK/Year	Percent of the value of the total fish catch in the central North Sea
41F3	299	2.1	0.1
41F4	7,560	11.4	0.6
40F4	1,814	5.7	0.3
Sum	9,673	19.2	1.0

However, if the entire project area is considered (ICES 41F3, 41F4 and 40F4), fishery is of some importance. The average annual Danish fishery in the project area thus amounts to approximately 9,673 tons with a value of 19.2 million DDK/year, corresponding to 1.0% of the value of the total fish catch in the Central North Sea (See Table 13-1).

13.3.2 Employment in the fishing sector

According to Statistics Denmark (Statistikbanken.dk 2020), 2,340 people were employed in the fishing sector[4] in 2018 in Denmark (exclusive fish shops, auction houses, wholesale etc.), corresponding to 0.1% of all Danish employees. Of them, 1,802 were employed with marine fishing (77%). Hence, marine fishing represents a high proportion of the total employment in the fishing sector in Denmark. However, compared to the total number of employees in Denmark, the number of employees in the fishing sector is small.

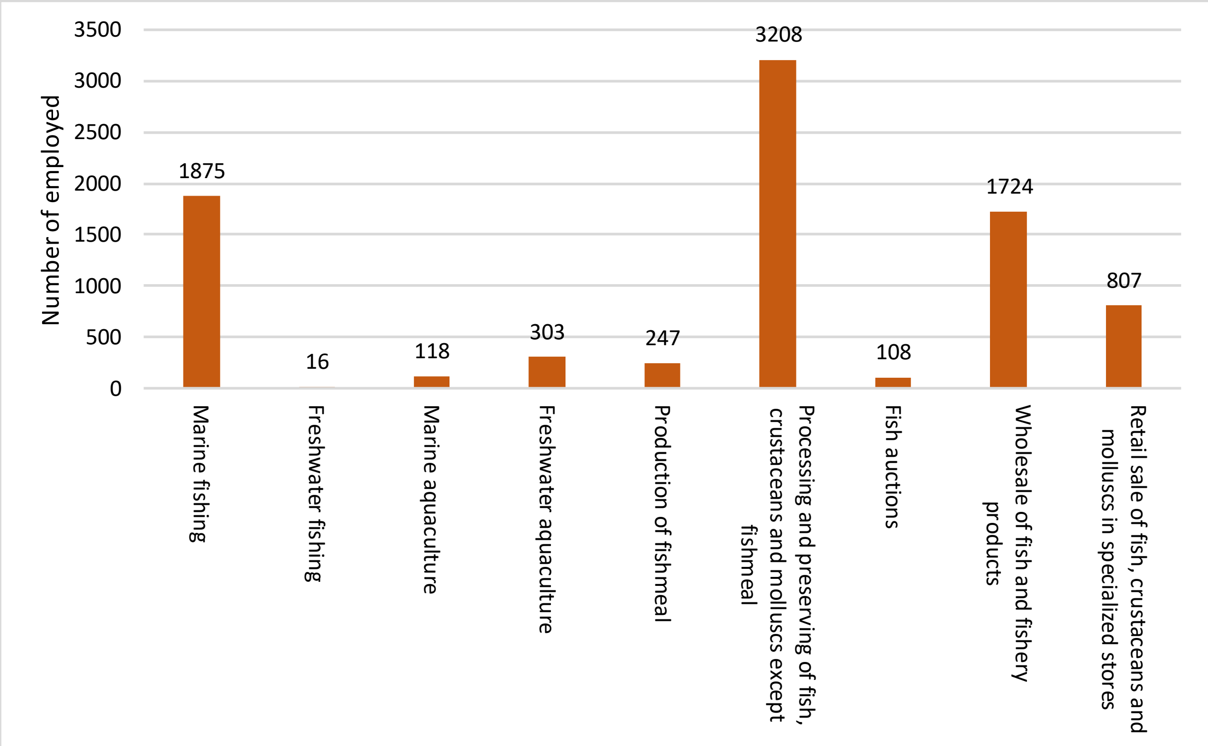


Figure 13-2 Number of people employed in the fishing industry in Denmark in 2013 distributed on sectors. Source: Danish Fisheries Agency, 2014 (based on Statistics Denmark - Registerbased Labour force Statistic (RAS)).

In 2013[5] (Danish Fisheries Agency, 2014), most of the employed in the fishing industry (including fish shops, auction houses etc.)[6] worked in the sector 'Processing and preserving of fish, crustaceans and molluscs except fishmeal', corresponding to 38% of the total employed in 2013 (See Figure 13-2). The second largest sector was 'Marine fishing', and the third largest was 'Wholesale of fish and fishery products'. These two sectors constitute 22% and 21% of the total employed in the fishery sector, respectively.

The processing sector thus plays a particularly important role in the total number of employees in the commercial fishery. In this connection, it should be mentioned that the Danish fishermen's landings form only

[4] Includes fishing, i.e. fishing catching, collecting and harvesting wildlife aquatic organisms (primarily fish, molluscs and crustaceans) including plants from sea- and coastal inland waters.

[5] 2013 is the latest data concerning the number of employed in the **total** fishing sector (including shopping).

[6] The total of this statistic differs from the one in mentioned earlier in the text (2,340 people were employed in the fishing industry). It includes fish shops, wholesale trade, auction houses etc.

part of the sector's total supplies of fish catch and raw materials (Danmarks Pelagiske Producentorganisation et al. (2018).

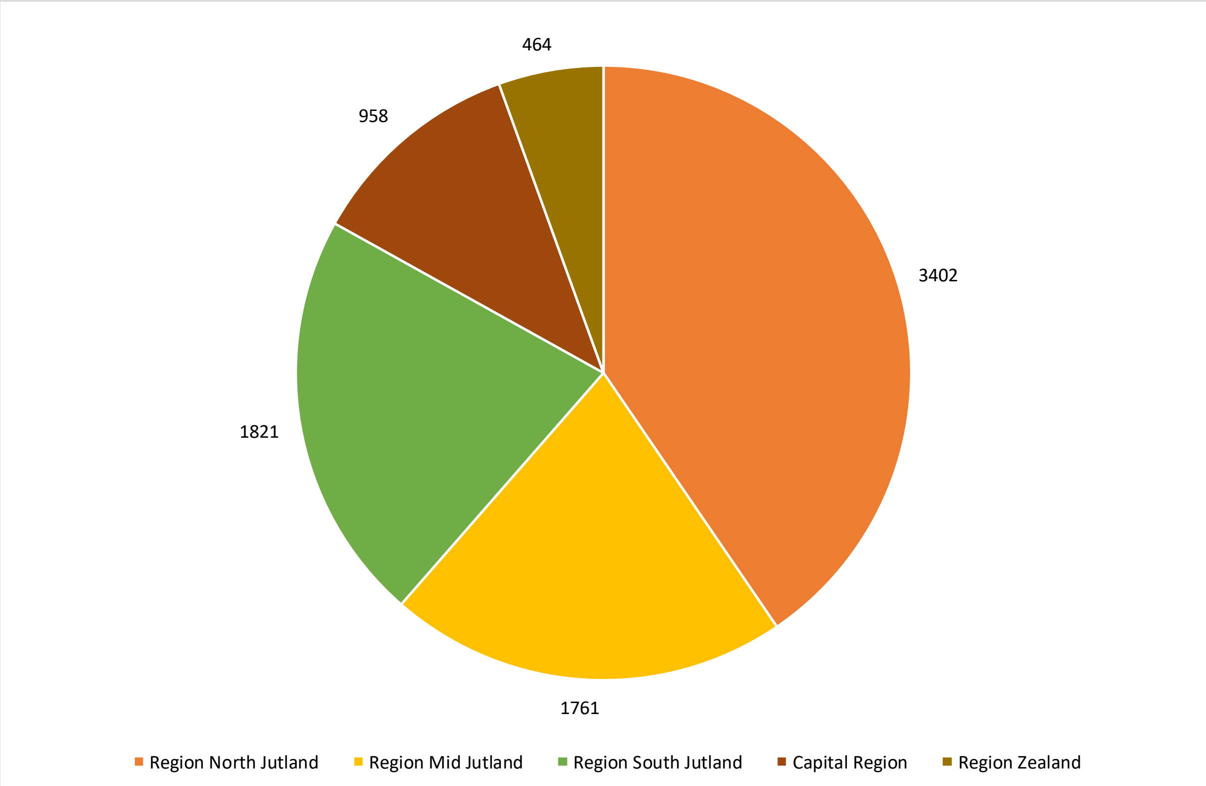


Figure 13-3 Number of people employed in the commercial fisheries sectors in Denmark in 2013 distributed on Regions[7]. Source: Danish Fisheries Agency, 2014.

Commercial fishery is of importance in Jutland, especially in North Jutland (Figure 13-3). Thus, 83% of the total employment in the fishing sector are resident in Region North Jutland, Region Mid Jutland and Region South Jutland, while only 17% are resident in Capital Region and Region Zealand. In case of an oil spill, the commercial fisheries and fishing sector located at the west coast of Jutland, especially North Jutland, is at risk of being economically affected.

13.3.3 Employment in the tourism sector

The tourism industry in Denmark creates about 160,000 jobs, corresponding to 6% of all jobs in Denmark (VisitDenmark, 2019). A major part of these jobs is related to the gastronomical sector and to the retail sector (VisitDenmark, 2019). 38% of the jobs are created in the Capital Region, 20% in Region South Jutland, 18% in Region Mid Jutland, 11% in Region North Jutland, and 10% in Region Zealand.

The gross value added from the tourism industry was 45 billion DDK in 2012 corresponding to 2.4% of the total gross value added in Denmark (VisitDenmark, 2019).

The turnover from coastal and natural tourism accounted for approximately half of the tourist sector's total revenue in 2017 (48%)[8]. Most of this (69%) was generated west of the Great Belt.

[7] The sectors correspond to the sectors mentioned in Figure 13-2.

[8] Source: Det Nationale Turismeforum, 2019: Statusanalyse af turismens udvikling og konkurrenceevne. November 2019

13.4 Derived consequences of environmental impacts

13.4.1 Changes in fish catches due to prohibition zones

The focus in this EIA is on the additional environmental impacts resulting from the Hejre tie-back to South Arne development project compared to the environmental impacts already described and approved with the approved Hejre Legacy EIA from 2011.

The assessment of the impact of the prohibition zones will therefore only include a calculation of the impact of a 200 m safety zone on either side of the new 30 km pipeline from South Arne to Hejre. Fishing and anchoring will be prohibited in the safety zone. The zone will only comprise of 11.2 km² and therefore only affecting a small area in relation to the 41F3 and 41F4.

The overall potential loss due to the safety zone around the new pipeline is very small compared to the surrounding fishing areas, which again comprise 0.1 and 0.6 percent of the catches in the North Sea. Compared to the total fish catches in the North Sea the decline in fish cashes due to the Hejre tie-back to South Arne development project is therefore negligible.

13.4.2 Changes in fishing tourism due to prohibition zones

The prohibition zones will be established at approximately 300 km offshore from the Danish west coast. Tourism is related to the nearshore (and onshore) areas, and thus no impacts of restricted zones on tourism are expected.

13.4.3 Changes in fishing industry and tourism due to accidental oil spill and gas escape

Blowout and rupture of pipelines causing discharge and dispersal of oil are extremely rare events. However, in case of a blowout or rupture, wide reaching and severe impacts on the marine environment may occur (See Chapter 11).

When evaluating the potential socio-economic consequences of oil spills and gas escape, the following sectors can be expected to be affected:

- The commercial fisheries, which consists of fishermen and businesses that are indirectly linked to the fishing industry. Two types of fisheries are relevant for the analysis: deep-sea fishery and coastal fishery. For the deep-sea fishery, spawning areas can be affected. For coastal fishery, shallow waters, fjords, bays and beaches can be affected during and following an oil spill.

- Fish farms along the coastal areas and interconnected businesses, which can be affected in the same manner as businesses, involved in coastal fishery.

- Tourism businesses along the coast, which can be affected by oil spills that reaches the shore or shallow waters.

- The personnel working on the platform is in risk of being injured or lose their life if gas escape occurs in connection with a blowout if they are not evacuated in due time.

In Chapter 11 – Environmental impacts of an oil release during a blowout incident – it is concluded that:

- an oil blowout at Hejre will not measurably affect the amount of fish eggs and larvae in the North Sea.

- the risk of oil stranding on coasts is negligible, the probability generally being < 1%. However, the probability along the Norwegian coast has been calculated at 1-5%.
- gas escape in connection with a blowout at Hejre might cause severe damages and mass mortality on zooplankton, benthic fauna and fish within the small, affected area. In the case personnel are not evacuated in due time, injuries or loss of lives of personnel may occur.
- the risk of oil spill or gas escape in connection with rupture of pipelines is minor as the system will close within a minute in case of pressure drop.

Thus, it can be concluded that it is unlikely that a potential oil spill or gas escape will affect the commercial fishery or the tourism sector.

13.4.4 Changes in employment

The oil and gas sector employed approximately 14,400 persons in Denmark in 2015 (Region Syddanmark, 2017). An analysis from 2012 (Quartz+co, 2012) found that out of 15,000 employed in the oil and gas sector approximately 1,700 employees were directly employed at the oil companies. This means that when one person is employed in the oil and gas sector, approximately 8 jobs are created in related industries.

The Hejre tie-back to South Arne development project is expected to be unmanned resulting in fever persons employed overall than in Hejre Legacy. Thus, the Hejre tie-back to South Arne development project will, all other things being equal, result in a negative impact on jobs relative to the Hejre Legacy.

The overall impact on employment from activities at the Hejre project is assessed to be negative compared to the Hejre Legacy.

13.4.5 Changes in tax revenue

The tax revenue from the Hejre tie-back to South Arne development project has not been quantified, but the tax revenue to the state of Denmark from oil and gas activities has historically been significant and include tax on hydrocarbon (52%) and corporate income tax (25%) (Danish Energy Agency).

State revenue from hydrocarbon production in the North Sea aggregated about 514 DKK billion in 2018 prices in the period 1972-2018. The total state revenue for 2018 has been calculated at 8,4 billion DKK (Danish Energy Agency, 2020). The overall impact on tax revenue from activities at the Hejre tie-back to South Arne development project is assessed to be positive, but less than the level for the Hejre Legacy as the resources estimated in the Hejre legacy was 40 percent larger than today.

13.5 Other consequences

Other consequences include potential impacts from noise, light, discharges and air emissions. As most of the activities take place more than 250 km from the coast, they will typically not affect neither the population along the coast nor the fishery industry in total.

13.5.1 Consequences of discharges

The clean-up and completion of wells can lead to

- Discharge of cuttings and drilling mud solids (water-based mud)
- Discharge of chemicals (chemicals from drilling mud, cementing, completion, rig utility and pressure testing)

- Discharge of treated sewage from the rig

None of the discharges are expected to result in persistent socio-economic effects. Oil-based muds and cuttings will not be discharged to sea but will be collected and sent to shore for recycling and further treatment or possible re-injected in dedicated cutting injection well.

13.5.2 Consequences of underwater noise

Several of the construction activities in connection with the Hejre tie-back to South Arne will generate underwater noise (Cf. chapter 9.7)

It is assessed that the environmental risks related to underwater noise generated during construction, commissioning and decommissioning is negligible (ref. chapter 8). In line with this, it is expected that the activities will not result in persistent socio-economic effects.

13.5.3 Consequences of artificial light

The drilling rig will be illuminated during the dark hours and the flaring during will produce a horizontal flame, that causes substantial light emissions. In clear weather, this flame may be visual from up to 10 km from the platform and be stronger at night than during the day.

Due to the distance and the assessment of the environmental risk, it is assessed that the artificial light will not result in socio-economic impacts.

13.5.4 Consequences of atmospheric emissions

Air emissions are created during the construction and production phases, and can be traced to multiple sources, among which are:

- Emissions from energy production and compressors
- Emissions from transport activities
- Emissions from flaring
- Emissions from maintenance activities.

However, most of the emissions take place more than 250 km from the coast and will not affect neither the population along the coast nor the fishery industry in total.

14. Cumulative effects assessment

Cumulative effects are the combined effects of projects or ongoing activities within a region.

Potential cumulative effects from the re-development of Hejre fall in two categories. Impacts from construction and operation of Hejre may interact with impacts from other oil and gas activities, and impacts from other activities such as wind farms, cable and pipeline installation and fishery and shipping in the region.

The assessment of potential cumulative effects from the re-development of Hejre is based on the strategic environmental assessment for the project area carried out in 2012 (Danish Energy Agency, 2012) and the technical report from DCE on the human uses, pressures and impacts in the eastern North Sea (Andersen et al., 2013) and information from DEA.

In addition to the above-mentioned references the DEA has appointed several areas for future wind farms (reservation of additional areas for national tendering of offshore wind farms according to the Energy agreement dated 29 June 2018. Reservation dated 28 August 2019). These areas are although closer to the coastal area about 100 km from the area with oil and gas installations, so no cumulative effects are expected.

EU has appointed a number of cross border infrastructure projects that links the energy systems of EU countries. The projects are typically oil or gas pipelines or cables. The list of these projects is published regularly on an EU homepage (https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest). These types of projects can have some environmental impact as underwater noise, sediment spill and discharge of chemicals during construction but no impacts are expected during normal operation.

Potential cumulative effects from Hejre have a low likelihood to occur during the production phase, with emission to air and as closest platform is around 25 km from Hejre, as mentioned earlier produced water is handled from the host (South Arne).

At the South Arne area, discharges of produced water are not likely to have potential cumulative effects as the distance to other platforms with similar discharges are too far to influence each other.

14.1 Cumulative effects with offshore energy related activities

Monitoring surveys have been carried out around Danish platforms in the North Sea for more than 20 years. Results from these surveys show that the impacts of a platform on the physical environment and biological communities reaches no further than 2 km from the platform. Hence, the installations at Harald and Trym do not impact the Hejre field during normal operation.

Other temporary impacts such as noise generation and chemical discharges during construction of installations and drilling of wells can possibly have an impact further away from the source. INEOS Energy Denmark is not aware of any planned activities at Harald and Trym which has the potential to cause impacts at larger distances (more than 2 km from the platform) during the construction phase of the Hejre tie-back.

INEOS Energy Denmark is planning to drill two Solsort wells from South Arne. The drilling will commence in 2023. However, since no drilling or other well-related activities will take place at South Arne in relation to the Hejre project, no cumulative impacts at South Arne from the construction phase of Hejre are foreseen.

Informed by Danish Energy Agency they are currently not evaluating any other applications for oil and gas installations or construction activities close to Hejre and/or South Arne, which can have cumulative effect on the Hejre project.

Cumulative effects from different environmental impacts from the same platform has not been evaluated since there are no foreseen overlapping activities such as workovers or other maintenance activities at either Hejre or South Arne. In regard to emissions to air and discharges to sea the rig emissions will contribute to both in the period of construction but only temporarily and no cumulative effects is expected since the emissions does not significantly affect air quality and no discharges from rig will be found at 250-5000 meters from discharge point (the latter at a time frame of approx. 12 hours).

A mapping of cumulative human pressures and impacts has been carried out for the North Sea (Andersen et al. 2013). The work combines a number of human activities with ecosystem components and presents three indices describing the intensity of human use, the magnitude of the resulting pressures and the potential for cumulative human impacts. The impact index (potential for cumulative human impacts) is shown in Figure 14-1. As it appears from the figure, the Hejre platform and South Arne is situated in an area of low risk of causing an impact in combination with other activities. The area to the southeast of the Hejre field, where the number of platforms is high, has a higher risk of cumulative effects.

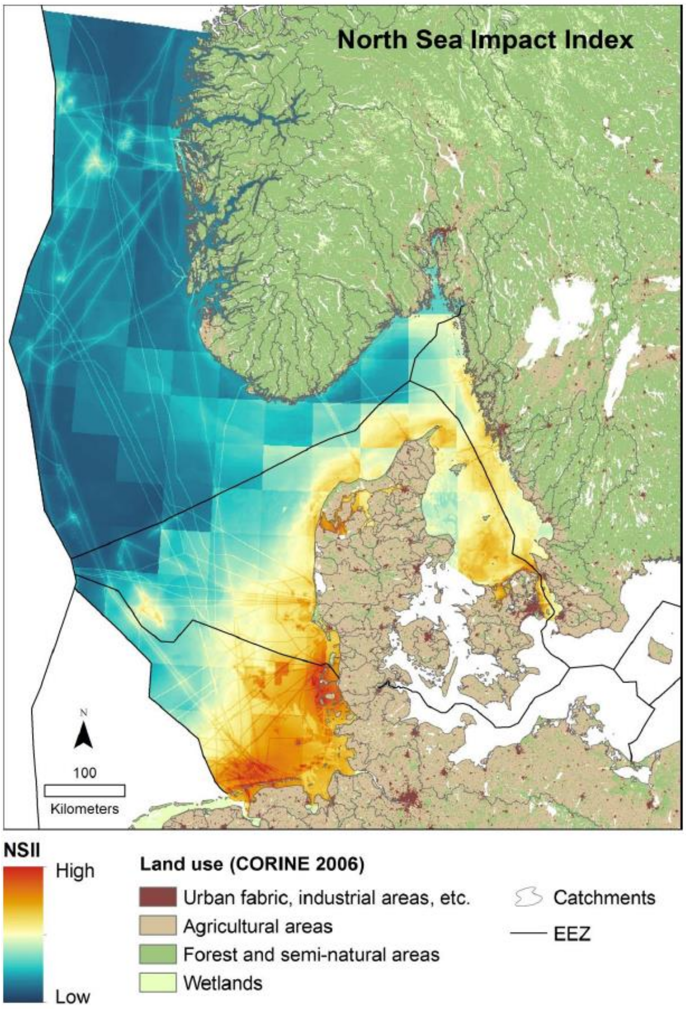


Figure 14-1 The North Sea Impact Index. From Andersen et al. (2013).

The DEA has prepared a map of the areas dedicated to windfarms as shown in Figure 14-2, as well as a proposal for energy islands see Figure 14-3.

According to the present stage of development of the above-mentioned plans it cannot be determined whether or not any cumulative effects will appear. The timing of the re-development of Hejre is anticipated to be earlier than the realisation of the energy island.

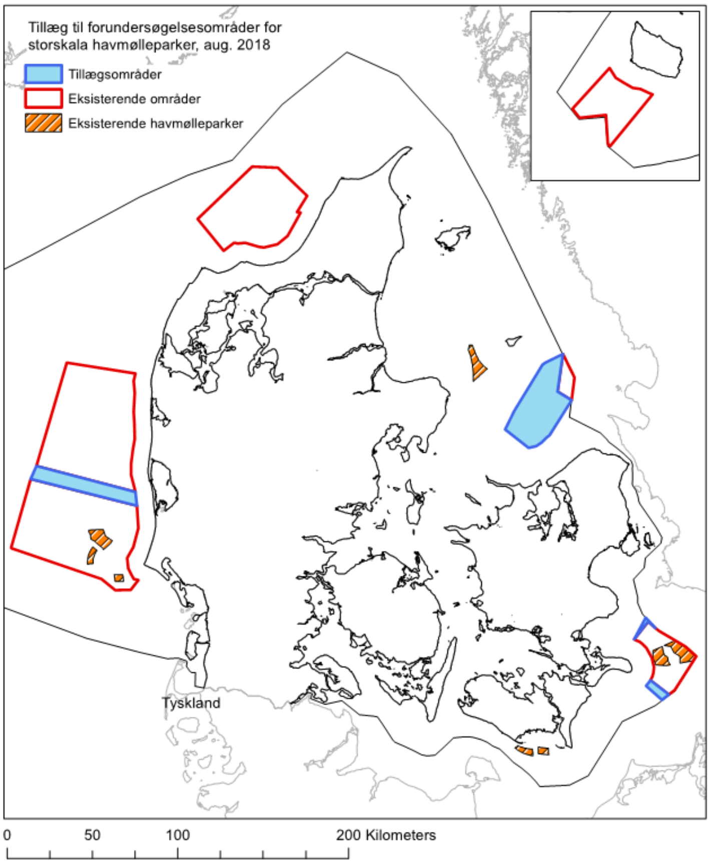


Figure 14-2 Areas appointed for wind farm projects

Figure 14-3 Areas in the North Sea designated for energy islands in Denmark's marine spatial plan, and the politically designated area for the location of the North Sea Energy Island. The geographical scope of the project will be refined in the final plan proposal for the North Sea Energy Island.

According to the present stage of development of the above-mentioned plans it cannot be determined whether or not any cumulative effects will appear. The timing of the re-development of Hejre is anticipated to be earlier than the realisation of the energy island.

In terms of designating areas for offshore energy project such as carbon capture and storage (CCS) and use of marine areas the marine spatial plan does not give any indications of any conflicting area planning in terms of the Hejre tie-back to South Arne development.

15. Cross-border impacts

An ESPOO notification has been prepared for the Hejre tie-back to South Arne concept including:

- Information about the Hejre re-development project introducing the main concept: Hejre tie-back to South Arne
- Information about the EIA process for the Hejre re-development project
- Information about the potential transboundary impact, which has been identified and to be described further in the EIA
- Invitation for consultation according to article 3 in the ESPOO Convention

The impacts in Table 15-1 have been identified as potential transboundary impacts.

The neighbouring countries has the possibility to comment to the topics to be included in the scoping of the environmental impact assessment regarding potential transboundary impacts and if relevant other topics that should be included in the environmental impact assessment.

The following impacts as shown in Table 15-1 can be seen as potentially transboundary and will therefore be elaborated in the ESPOO report. Other impacts can be included based on consultation with the neighbouring countries.

Table 15-1 Potential transboundary impacts

Potential transboundary impact	Receptor
Impacts of planned discharges to the sea during completion of wells and pressure testing of pipelines.	Fish eggs and larva, fish, plankton (pelagic organisms)
Impacts of planned discharges to the sea (produced water and production chemicals).	Fish, plankton (pelagic organisms)
Impacts of accidental spills and blowout events.	Fish, marine mammals, birds, ecosystems, tourism
Impact of air emissions during construction, production and decommissioning phases.	Air quality and climate

16. Natura-2000 screening

16.1 Potential impacts

The Hejre re-development project must meet the requirements of a Natura 2000 screening set by Consolidated Act No. 2091 of 12/11/2021 on identification and administration of international conservation areas and protection of species. It is noted that the project also complies with the Executive Order no. 1050 of 27/06/2022 on offshore impact assessment (§4, 4). This chapter thus makes up the Natura 2000 screening.

The Natura 2000 screening examines the likely effects of the Hejre re-development project alone and in combination with other projects upon Natura 2000 sites. The screening includes a description of the legal framework, the basis of the designations and an assessment of the likely environmental impacts of the Hejre re-development project on Natura 2000 sites by referring to previous chapters. The following potential impacts on Natura 2000 sites and Annex IV species have been summarised in this chapter:

- Impacts of a major oil spill during an uncontrolled blowout (a detailed assessment in Chapter 11)
- Impact of underwater noise (detailed assessment can be found in Sections 0 and 10.6)

All species of cetaceans (whales, dolphins and porpoise) are listed in Annex IV in the Habitats Directive and are therefore strictly protected. A total of 23 different species of cetaceans have been observed in the North Sea, however only harbour porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhynchus albirostris*) and minke whale (*Balaenoptera acutorostrata*) are encountered regularly in the western part of the Danish sector of the North Sea. The harbour porpoise is the most abundant species in the North Sea and occur regularly in the project area (Section 6.8).

16.2 Objective and procedures

According to the EU Habitats Directive 92/43/EEC of the Council of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, projects are not allowed to significantly impact habitats or species that form the basis of a Natura 2000 designation. A Natura 2000 screening aim to assess if the project alone or together with other plans and projects is likely to have significant effects on Natura 2000 sites. The screening is based on existing data.

If the Natura 2000 screening shows that the project is likely to have a significant impact on a Natura 2000 site, an appropriate assessment must be conducted according to Article 6 of the Habitat Directive (Directive 92/43/EEC) implemented in Danish regulation as the Nature Protection Act (Consolidation act no. 1986 of 27/10/2021). In the appropriate assessment it is assessed if the project will adversely affect the integrity of the site. This is evaluated by assessing the implications for the conservation objectives of the sites. If a significant effect cannot be excluded, alternative solutions must be assessed. In the absence of alternatives, compensatory measures must be assessed (Figure 16-1).

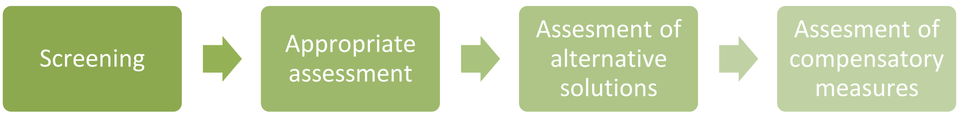


Figure 16-1 Stages of the Article 6 procedures in the assessment of a plan or a project potentially affecting a Natura 2000 site. The current stage of the Natura 2000 assessment of the Hejre re-development project is the screening phase.

16.3 Identification of Natura 2000-areas and the existing conditions

The Hejre Development is situated far from Danish designated Natura 2000 areas (Figure 16-2). The closest Natura 2000 area is the German Special Area of Conservation (SAC) *Doggerbank* (DE 1003-301) which is located approximately 49 km from Hejre. As an extension of this area is the Dutch NL 2008-001 *Doggerbank* and the UK0030352 *Dogger Bank* in the UK sector. In the unlikely event of a major oil spill during a blowout, Danish Natura 2000 areas may potentially also be affected.

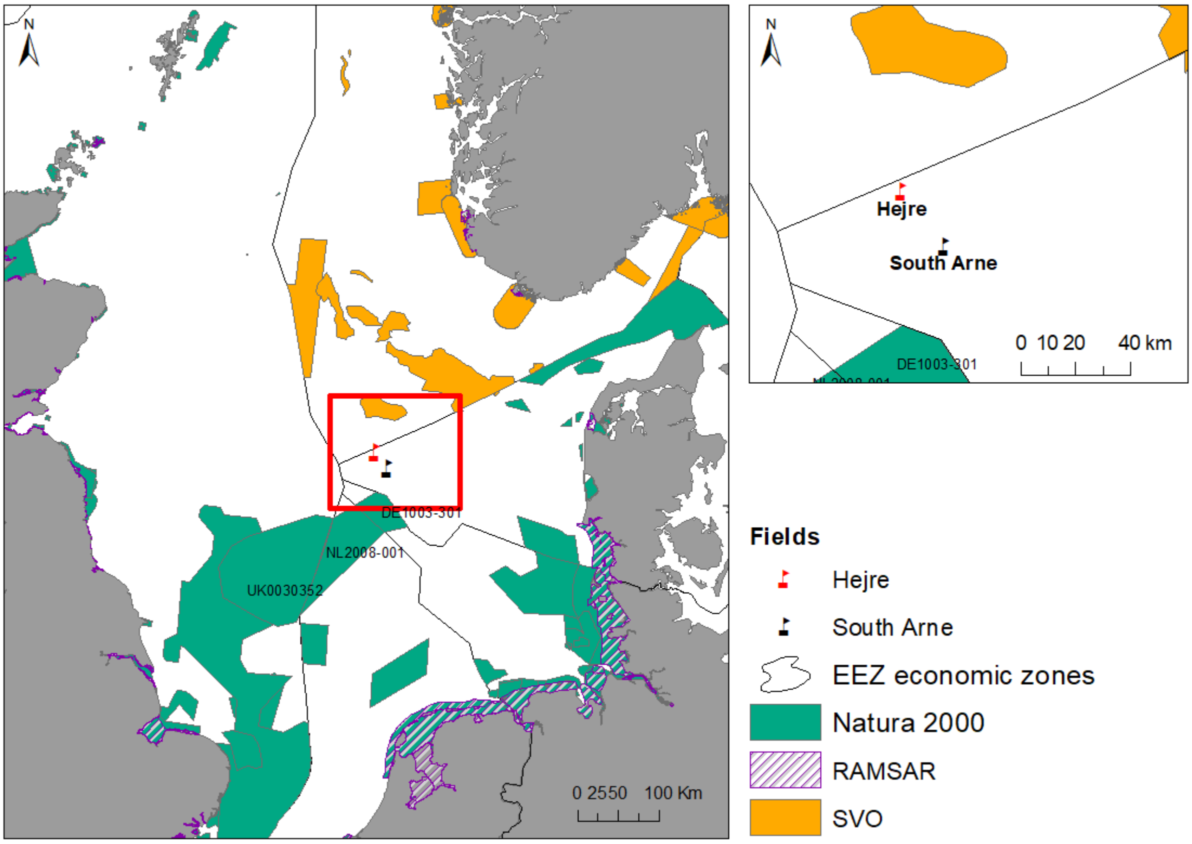


Figure 16-2 Location of natura 2000-areas (SACs) in the North Sea in addition to designated RAMSAR and SVO areas.

16.4 SAC DE 1003-301 Doggerbank

The German SAC DE 1003-301 *Doggerbank* is situated approximately 49 km south of Hejre Development. DE 1003-301 *Doggerbank* covers 1,624 km². and is situated on a receding flank of the Doggerbank (the tail end) with water depths increasing from 29 m to about 40 m.

16.4.1 Basis for designation

The basis for the designation of DE 1003-301 *Doggerbank* is:

- The Annex I habitat type 1110 *Sandbanks*, which are slightly covered by sea water all the time and
- The Annex II species 1351 *Harbour porpoise* and 1365 *Harbour seal*.

16.4.2 Status and conservation objectives Habitat type 1110 *Sandbanks*

More than 95% of the area of the SAC is sandbanks with mostly fine sands containing many shell fragments and is representative of the open offshore sublittoral zone (Bundesamt für Naturschutz 2008).

The sandbanks are without vegetation and are colonised by a community of benthic infauna that can be characterised as a Bathyporeia-Fabulina (Amphipod-Tellina) community, with the crustacean *Bathyporeia elegans* and the bristle worms *Spiophanes bombyx* and *Spio decorata* as characterising species. Other common species that may be encountered include the crustaceans *Bathyporeia nana*, *Scopelocheirus hopei* and *Megaluropus agilis*, the bristle worms *Anaitides lineata* and *Sigalion mathildae* and the bivalves *Dosinia sp*. and *Gari fervensis* (Bundesamt für Naturschutz 2008).

Some 38 species on the German Red Lists have so far been recorded in the Doggerbank area. (Bundesamt für Naturschutz 2008).

16.4.3 Status and conservation objectives 1351 *Harbour porpoise*

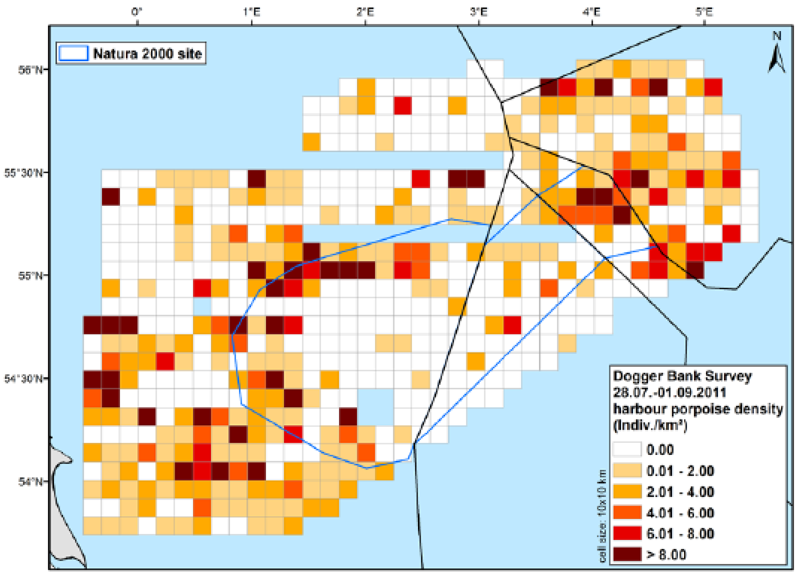
Harbour porpoise is the most abundant cetacean species in the North Sea. A clear seasonal pattern is apparent in the presence of harbour porpoises. A peak in numbers in coastal waters of the southern North Sea is reached between February and April and in late spring, a northward migration towards more offshore waters is observed (Haelters & Camphuysen 2010).

Harbour porpoises feed mostly on fish such as cod, whiting, mackerel, herring and sprat. They tend to be solitary foragers but do sometimes hunt in packs. The mating season is July-August. The gestation period typically lasts 10–11 months and most births occur in late spring and summer. Calves are weaned after 8–12 months.

Aerial surveys of the spatial distribution of marine mammals in the Doggerbank area was carried out in August-September 2013 and during summer 2011 (Geelhoed et al. 2014).

The surveys showed that the Doggerbank area constitutes an important habitat for harbour porpoises (*Phocoena phocoena*) in the North Sea. The 2013 survey resulted in an abundance estimate of ca. 45.000 individuals. This represents a substantial proportion of the abundance estimate for the North Sea and adjacent waters (i.e., ca. 12%).

The main aggregations were encountered outside the shallow parts of the Doggerbank. In 2011 and 2013 high densities of harbour porpoise was observed on the western/ south-western slope of the bank and the area between the bank and the UK coast. In 2011, high densities were also observed in the Danish sector north-east of the Doggerbank (Figure 16-3).



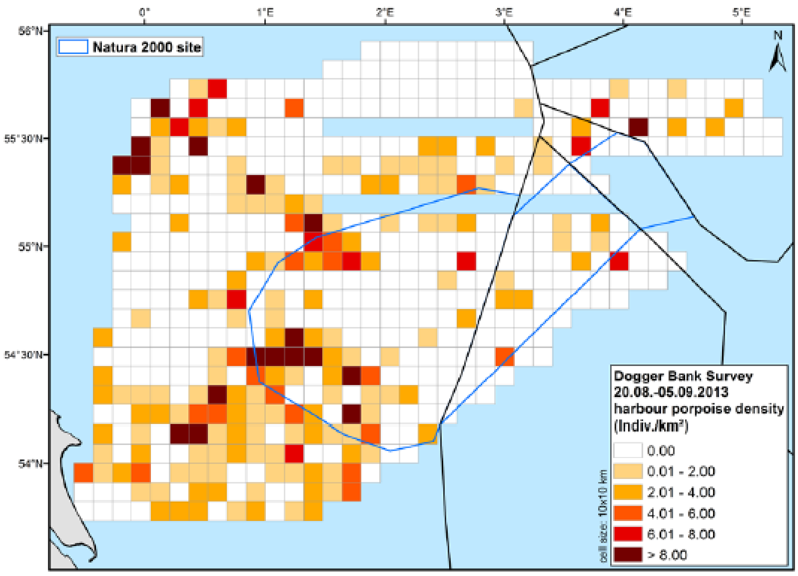


Figure 16-3 Spatial distribution of harbour porpoise density (number/km^2) in the Doggerbank area during 2011 (top) and 2013 (bottom. From Geelhoed et al. 2014).

16.4.4 Status and conservation objectives 1365 *Harbour seal*

Harbour seal (*Phoca vitulina*) is the only species of seal that has been observed regularly in the central part of the North Sea. Harbour seals are primarily coastal, depending on isolated and undisturbed land areas for resting, breeding and moulting (such as undisturbed islands, islets sandy beaches, reefs, skerries and sandbanks). They are gregarious animals and when not actively feeding, they will haul onto a terrestrial resting site. The harbour seal does not generally venture more than 20 kilometres offshore. However, radio-tagging experiments using satellite tracing have indicated that harbour seals may undertake foraging migrations far out into the North Sea from their core areas along the coast (Tougaard et al. 2003, Tougaard 2007). They are known to prey primarily on fish such as herring, mackerel, cod, whiting and flatfish, and occasionally upon shrimp, crabs, molluscs and squid. Females give birth once a year, with a gestation period of approximately nine months. Harbour seal breed in large numbers in the Wadden Sea. It is less common along the British coast.

16.5 SAC NL 2008-001 Doggerbank

16.5.1 Basis for Designation

The basis for the designation of NL 2008-001 *Doggerbank* is:

- The Annex I habitat type 1110 *Sandbanks*, which are slightly covered by sea water all the time and
- The Annex II species 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1364 *Grey seal*

There is currently no basis analysis and management plan for the SAC NL 2008-001 Doggerbank. The general conservation objective is to protect habitat types and species that are the basis for the designation.

16.5.2 Status of and conservation objectives of Habitat type 1110 *Sandbanks*

The habitat type covers approximately 4.700 km² which is almost all the designated Natura 2000 area. The area is shallow with water depth in the range 24-40 m. There is limited literature about the Dutch part of the Doggerbank, but its major characteristics is assumed to be comparable to the UK section of the bank. I.e., it is composed of fine sand with no vegetation.

16.5.3 Status and conservation objectives 1351 *Harbour porpoise*

The status of harbour porpoise (*Phocoena phocoena*) in the central North Sea is described in section 1.3.318.4.3 above. The total number of harbour porpoises on the Dutch Continental Shelf has been estimated at 46,580 individuals (Geelhoed 2017) (Figure 16-4). The highest abundance was observed off-shore, while the Dogger Bank was a less important habitat accounting less than 3 % of the total population in Dutch North Sea.

It has not been possible to find specific information on conservation objectives for harbour porpoise in NL 2008-001 *Doggerbank*.

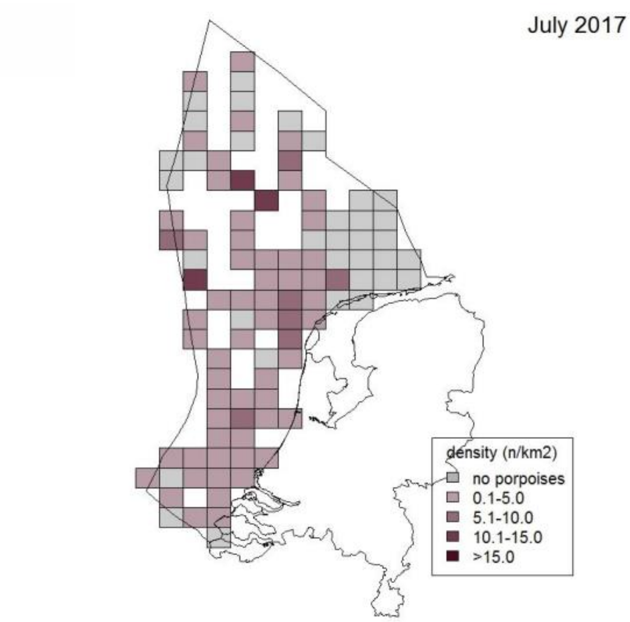


Figure 16-4 Density of Harbour porpoises in the Dutch North Sea. From Geelhoed et al. 2017.

16.5.4 Status and conservation objectives 1365 *Harbour seal*

There are no specific data on the status of harbour seal (*Phoca vitulina*) in NL 2008-001 Doggerbank. However, arial surveys were conducted in 2017 in the Dutch part of the North Sea where there were a few sightings. It is however assumed that they migrate to the area from the Wadden Sea to forage. The harbour seal population in the Dutch part of the North Sea is estimated to 6000 individuals (Nordseelocket). Of these most occur in the Wadden Sea.

16.5.5 Status and conservation objectives 1364 *Grey seal*

The Dutch North Sea zone is an important area for Grey seal in terms of foraging and migration. Seals spend most of their time near their breeding colonies (haul outs), but the grey seal may also migrate long distances to forage. Seals foraging at the Doggerbank are reported to belong to hauls from the Frisian Front and the Wadden Sea but may as well originate from the UK (Brasseur et al. 2010). The grey seal feeds on a wide variety of fish including sand eels, cod and other gadoids, flatfish, herring and skates. They may also take octopus and lobster.

16.6 SAC UK0030352 Doggerbank

16.6.1 Basis for Designation

The basis for the designation of UK0030352 *Doggerbank* is:

- The Annex I habitat type 1110 *Sandbanks* which are slightly covered by sea water all the time and
- The Annex II species 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1364 *Grey seal*

16.6.2 Status and conservation objectives Habitat type 1110 *Sandbanks*

The habitat type 1100 Sandbanks covers almost the entire UK Doggerbank. Large parts of the sandbanks are in the southern part covered by less than 20 m water. The bank is without vegetation and is moderately mobile with clean sandy sediments. The fauna of the banks is impacted by bottom trawling which has reduced the number of long lived or fragile organisms. The fauna is therefore dominated by robust short-lived invertebrates including polychaetes such as *Nephthys cirrosa*. The major parts of the bank are intact. Sandeels are an important prey resource found at the bank supporting a variety of species including fish, seabirds and cetacean (JNCC, 2017).

16.6.3 Status and conservation objectives 1351 *Harbour porpoise*

The Doggerbank is a core area for harbour porpoises and the population is well documented. In 2013 the Harbour porpoise population at Doggerbank was investigated by aerial surveys. The total population was estimated to 45,000 individuals. Of these more than half were observed on the slope of the bank in the UK sector of the Doggerbank (Geelhoed et al. 2014). In the shallow part of the banks, the density of harbour porpoises is generally lower.

16.6.4 Status and conservation objectives 1365 *Harbour seal*

Harbour seal (*Phoca vitulina*) is known to visit the Doggerbank (Geelhoed et al. 2014). There are no specific data on the population occurring on Doggerbank, but it is a common foraging visitor.

16.6.5 Status and conservation objectives 1364 *Grey seal*

The grey seal (*Halichoerus grypus*) breeds in several colonies on islands on the east coasts of Great Britain. Tagging experiments have indicated that grey seals breeding in Great Britain migrate long distances into the North Sea from their breeding colonies (McConnell et al. 1999) and migrate to the Doggerbank to forage. The grey seal feeds on a wide variety of fish including sand eels, cod and other gadoids, flatfish, herring and skates. They may also take octopus and lobster.

16.7 Potential impacts

The potential effects from construction, production and decommissioning of the Hejre field for this EIA Addendum have been assessed as a part of the environmental impact assessment in chapter 8 to chapter 11. The results of these assessments have been used as basis for the Natura 2000 preliminary appropriate assessment (Natura 2000 screening) of the Hejre re-development project.

The following potential impacts on Natura 2000 sites and Annex IV species have been assessed:

- Impacts of a major oil spill during an uncontrolled blowout
- Impacts of underwater noise

16.7.1 Impacts of oil spill during blowout

A blowout is the uncontrolled release of crude oil and/or natural gas from a well after pressure control systems have failed. The probability of a blowout occurring is very low but in case a blowout occurs, wide reaching and severe impacts on the marine environment may occur.

Impacts of a blowout at Hejre on Natura 2000 habitats and species have been assessed in Chapter 11. The assessment is based on modelling, using the OSCAR statistical oil drift model and known effects of oil on the habitats, and species that form the basis for the designating of the Natura 2000-areas.

The assessment concludes that risks of deleterious impacts of a blowout at Hejre on Natura 2000 areas and Annex IV species will be negligible because the probability that a blowout will occur is extremely small. In the unlikely event of a blowout and in a case where oil spill combat is not carried out, impacts on the conservation status of 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1365 *Grey seal* as well as the conservation status and integrity of 1110 *Sandbanks* in the nearest Natura 2000 areas (German and Dutch Natura 2000 areas south of Hejre) is assessed to be limited: Harbour porpoises, harbour seals and grey seals may be affected by oil, but it is assessed that only a tiny fraction of the populations the three species in the North Sea is likely to be affected.

It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the three species.

There may be a very small risk of sedimentation of oil on the habitat type 1110 *Sandbanks*, especially in the German area, thereby affecting the benthic infauna community. It is assessed that the effect is negligible.

The risk of deleterious impacts on marine species and habitats, which form the basis for designating the Danish Natura 2000-sites, is negligible.

In case of an uncontrolled blowout or other types of spills the INEOS Energy Denmark's oil spill contingency plan will be activated, which will reduce the spreading of oil and mitigate impacts of the spill.

16.7.2 Impacts of underwater noise

Underwater noise for the Hejre Development – Tie-back to South Arne is in general generated during the construction phase and the decommissioning phase:

- Construction phase: Noise from the rigs, installation of a new topside at Hejre, due to modifications to both Hejre and South Arne and pipe laying (including pre-installation survey). In addition, noise from machinery, propellers and thrusters of ships during the completion, modifications and installation operations. Finally, noise from drilling activities of the Lunde well, including noise from the rotating drill string, machinery and pumping systems.

- Decommissioning phase: Noise from vessels and cuttings of underwater structures.

Underwater noise has the potential to impact designated species as basis for designation of the Natura 2000 area, including Annex IV species. However, underwater noise caused by the Hejre Development project do not have the potential to impact habitat types as the basis for designation of the Natura 2000-area.

Impacts from underwater noise during the construction phase has been assessed to be negligible (section 8.4). Impulse noise will be limited to seismic surveys during the pre-installation survey of the pipeline route. Potential impacts are assessed to be short term and impact distances for potential TTS for harbour porpoises is limited to 205m (conservative assessment). The noise activities during completion, repair of well, installation of topside and laying of pipelines are not expected to exceed the threshold for triggering avoidance and other behavioural impacts of harbour porpoises. It is not expected that the project activities at Hejre and South Arne will exceed the sound exposure levels that are harmful to cetaceans and seals (section 8.4).

Impacts from underwater noise during the decommissioning phase has been assessed to be negligible (section 10.5). Noisy activities during decommissioning include broad band noise from heavy lift vessels and service vessels, which may cause harbour porpoises to react to the noise, however underwater noise from vessels is not expected to exceed the threshold for hearing damage. In addition to the noise from vessels there will potentially be underwater noise from diamond wire cuttings, although this is not expected to lead to hearing damage of marine mammals (section 10.5).

Based on the above considerations and assessments, underwater noise from the Hejre re-development will have insignificant impact on the conservation objectives of the habitat types and species in the Natura 2000 sites.

It is expected that the noise from vessels and cutting works potentially will scare cetaceans (Annex IV species) to safe distances from the working field. If noise work occurs, a marine mammal observer (MMO) can look for mammals in the vicinity of the area. If found beneficial, passive acoustic monitoring (PAM) equipment can be deployed to assist the MMO to detect marine mammals. It is noted that the use of MMO and PAM is required for the pre-installation survey according to 'Standardvilkår for forundersøgelser til havs'.

16.8 Conclusion

It is concluded that the Hejre tie-back to South Arne will not negatively affect the conservation status of habitats and species, for which potentially affected Natura 2000-sites have been designated as well as species listed on Annex IV of the EU Habitats directive (Directive 98/43EEC of 21 May 1992). Nor will the re-development affect the integrity of the areas negatively.

Based on the environmental impact assessment in chapter 8 to chapter 10 and using the criteria described in Chapter 7, it is assessed that the environmental risks related to physical disturbance of seabed, sediment disposal, presence of pipelines, discharge of produced water and chemicals, emissions to air, waste and artificial light is negligible or low. Since the nearest Natura 2000 area is 49 km away and since there is not documented negative impact on cetaceans (Annex IV species) from these operations, the abovementioned operations are not considered to potentially affect Natura 2000 sites or Annex IV species.

17. Danish Marine Strategy II

The EU Marine Strategy Framework Directive (MSFD) is put in place to protect the marine ecosystem and biodiversity upon which the health and marine-related economic and social activities depend.

To help EU countries achieve a good environmental status (GES), the directive sets out 11 illustrative qualitative descriptors. The descriptors D1, D4 and D6 are related to the existing conditions of the marine environment while descriptor D2, D3, D5-D11 are related to the impact on the marine environment from human activities.

According to the Danish Marine Strategy II (Ministry of Environment and Food 2019), which implement the MSFD, the most important impacts in the North Sea/Skagerrak are caused by these aspects: nutrients, non-indigenous species, fisheries, noise, contaminants, marine litter (micro plastic in sediment), shipping and physical modifications (Danish Marine Strategy II figure 19.6). Not all of these aspects are relevant for the general oil and gas production activities.

The most relevant and important descriptors for oil and gas production activities in general are D8 Contaminants, specifically for acute pollution events, and D11 Underwater noise (Ministry of Environment and Food 2019).

The EU Commission has defined criteria and methodological standards on good environmental status of marine waters (GES Commission Decision (EU) 2017/848 of 17 May 2017). The Ministry of Environment and Food has defined environmental targets for each descriptor, based on the criteria defined in the GES Decision. According to the Marine Strategy Act (Consolidation act no. 1161 of 25/11/2019, (§18), the Danish authorities may not issue approvals etc. which are in conflict with these environmental targets in addition to the programme of measures.

17.1 Potential impacts

The activities during construction, production and decommissioning may potentially affect the Marine Strategy Framework Directive's (MSFD) 11 descriptors for Good Environmental Status (GES). The project activities that may potentially affect GES are listed below (Table 17-1).

Table 17-1 Activities potentially affecting the MSFD's 11 descriptors of Good Environmental Status (GES).

Project phase	Activity
Construction	Vessel noise, noise from rig and installation of topside and pipelaying including pre-installation survey of pipeline route Artificial light Physical disturbance and damage of the seabed Spreading of sediment during pipelaying. Planned discharge of chemicals and treated sewage. Accidental spill and blow-out events Spreading of non-indigenous species through ballast water and marine fouling on vessels

Production phase	Establishment of fisheries exclusion zones and safety zones Discharge of produced water Discharge of production chemicals Accidental spill and blow-out events Spreading of non-indigenous species through ballast water and marine fouling on vessels
Decommissioning	Vessel noise, noise from rig and removal of installation during decommissioning Artificial light during decommissioning . Planned discharge of chemicals. Waste during decommissioning Air emissions

In the following sections the potential impacts are compared with the environmental targets from the Danish Marine Strategy II.

17.1.1 Descriptor 1 – Biodiversity

The environmental targets for descriptor 1 from the Danish Marine Strategy II for Biodiversity, including birds, marine mammals and fish are shown in Table 17-2. It is also stated if the descriptor is impacted by the Hejre to South Arne Development project.

Description of the status of birds, marine mammals and fish in the project area are described in Sections 6.6, 6.7 and 6.8. The environmental targets for descriptor 1 are described in Table 17-2.

Table 17-2 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 1 according to the Danish Marine Strategy II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Birds	1.1 Incidental by-catch of birds is at a level that does not threaten the species in the long term	Not applicable	The project does not engage in incidental by-catch of birds.

	1.2 Populations and habitats for birds are conserved and protected in accordance with objectives under the Birds Directive	Potential impacts include noise and light disturbances in addition to unplanned discharges/accidental spills during the construction, production and decommissioning phase. Potential impacts cause by noise and light disturbances are assessed to be either negligible or no impacts are expected (Section 8.7, 9.7 and 10.5). Accidental spills are assessed in Chapter 0.	Birds and the existing conditions are described in Section 6.7. The project area is not considered as important for seabirds and is not located within a bird protected area. Mitigating measures described in Section 19.6.
	1.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status and works to ensure that the status for biological diversity is in accordance hereto.	Not applicable	The oil and gas industry is not involved in the work with establishment of threshold values.
	1.4 More knowledge about by-catch of seabirds is collected pursuant to the relevant monitoring programmes.	Not applicable	The project do not engage in incidental by-catch of birds and is not engaged in monitoring of the same.
	1.5 Need for protection initiatives for HELCOM and OSPAR Red List species is assessed. If there are any Red List species that are endangered or not sufficiently protected, the Ministry of Environment and Food will assess specifically the need for further initiatives in collaboration with relevant ministries.	Not applicable	The oil and gas industry is not involved in the assessment of whether Red List species are sufficiently protected.
Marine mammals	1.6 Incidental by-catch of harbour porpoise is reduced as much as possible, and as a minimum to a level below 1.7% of the total population	Not applicable	The project is not engaged in activities that my cause incidental by-catch of harbour porpoises.
	1.7 Incidental by-catch of seals is at an adequately low level that does not threaten populations in the long term.	Not applicable	The project is not engaged in activities that my cause incidental by-catch of seals.
	1.8 Harbour porpoise, harbour seal and grey seal achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	Potential impacts include underwater noise during the construction phase and unplanned discharges/accidental spills. Potential impacts from underwater noise are assessed to be negligible (Section 0). Accidental spills are assessed in Chapter 0.	Mitigating measures described in Section 19.6.

	1.9 The Ministry of Environment and Food contributes to setting population-specific threshold values for by-catches of harbour porpoise in a regional context with a view to subsequently setting environmental targets for vulnerable populations of harbour porpoise.	Not applicable	The oil and gas industry is not involved in the work with establishment of threshold values.
	1.10 More knowledge about by-catches of marine mammals is collected pursuant to the relevant monitoring programmes.	Not applicable	The oil and gas industry is not involved in by-catches of marine mammals or relevant monitoring of the same.
Fish	1.11 The Ministry of Environment and Food carries out an analysis of by-catches of shark and ray in Danish marine areas, and the possibility of a DNA-based approach to determining species is investigated.	Not applicable	The oil and gas industry is not involved in this work.
	1.12 The Ministry of Environment and Food establishes a national indicator to evaluate the status of Danish fish that are not exploited commercially, and the opportunities to further develop regional indicators are investigated.	Not applicable	The oil and gas industry is not involved in this work.
	1.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status, and works to ensure that the status for biological diversity is in accordance hereto	Not applicable	The oil and gas industry is not involved in this work.
Pelagic habitats	1.13 Occurrence of plankton follows the long-term average.	Potential impacts on plankton include planned discharges to the sea during the production phase and unplanned discharges/accidental spills. Potential impact on plankton from planned discharges are assessed to be negligible (Section 9.4). Accidental spills are assessed in Chapter 0.	The primary production of plankton is generally higher in the coastal regions compared to offshore areas. The general conditions of plankton in the project area are described in section 6.5. Mitigating measures described in Section 19.6.
	1.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status, and works to ensure that the status for biological diversity is in accordance hereto	Not applicable	The oil and gas industry is not involved in the work with establishment of threshold values.
	1.14 The Ministry of Environment and Food is tracking developments and improving the knowledge base about plankton through monitoring.	Not applicable	The oil and gas industry is not involved in this work.

17.1.2 Descriptor 2 – Non-indigenous species (NIS)

The environmental targets for descriptor 2 are described in Table 17-3. Distribution of non-indigenous species (NIS) related to oil and gas installations are described in OGD's report from February 2017 "Descriptor-based review of 25 years of seabed monitoring data collected around Danish offshore oil and gas platforms" and included in the monitoring report from South Arne from 2021, see section 6.4. The environmental targets for descriptor 2 are described in Table 17-3.

Table 17-3 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 2 according to the Danish Marine Strategy II

	Goals	Impact from the Hejre to South Arne Development project	Comments
NIS	2.1 The number of new non-indigenous species introduced through ballast water, ship fouling and other relevant human activities is decreasing	Two species identified as NIS in the South Arne area. The rare occurrence and low abundance reported is not indicative of a well-established population considering that the four benthic NIS observed in the areas with oil and gas installations have been present in the North Sea coastal areas for several decades. Potential impacts from non-indigenous species are described in section 0. The environmental risk is assessed to be low.	Non-indigenous species are described in section 6.4. Mitigation measures described in section 0.
	2.2 The distribution of certain invasive species is, as far as possible, at a level so that significant adverse effects are stable or decreasing.	Platforms may be used as stepping-stones during a secondary dispersal of non-indigenous species. However, as the structures at Hejre and South Arne are already present, there is no additional risk to be evaluated for this EIA Addendum.	Non-indigenous species are described in section 6.4. Mitigation measures described in section 19.7.
	2.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status, and works to ensure that the number of new non-indigenous species and impacts from invasive species are in accordance hereto	Not applicable	The oil and gas industry is not involved in the work with establishment of threshold values.

17.1.3 Descriptor 3 – Commercially exploited fish stocks

The commercially exploited fish in the area are described in section 6.6. Most of the commercially exploited Norths Sea stocks of the typical fish species encountered in the project area are in good condition and are fished at a sustainable level. However, the cod stock in the North Sea is in a poor condition. The area around Hejre and South Arne are although not considered as a core area for cod. The environmental targets for descriptor 3 are described in Table 17-4.

Table 17-4 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 3 according to Danish Marine Strategy II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Commercially exploited fish stock	3.1 The number of commercially exploited fished stocks regulated pursuant to the MSY principles in the Common Fisheries Policy is increasing.	Not applicable	Descriptions of fish in the project area is described in section 8.10. Commercially exploited fish stocks are described in 8.10.3.
	3.2 Within the framework of the Common Fisheries Policy, fish mortality (F) is at levels that can ensure a maximum sustainable yield (Fmsy).	Potential impacts on fish include spreading of sediment from pipelaying, underwater noise during the construction phase and planned discharges/accidental spills. The impacts from spreading of sediment (section 0) and underwater noise (section 0) are both assessed to be negligible. Potential impact on fish from planned discharges are assessed to be negligible (Section 9.4). Accidental spills are assessed in Chapter 0.	Mitigating measures described in Section 19.6.
	3.3 Within the framework of the Common Fisheries Policy, spawning biomass (B) exceeds the level that can ensure a maximum sustainable yield (MSY Btrigger)	See 3.2	

17.1.4 Descriptor 4 – Food webs

Marine food webs can potentially be affected by physical disturbance of the seabed, underwater noise, artificial light, planned discharge of chemicals and unplanned oil spill (blowout). The environmental targets for descriptor 4 are described in Table 17-5.

Table 17-5 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 4 according to Danish Marine Strategy II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Food webs	4.1 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status and works to ensure that the anthropogenic impacts on the food web are in accordance hereto.	Not applicable	The oil and gas industry is not involved in the work with establishment of threshold values.

	4.2 The Ministry of Environment and Food contributes to regional knowledge and methodology development on marine food webs.	Not applicable	The seabed monitoring programme conducted around the oil and gas installations conducted every 3 years gives input to the knowledge of the benthic fauna.
	4.3 The Ministry of Environment and Food is tracking the development in the food web through monitoring the individual sub-elements of the web	Not applicable	The seabed monitoring programme conducted around the oil and gas installations conducted every 3 years gives input to the knowledge of the benthic fauna.

17.1.5 Descriptor 5 – Eutrophication

As described in the Danish Marine Strategy II, section 12 the loads related to eutrophication is mainly due to discharge from land-based activities. The environmental targets for descriptor 5 are described in Table 17-6.

Table 17-6 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 5 according to the MSDF II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Eutrophication	5.1 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status for the North Sea, including the Skagerrak, and works to ensure that anthropogenic eutrophication and its effects are in accordance hereto	Not applicable	The project has no impact on the eutrophication. The oil and gas industry is not involved in the work with establishment of threshold values.
	5.2 Danish inputs of nitrogen and phosphorus (TN, TP) comply with the maximum acceptable inputs stipulated under HELCOM.	Not applicable	The project has no impact on the eutrophication.
	5.3 Coastal waters: Target loads and needs for measures for fjords, estuaries and coastal waters determined in accordance with the Water Framework Directive are complied with. Targets and needs are described in the Danish river basin management plans	Not applicable	The project has no impact on the eutrophication. The project is not located in coastal waters.

17.1.6 Descriptor 6 – Sea Floor Integrity

The physical disturbance of the seafloor from oil and gas installation is limited as described in Table 13-3 in the Danish Marine Strategy II. The only impact from the Hejre to South Arne Development project on the seafloor will be during the pipelaying in addition to the rig activities for the well perforation and clean-up activities. It is acknowledged, that according to the Danish marine Strategy II Table 13.2 oil- and gas installations (platforms and pipelines) are viewed as physical loss of the seabed, however, as the pipeline between Hejre and South Arne is expected to be trenched and subsequently backfilled and the before mentioned rig is only temporary, this is viewed as physical disturbance of the seabed. The impact will thus be temporary. The environmental targets for descriptor 6 are described in Table 17-7.

Table 17-7 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 6 according to the Danish Marine Strategy II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Losses and physical impacts	6.1 Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status, and works to ensure that losses, physical disturbance and adverse effects on the sea floor are in accordance hereto.	Not applicable	The oil and gas industry is not involved in the work with establishment of threshold values.
	6.2 The knowledge base about the Danish sea floor, as well as the abundance and the location of the benthic habitats and their status, is improved pursuant to the monitoring programme (NOVANA)	Not applicable	The oil and gas industry is not involved in the NOVANA monitoring programme. The project activities will not impact NOVANA monitoring stations.
	6.3 Through regional work and the work in the EU, better understanding of the impacts on the sea-floor in relation to losses, disturbances and adverse effects is achieved.	Not applicable	The oil and gas industry is not involved in the regional work.
	6.4 In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority encourages assessment and reporting to the Danish Environmental Protection Agency (monitoring programme) of the extent of physical losses and physical disturbances of benthic broad habitat types.	The potential temporary impacts on the seabed integrity caused by the pipeline laying and the rig activities for well perforation and clean up activities are assessed to be negligible (section 0).	If required, the project will report the calculated area for physical disturbance of the seabed caused by the pipeline laying and rig activities to the Danish Environmental Protection Agency.
Seabed habitat types	6.5 The marine habitat types under the Habitats Directive achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km². The temporary impact from the pipeline laying and the rig activities of the physical disturbance on the seabed is limited.	The project area is not located within a Natura-2000 area.
	6.6 The northern Sound is designated as a marine protected area pursuant to the Marine Strategy Framework Directive, and new licences to extract mineral resources	Not applicable	The oil and gas industry is not involved in designation of the Northern Sound as a marine protected area.

	are stopped. This will not result in any changes in relation to the existing fisheries regulation.		
	6.7 The most important habitats contain the typical species and communities for Danish marine areas.	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km². This habitat is probably not viewed as "a most important habitat". The potential temporary impacts on the seabed and the associated species have been assessed as negligible (section 0). It is not expected that the project will impact this target.	
	6.8 When threshold values for losses, disturbances and adverse effects are established through co-operation at regional and Union level, the Ministry of Environment and Food will initiate a project to form the basis for establishing environment targets in accordance with the thresholds and good environmental status.	Not applicable	The oil and gas industry is not involved in the work with establishment of environmental targets.
	6.9 Need for protection initiatives for HELCOM and OSPAR Red List habitats is assessed. If there are any natural habitats on the Red Lists that are endangered or not sufficiently protected, the Ministry of Environment and Food will assess specifically the need for further initiatives in collaboration with relevant ministries.	Not applicable	The oil and gas industry is not involved in the assessment of whether Red List species are sufficiently protected.
	6.10 The need for additional marine protected areas or other initiatives in the Baltic Sea and the North Sea is assessed, and a similar assessment is subsequently carried out for the Danish Straits.	Not applicable	The oil and gas industry is not involved in the assessment for marine protected areas in the Baltic Sea or in the North Sea.

17.1.7 Descriptor 7 – Alteration of hydrographical conditions

The presence of the substructure of a rig may locally impact the hydrographical conditions. However, as the project does not introduce new substructures, no impacts are expected. Any potential impact on the hydrographical conditions will revert to existing conditions once the rig disappears. The environmental targets for descriptor 7 are described in Table 17-8.

Table 17-8 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 7 according to the Danish Marine Strategy II.

	Targets	Impact from the Hejre to South Arne Development project	Comments

Alteration of hydro-graphical conditions	7.1 Anthropogenic activities that are particularly associated with physical loss of the sea floor, and which cause permanent hydrographical changes only have local impacts on the sea floor and in the water column, and are designed to take account of the environment and what is technically possible and financially reasonable to prevent harmful effects on the seabed and in the water column.	The project will not alter hydrograph-ical conditions.	
	7.2 In connection with licensing off-shore activities requiring an environ-mental impact assessment (EIA), the approval authority is encourag-ing reporting to the Danish Environ-mental Protection Agency (monitor-ing programme) of hydrographical changes and the adverse effects of these.	The project will not alter hydrograph-ical conditions.	

17.1.8 Descriptor 8 – Contaminants

Contaminants may potentially arise from planned or unplanned discharges. The regular seabed monitoring performed every three years by the oil- and gas operators in the North Sea generally show a rather local impact if any. The environmental targets for descriptor 8 are described in Table 17-9.

Table 17-9 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 8 according to the Danish Marine Strategy II.

	Targets	**Impact from the Hejre to South Arne Development project**	**Comments**
Contaminants	8.1 Discharges of contaminants in the water, sediment and living or-ganisms do not lead to exceeding of the environmental quality standards applied in current legislation	Potential impacts include planned discharges in addition to unplanned discharges/accidental spills. According to the Danish Marine Strategy Directive II threshold val-ues are decided for PFOS, PBDE, Benz(A)pyrene and mercury. Only Benz(A)pyrene and mercury are present around the installations in very small concentrations. The val-ues can although not directly be compared as the thresholds are de-fined by concentrations in fish or mussels. For planned discharges the potential impact is assessed to negligible (section 9.3). Accidental spills are assessed in Chapter 0.	Mitigating measures de-scribed in Section 19.6. The laying of pipelines may potentially mobilise contaminants in the sedi-ment., However, as the levels of contaminants are relatively low and below thresholds (6.4.6), no im-pacts are expected.

	8.2 Emissions, discharges and losses of PBDE and mercury are ceased or phased out	See 8.1	
	8.3 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and works to ensure that the quantities of contaminants are in accordance here to.	Not applicable.	Information about chemicals used offshore is communicated to the Authorities as part of the discharge applications and permit reporting conditions.
	8.4 There is a gradual decrease in the levels of imposex/intersex in marine gastropods.	Not applicable.	This is a result of the ban of using TBT as antifouling. The oil and gas industry is not engaged in monitoring of imposex/intersex in marine gastropode.
	8.5 By 2021, a process has been carried out to trace the source of the most polluting substances which prevent meeting the environmental targets laid down for surface water bodies in the Water Framework Directive. If necessary, the relevant licences and permits will be revised as far as possible	Not applicable.	See 8.1
	8.6 The Ministry of Environment and Food is working to ensure that more indicators for contaminants are established	Not applicable.	See 8.1
	8.7 The Ministry of Environment and Food ensures increased coordination between policy areas/directives when new national environmental quality requirements are set for selected substances in matrices, where there is monitoring data.	Not applicable.	See 8.1
	8.8 The Ministry of Environment and Food is working to develop additional regional joint tests for biological impacts.	Not applicable.	See 8.1
	8.9 The spatial extent and duration of acute pollution events is gradually reduced as much as possible through prevention, monitoring and risk-based scaling of contingency and response facilities.	Accidental spills are assessed in Chapter 0. Acute pollution events are extremely rare events. The risk of accidental spill and blow-out is furthermore prevented through a number of mitigating measures	Mitigating measures described in Section 19.6.

	8.10 Adverse effects on marine mammals and birds from acute pollution events are prevented and minimised as much as possible. For example, this may be secured by means of floating booms as well as through contingency plans for marine mammals and birds injured in oil spills	See 8.9	
	8.11 Up to the next monitoring programme (2020), the Danish Environmental Protection Agency will examine how the adverse effects of the most significant pollution events can be monitored and registered in the specific cases	Not applicable.	The new monitoring programme has been issued in 2020.

17.1.9 Descriptor 9 – Contaminants in seafood and human consumption

The Hejre to South Arne Development project is situated in an area with low fishery intensity and as such the area is not considered as a core area for seafood. The environmental targets for descriptor 9 are described in Table 17-10.

Table 17-10 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 9 according to the Danish Marine Strategy II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Contaminants in seafood and human consumption	9.1 Emissions of contaminants generally do not lead to exceeding of the maximum residue levels applicable in the food legislation for seafood.	Potential impacts include planned discharges in addition to unplanned discharges/accidental spills. For planned discharges the potential impact is assessed to negligible (section 9.3). Accidental spills are assessed in Chapter 0.	Mitigating measures described in Section 19.6.
	9.2 Emissions of contaminants generally do not lead to exceeding of the maximum residue levels applicable in the food legislation for seafood.	See 9.1	
	9.3 The Danish Environmental Protection Agency is monitoring developments in relation to emissions of POPs (including dioxins) from wood-burning stoves to assess the need for further initiatives.	Not applicable.	The oil and gas industry do not emit POPs from wood-burning stoves.
	9.4 The Danish Environmental Protection Agency is gradually improving emission estimations of POPs into the air	Not applicable.	The oil and gas industry is not involved in emission estimations of POPs into the air.

	9.5 Danish Veterinary and Food Administration is inspecting concentrations of contaminants, particularly dioxins and PCBs to monitor developments in organisms at risk of containing high concentrations.	Not applicable.	The oil and gas industry in not involved in this inspection.

17.1.10 Descriptor 10 – Marine litter

All waste generated during construction, production and decommissioning will be transported to Esbjerg by vessel. The waste will be further sorted out to improve recycling, send for further treatment at approved waste treatment plants, send for combustion or for final disposal.

The environmental targets for descriptor 10 are described in Table 17-11.

Table 17-11 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 10 according to the Danish Marine Strategy II

	Targets	Impact from the Hejre to South Arne Development project	Comments
Marine litter	10.1 The amount of marine litter is reduced significantly to achieve the UN goal that marine litter is prevented and significantly reduced by 2025.	No impact as all waste is transported to shore. The potential impacts on waste generation during construction and production is assessed to be negligible (section 0 and 9.6).	
	10.2 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status, and works to ensure that the quantities of marine litter are in accordance hereto	Not applicable.	The oil and gas industry is not involved in the work with establishment of threshold values.
	10.3 Losses of fishing gear in Danish waters are prevented to achieve the UN goal that marine litter is prevented and significantly reduced by 2025	Not applicable.	The oil and gas industry is not involved in activities that result in losses of fishing gear.
	10.4 The Ministry of Environment and Food implements the National Plastics Action Plan and the associated Political Agreement on collaboration of 30 January 2019, with a view to improving recycling of plastic and reducing plastic litter and pollution from plastic litter	Not applicable.	The oil and gas industry is not involved int the implementation of a national plastics action plan.
	10.5 The Ministry of Environment and Food is working to develop indicators and measurement methods for microplastics in seabed sediments and the water column.	Not applicable.	The oil and gas industry is not involved in developing these indicators and measurements.

			The oil and gas industry will cooperate with authorities about the framework for the seabed monitoring programme taking place every 3 years.
	10.6 The Danish Fisheries Agency draws up an estimate of the amount of lost fishing gear in Danish marine areas up to 2020.	Not applicable.	The oil and gas industry is not involved in this estimate.
	10.7 The Ministry of Environment and Food prepares a catalogue of potential and targeted measures to prevent marine litter	Not applicable.	The oil and gas industry is not involved in preparation of this catalogue.

17.1.11 Descriptor 11 – Underwater noise

Underwater noise can be expected during the construction phase. The environmental targets for descriptor 11 are described in Table 17-12.

Table 17-12 Potential impacts from the Hejre to South Arne Development project on environmental targets for descriptor 11 according to the Danish Marine Strategy II

	Targets	**Impact from the Hejre to South Arne Development project**	**Comments**
Underwater noise	11.1 As far as possible, marine animals under the Habitats Directive are not exposed to impulse sound which leads to permanent hearing loss (PTS). The limit value for PTS is currently assessed as 200 and 190 dB re.1 uPa2s SEL for seals and harbour porpoise, respectively. The best knowledge currently available is on these species. However, it is likely that these limits will be revised as new knowledge on the area becomes available. The values are the sound-exposure level accumulated over two hours.	During construction it is expected that the majority of noise generated will be low frequency noise although impulse noise will be emitted during the pre-installation survey of the pipeline route. The potential impacts from noise is assessed to be negligible (section 0).	Mitigating measures described in Section 19.6.
	11.2 Anthropogenic activities causing impulse sound are planned such that direct adverse effects on vulnerable populations of marine animals from the spatial distribution, temporal extent, and levels of anthropogenic impulsive sound are avoided as far as possible and such that these effects are assessed not to have long-term adverse effects on population levels.	See 11.1	

	11.3 Activities by the authorities under the Ministry of Defence that cause impulse noise in the marine environment are, as far as possible, being assessed and adapted to reduce possible adverse effects on marine animals under the Habitats Directive, provided this does not conflict with national security or defence objectives. Defence Command Denmark applies current NATO standards when carrying out environmental assessments.	Not applicable.	The oil and gas industry is not involved in these activities.
	11.4 When conducting preliminary seismic studies, adequate remedial action is taken in accordance with the Danish Energy Agency's guidelines on standard terms and conditions for preliminary studies at sea.	Not applicable.	The preliminary studies are conducted according to the DEA guideline
	11.5 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and is working to ensure that the level of underwater noise is in accordance hereto.	Not applicable.	The oil and gas industry is not involved in the work with establishment of threshold values.
	11.6 In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority is encouraging reporting to the Danish Environmental Protection Agency (monitoring programme) of registrations of impulse noise.	Not applicable.	The project will report impulse noise if relevant.
	11.7 Through increased monitoring, the Ministry of Environment and Food is improving knowledge about the extent and levels of low-frequency noise in the Baltic Sea and the North Sea.	Not applicable.	The oil and gas industry is not involved in monitoring of low frequency noise.

Based on the assessment above and the summary prepared below (

Table 17-13) it is concluded, that the Hejre to South Arne Development project will not prevent or delay the achievements of good environmental status for each descriptor as defined by targets in the Danish Marine Strategy II.

Table 17-13 Potential impacts on the 11 descriptors given by the Marine Strategy Framework Directive is summarised below. The environmental risk of preventing or delaying good environmental status is assessed.

Descriptor	Assessment of potential impact
D1 Biodiversity	Potential impact on species and habitats include impacts from airborne and underwater noise, light, spreading of sediment, physical disturbance of seabed, planned discharge, accidental spill of oil and chemical and risk of blowout. The potential impacts are assessed either to be negligible or no impact The impact on the environmental targets for descriptor 1, biodiversity, will not prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D2 Non-indigenous species	International vessels can introduce non-indigenous species though marine fouling and discharge of ballast water. The risk of introduction of new non-indigenous species is considered low. Due to the low risk of a major impact on the environmental targets for descriptor 2, non-indigenous species, it is assessed that the project will not prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D3 Commercially exploited fish stocks	Commercially exploited fish stock can potentially be affected by physical disturbance, spreading of sediment, underwater noise, planned discharge of chemicals and unplanned oil spill (blowout). It is assessed that the potential risk of affecting fish stocks is negligible. The potential impacts on the environmental targets for descriptor 3, commercially exploited fish stocks, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D4 Marine food webs	Marine food webs can potentially be affected by physical disturbance of the seabed, spreading of sediment, underwater noise, artificial light, planned discharge of chemicals and unplanned oil spill (blowout). The potential impacts on the environmental targets for descriptor 4, Marine food web, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D5 Eutrophication	There will be no impact on descriptor 5, eutrophication and it is assessed that the project will not prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D6 Sea floor integrity	The seafloor integrity will be temporarily affected during pipelay due to physical disturbance of the seabed and by the rig activities for well perforation and clean up activities. The pipelines will be buried >1 m below the seabed and the integrity of the seabed is expected to recover few years after pipelay. It is assessed that the potential risk of affecting the sea floor integrity is negligible. The potential impacts on the environmental targets for descriptor 6, sea floor integrity, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D7 Alteration of hydrographical conditions	The hydrography may be impacted by the presence of the rig for well perforation and clean-up activities. The project will not alter hydrographical conditions. The potential impacts on the environmental targets for descriptor 7, alteration of hydrographical conditions, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.

D8 Contaminants (concentrations and species health)	Discharge of produced water and production chemicals will not exceed threshold values set in the Marine Strategy II. It is assessed that the potential risk of affecting the contaminants is negligible. Acute pollution events include accidental spill and blow-out. These are extremely rare events. The risk of accidental spill and blow-out is furthermore prevented through a number of mitigating measures. The potential impacts on the environmental targets for descriptor 8, contaminants, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D9 Contaminants in fish and other seafood for human consumption.	Measurable contaminants in fish and other seafood will only occur as a result of major oil spill. It is assessed that the potential risk of affecting the contaminants in fish and other seafood for human consumption is negligible. The potential impacts on the environmental targets for descriptor 9, contaminants in fish and other seafood for human consumption, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D10 Marine litter	Littering will be prohibited on the platform and all waste are collected, sorted and send to shore. It is assessed that the potential risk of affecting the marine litter is negligible. The potential impacts on the environmental targets for descriptor 10, marine litter, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.
D11 Underwater noise	During construction it is expected that the majority of noise generated will be low frequency noise although impulse noise will be emitted during the pre-installation survey of the pipeline. Noise levels will not exceed the thresholds for PTS set in the Marine Strategy II. It is assessed that the potential risk of affecting the underwater noise is negligible. The potential impacts on the environmental targets for descriptor 11, underwater noise, are assessed not to prevent or delay the achievement of good environmental status for this descriptor as defined by its targets.

It is noted, that eight protected areas under the Marine Strategy Framework Directive have been designated in the North Sea. However, as the project is not located within these areas and this protection regulates activities within the area itself but not activities outside the protected area (Ministry of Environment 2021), these protected areas are as such not relevant for the project.

The Danish Environmental Protection Agency (DEPA) has issued a monitoring programme specifically for the Marine Strategy Framework Directive (Ministry of Environment and Food 2020). Monitoring activities have been defined for each of the 11 descriptors. The Hejre to South Arne Development project is assessed not to impact any of the monitoring activities described in the monitoring programme (Figure 17-1).

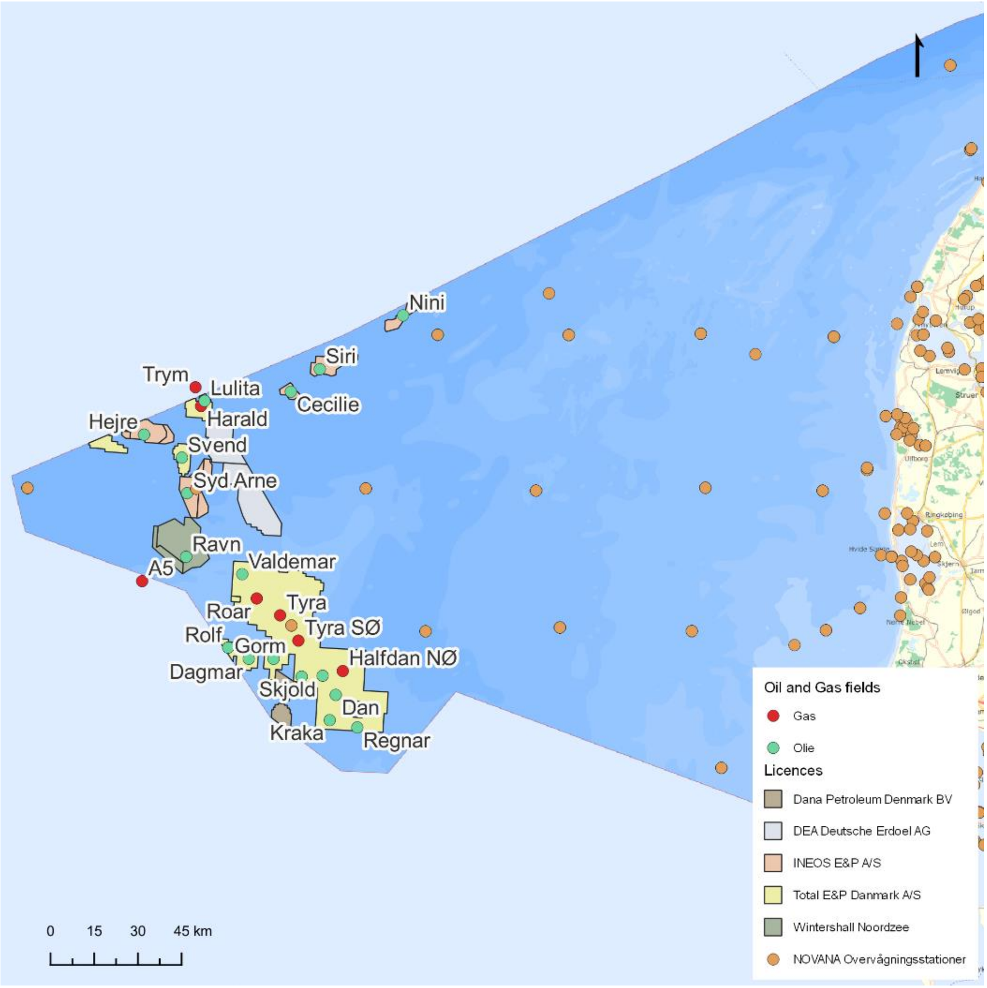


Figure 17-1 Location of NOVANA monitoring stations designated under the marine strategy framework directive.

Denmark's current programme of measures is from 2017 (Ministry of Environment and Food 2017), however a new programme of measures is expected to be released in 2022. Measures have been introduced for each of the 11 descriptors and include measures and efforts to be implemented to achieve or maintain a good environmental status. The Hejre to South Arne Development project is assessed not to impact any of the measures described in the programme of measures.

Multiple pressures may impact the marine environment. If these pressures enhance the overall impact beyond what each pressure would, they are called cumulative impacts. According to the Marine Strategy Framework Directive there is a requirement to assess the cumulative impacts, both from pressures within the same project (discussed below) and from pressures from different projects (discussed in section 14). When assessing cumulative impacts, aspects like the duration of the impact, severity of impact, location for the impact and its vulnerability must be considered.

During the construction phase, benthic infauna and fish may potentially be impacted simultaneously by spreading of sediment and discharges (planned and unplanned discharges/accidental spills) and marine mammals may be simultaneous impacted by underwater noise and unplanned discharges/accidental spills. These impacts are all classified as negligible. In addition, fish and marine mammals will swim away from potential impacts from spreading of sediment and noise impacts, thus reducing the risk of impacts from discharges. Finally, unplanned discharges/accidental spills occur very rarely. Based on these considerations it is concluded that the potential cumulative impacts will not prevent or delay the achievements of good environmental status for each descriptor in the Danish Marine Strategy II.

18. Monitoring programme

A monitoring programme is already in place for South Arne and a similar monitoring programme will be set up for Hejre in agreement with relevant authorities and based on legal requirements in legislation and permits.

18.1 Environmental monitoring programme – Production and drilling activities

The environmental monitoring programme is expected to include:

Daily monitoring of:

- Dispersed oil in produced water (mg/l)
- Volume of discharged produced water (m^3)
- Flaring volume (m^3)
- Volume of diesel or fuel gas used in the turbine (m^3)
- CO_2 emissions (ton)
- NO_X emissions (kg and mg NOx/m^3)

Quarterly monitoring of:

- Radioactive substances in discharged produced water
- Oil in water correlation curve

Yearly monitoring of:

- Dissolved oil in produced water
- Use of chemicals (kg)
- Control measurements for calibration of the NO_X emission prediction model

Based on the monitoring results the following are reported to authorities:

- Monthly report on oil in produced water and year to date oil discharge including explanation of any irregularities in the production, which has caused higher values
- Yearly prognosis for use and discharge of production chemicals, which is updated if a new chemical is approved and taken in to use
- Yearly reporting on emission of CO_2 and NO_X
- Use and discharge of drilling chemicals if drilling has taken place
- Amount of NORM stored onshore
- In addition to the monitoring described monthly information about the waste produced at the installation and handled onshore is generated by the waste handling company.

18.2 Evaluation of environmental risk of discharges to sea

A risk-based approach for produced water management has been developed and agreed between the OSPAR contracting parties. An OSPAR guideline has been prepared based on the OSPAR 2012/5 Recommendation. The guideline describes a procedure, which is adopted in Denmark as shown in Figure 18-1. below. The substance-based approach is required for all installations with discharge of produced water. New installations like Hejre should prepare a substance-based risk assessment within the first half year of production. Since no discharges will take place at Hejre, the risk assessment for South Arne will be updated instead.

The impacts from the discharge of produced water are calculated based on the following input:

- Location and release depth of the discharge point
- Produced water rate
- Reinjection rate
- Produced water composition based on:
- Composition of the oil based on samples
- Concentration and toxicologic data of added chemicals
- A 3-dimensional hydraulic model
- Predicted No Effect Level (PNEC) for both oil and added chemicals

Based on the input the concentrations of oil and added chemicals are calculated and compared with PNEC. The calculated impact on the surrounding marine environment is illustrated Figure 18-1.

Based on the PEC/PNEC, the environmental risk is calculated for a predefined volume of water. The resulting EIF (Environmental Impact Factor) is an expression of the risk level from discharge of the produced water. Calculation of EIF is based on a combination of the calculated concentrations and the sensitivities of the species represented in the area. In Denmark it is decided that the EIF of 10 or below is acceptable and no mitigating actions are required. EIF calculations must be made at least every 5 years. The latest EIF calculation for South Arne is from 2022 based on production and chemical data from 2021. The EIF is well below 10 and mitigating actions have not been required. EIF is low at South Arne due to the high produced water reinjection rate limiting the discharge to sea.

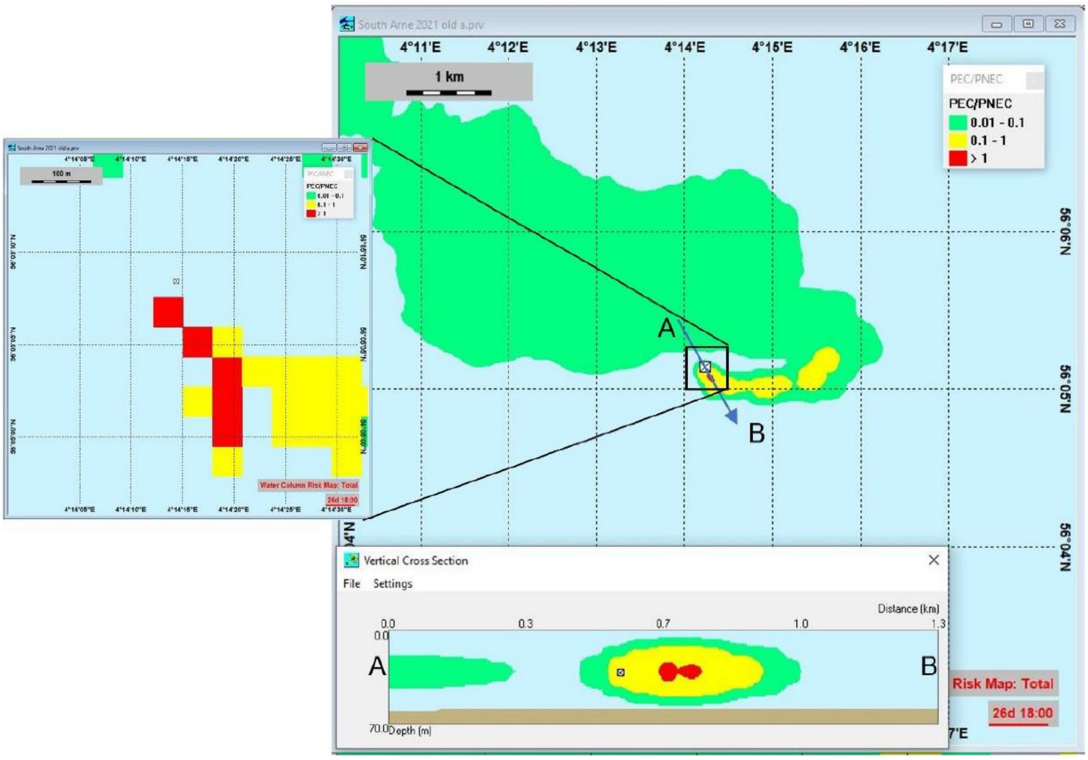


Figure 18-1 Example of a PEC/PNEC snapshot calculation of risk for a worst-case scenario from South Arne in the report for 2021 (NORCE, 2022).

The overall EIF and the % contribution to EIF from each component in the produced water is shown in the figure below.

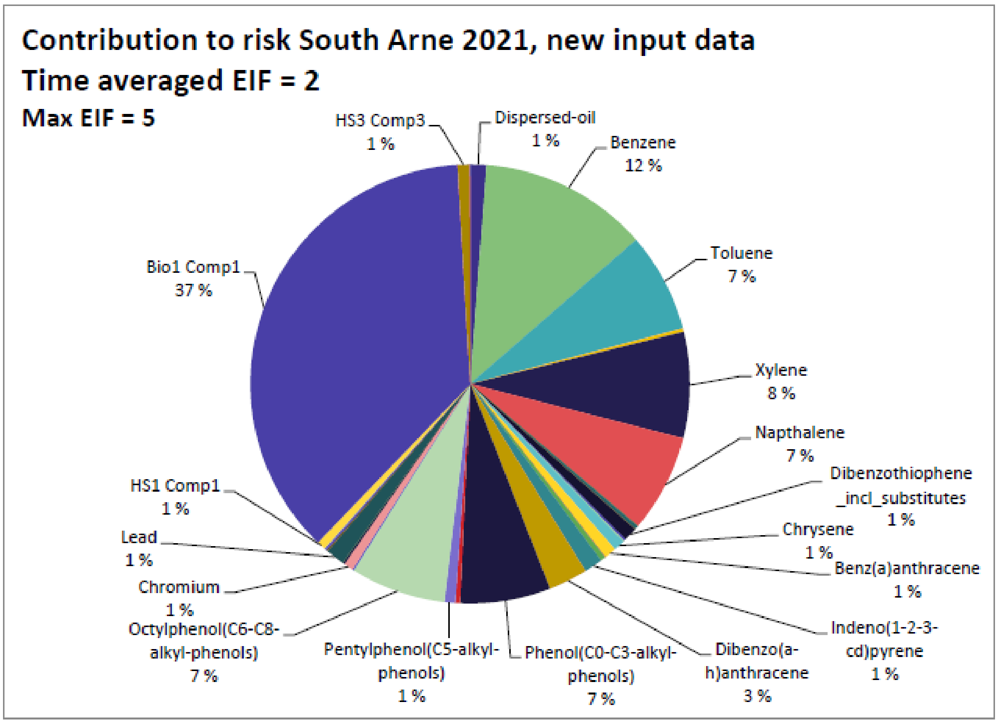


Figure 18-2 Contribution to the risk from different components in the produced water.

The information makes it possible to evaluate which components to look at to minimize the overall risk from discharge of produced water. As can be seen from Figure 18-2 almost 2/3 of the environmental risk can be assigned to naturally occurring components and about 1/3 can be assigned to added chemicals. At South Arne it is evident that a component in one of the biocides (Bio1_Comp1) constitute the majority of the environmental risk (37%).

18.3 Seabed monitoring

A monitoring programme for the Danish part of the North Sea is agreed with the Danish Environmental Protection Agency including monitoring of the environmental status of the seabed around the Danish installations.

The survey takes place every third year. The Danish operators and DEPA agree on the installations to be included in the specific surveys. The latest survey at South Arne took place in 2021.

In addition to that a baseline survey is carried out for all installations before start-up of production. Baseline surveys has both been carried out for South Arne (2021) and Hejre (2013).

19. Project design and impact mitigation

19.1 General operations

In general, a range of parameters are applied through INEOS's general environmental management system including proper working procedures to minimize the environmental impact from operation, using BAT and BEP (best available technology and best environmental practice) in the process of selecting the technical solutions. Also, it is considered a general INEOS practice to have proper contingency plans in place with established working procedures to minimize the effects of incidents or to effectively collect spills, should an incident happen.

INEOS also systematically register and analyse incidents and near-miss events to prevent unintended environmental impact in the future.

In the following is a brief description of how and which project adaptations are applied. The adaptations are through environmental management procedures conducted generally by INEOS in relation to the re-development of Hejre and other installations owned by INEOS and the need for specific mitigating measures are considered for the current tie-back project.

19.2 QHSE Policy

INEOS systematically works on reducing the environmental impact of its offshore activities. This has the following influence on a project like the re-development of Hejre:

- Continuous work on reducing the project's impact on the environment from an overall perspective
- Continuous and systematic work on reducing the use and discharge of chemicals
- Implementation of working procedures for storage of chemicals at the platform to reduce the risk of incidents and spills
- Analysis and registration of incidents and near-miss events to prevent unintended environmental impact in the future
- The principles of BAT and BEP (best available technology and best environmental practice) are used in the process of selecting the technical solutions
- The Hejre platform will be comprised by INEOS's oil spill contingency plan with established working procedures to minimise the effects of incidents or to effectively collect spills, should an incident happen.
- INEOS Energy Denmark works in cooperation with operators of spill response equipment on emergency response agreements and has agreements with other offshore operators (national as well as international via Operators Co-operative Emergency Service) for mutual assistance in case of major offshore accidents as described in Chapter 11.4.

19.3 Operational excellence

Some of the most important factors in relation to minimizing the environmental impacts as discharge to sea and emissions to air is a stable production, reduction of slugging and limiting the number of unplanned shutdowns.

A control system for South Arne is in place and a control system is planned for Hejre to be able to follow the production and the performance of the process systems in detail. Regular reviews are and will be performed of the process alarm settings among others to avoid unplanned shutdowns.

A yearly energy efficiency review is prepared evaluating ongoing initiatives and describing coming initiatives to be evaluated and if reasonable implemented.

19.4 Discharges to sea

During the Hejre tie-back project several BAT and BEP considerations have been performed in relation to the technical solutions to reduce the impact to the environment in relation to discharge to sea. A short description of the evaluations is described below.

19.4.1 Produced water reinjection

With the new concept all Hejre produced water will be exported to South Arne where there is a possibility for produced water reinjection.

19.4.2 Selection and use of chemicals

In general INEOS will select chemicals which are classified as green or yellow and only use chemicals approved for offshore use and discharge by the DEPA. INEOS is continuously seeking to reduce the amount of chemicals used thereby reducing the environmental impact.

19.4.3 Oil spill contingency plan

INEOS has established a legally binding cooperation arrangement with Total E&P Denmark for mutual assistance in case of an oil spill incident from one of the operator's production installations (INEOS Oil and Gas, 2022). This arrangement ensures that four containerized DESMI fast sweep oil collection systems will be available for containing and collecting spilled oil, depending on the magnitude of the spill. In case of blowout, further resources will be provided by Oil Spill Response Ltd (OSRL). In Denmark, the preferred response strategy is containment and recovery of spilled oil. Dispersant spraying may be used based on case-by-case approval from the DEPA. Details on the specific equipment available for the preferred response strategy (mechanical containment and recovery) for the three Tier responses are outlined in Chapter 11.4.

19.5 Emissions to air

The Hejre re-development concept eliminates the need for a turbine on Hejre since power will be supplied from South Arne. During developing of the Hejre tie-back to South Arne concept the following initiatives which can have an impact on emission to air have been evaluated. The initiatives are described in Table 19-1 below.

Table 19-1 Overview of initiatives having an impact on emissions to air

Initiative	Impact on emission to air
No gas turbine on Hejre	All power for Hejre is supplied from South Arne via power cable. There are low NOx turbines on South Arne, resulting in less air emissions compared to a non-low-NOx turbine on Hejre
Electrical driven crane installed instead of diesel driven	Using electricity produced from the turbine result in less emission to air compared to using diesel as fuel for the crane

Design for shut-in pressure and thus no flaring at Hejre	No flaring will occur on Hejre.
Air cooling fans instead of sea water cooling.	Seawater cooling will require pumps instead of cooling fans. Fans are less power consuming than pumps resulting in less emission to air.

In addition to the initiatives mentioned in the Table 19-1 above INEOS has reviewed the possibilities to reduce the number of supply boats and helicopter flights among others by bundling maintenance activities in campaigns and coordinating helicopter flights with other operators.

19.6 Underwater noise

For the pre-installation survey of the pipeline route, which is expected to account for the vast majority of impulse noise, the project will adhere to "Standard terms for preliminary investigations at sea" from the Danish Energy Agency (2018). These measures include a soft start procedure, a line shift procedure and a procedure for planned and un-planned interruption. Additionally trained marine mammal observers (MMO) will monitor the occurrence of marine mammals prior to the soft start procedure. There may also be deployed passive monitoring equipment (PAM) to assist the MMO in detecting marine mammals.

19.7 Non-indigenous species

The potential risk of introducing non-indigenous species that may be invasive is at the same level as for other vessels in Danish waters arriving from international waters. The vessels (including rig) are following IMO standards to prevent introduction of non-indigenous species though ballast water. In addition, some measures to mitigate against impacts from non-indigenous species available, including installation of a ballast water treatment system or vessel requirement of regular removal of marine fouling on the vessel's sides.

19.8 Impact mitigation

All potential impacts described in Chapters 8-17 are assessed to be either ‘insignificant’ or ‘low’, and there are therefore no proposed mitigation measures other than the above-mentioned operational practises and compliance with Danish legislation and standard terms for survey.

20. Data quality and limitations

20.1 The surrounding environment

The North Sea is a well-mapped area in terms of biological and physical parameters. The Hejre and South Arne fields are furthermore well surveyed.

20.1.1 Plankton

The plankton distribution and species composition in the North Sea is well known due to continuous surveying which has been ongoing for several years (OSPAR). The surveying is carried out from ships equipped with automated plankton samplers collecting samples from all over the North Sea.

20.1.2 Benthic infauna

The benthic infauna in the North Sea, including at the Hejre and South Arne fields, is well described in a comprehensive study of benthic fauna in the North Sea published by Reiss in 2010. These findings were confirmed by a baseline study carried out at Hejre during 2013 and by regular studies at South Arne and a reference station, the latest study being from 2021 (DONG 2013, INEOS 2022).

20.1.3 Fish

Fish distribution in the North Sea is well documented. ICES has an electronic atlas based on ICES' International Bottom Trawl Survey (IBTS), which has been carried out since 1970. The ICES database is linked to DATRAS; hence, maps show the most recent available data.

Distribution of fish spawning areas are based on published data available from ICES' Working Group 2 on North Sea cod and plaice egg surveys in the North Sea (WGEGGS2). The working group collects data on fish eggs and larvae of a large number of species in the North Sea. The data on spawning areas for sandeel is public available data from DTU aqua (van Deurs et al. 2019).

20.1.4 Birds

The seabird distribution in the North Sea is based on a substantial amount of reports and data, including data from the OBIS Seamap (2013) and the online database hosted by the Joint Nature Conservation Committee (JNCC) in the UK. Several European organisations have contributed with data to this database using standardized methods for bird counting primarily from ships.

20.1.5 Marine mammals

Data on the description of the distribution of marine mammals in the North Sea is considered adequate for this environmental impact assessment. Recently, several studies have investigated the distribution of seals and harbour porpoise in the North Sea (SCANs survey data, Geelhoed et al. 2014, Gilles et al. 2016, Sveegaard et al. 2018). Some of the studies were initiated as part of environmental impact assessments of offshore windfarms.

20.2 Environmental assessment of emissions to air

The assessment of emissions to air is attached with some uncertainties regarding the fuel consumption, emission factors, days of operation of vessels etc.

The emission factors that are used calculating emissions from vessels are generic emission factors and are comparable to the original Hejre Legacy. This also means, that the actual emission from vessels could be different if measuring the emissions.

Likewise, the fuel consumption are generic data, as the actual vessel fleet is not decided upon yet, and thus it could be other types of vessels used when actually carrying out the work. However, it is tries to use data for vessels that could be expected to be used.

The estimated days of operation are estimated and include weather delays and other unforeseen events. Thus, these can be expected to be conservative.

20.3 Environmental assessment of planned discharges

The assessment of planned discharges of chemicals is based on the concept and design of the Hejre tie-back to South Arne combined with experience from other oil and gas developments in the North Sea.

The assessment is based on:

- Discharge amounts of the different types of chemicals
- Discharge patterns
- Assessment of the ecotoxicity of the chemicals

The amount and type of chemicals to be used have been assessed based on best available estimates from INEOS Energy Denmark together with experience from previous projects and information from chemical suppliers. The specific chemicals to be used has not yet been settled, however, the environmental impact (colour code) will not increase. The assessment of the impacts from the discharge of chemicals is based on ecotoxicological data provided in the HOCNF documents for the chemicals or pre-screening documents and thus a conservative estimate for the toxicity is used, as the toxicity for the original chemicals are used as a worst-case scenario though some of the product will degrade into reaction products with a lower toxicity.

These data have been used in the modelling of impacts.

The dispersal modelling has been carried out using a model developed by COWI, based on the CHARM-model[9] developed by the industry, chemical suppliers and members of OSPAR. The dilution part of the model is a slightly modified version of the CHARM model, and estimations of risk indicators of negative environmental effects (PNEC and PEC/PNEC ratios) are calculated according to OSPAR guidelines. The dispersion model calculates PEC/PNEC ratios in up to 5000 meters from the discharge point.

By the use of the dilution model, the distance at which the chemical will impact the pelagic environment may be calculated. Rapid dilution of the discharges and biodegradation in the water column is ignored.

The distance at which the chemical will impact the benthic environment is calculated under the assumption that the sedimenting particles settle evenly around the platform under the influence of a standard refreshment rate of the seawater. Biodegradation in the sediment is assumed to occur only approx. 10 % of the time due to bioturbation of anaerobic marine sediments and resulting oxygen depletion.

[9] CHARM = Chemical Hazard Assessment and Risk Management (Thatcher et al., 2017).

The potential for bioaccumulation of discharged chemicals is assessed on the basis of information on bio-concentration factors (BCF) or octanol-water partition coefficients (P_{ow}). The potential for bioaccumulation is not quantified.

The model considers the conditions in the North Sea with a current velocity of 0.05 m/s. The flowrate of produced water is 2,781 m³/day based on data from the Solsort EIA. The flow is modelled as continuous over 24 hours per day. As the point of discharge for PW at South Arne is above sea level, the results are modelled with discharge point at surface.

The modelled concentrations are shown in Table 20-1 below.

Table 20-1 Modelled concentrations for chemicals discharged at South Arne

Type of chemical	Modelled concentration (ppm)
Defoamer	1.18
Corrosion inhibitor	5.5
Demulsifier	0.41
Scale inhibitor	4.11
Wax inhibitor	600.95

The input and the model are attached with a range of uncertainties including:

- Uncertainties related to the actual products to be used
- Uncertainties related to estimated amounts of chemicals to be used and discharged
- Uncertainties related to the chemical testing including ecotoxicity of the chemicals
- Uncertainties related to the model

The products modelled are what is expected to be used at the moment. However, the exact product is not yet decided upon, and thus the exact ecotoxicity profile can vary. However, it can be expected that the products used will be within the predicted pre-screening categories.

The exact amounts and discharges are estimated at the moment, and thus can be expected to be a conservative estimate and may vary with up to a factor 2.

The results are based on a range of assumptions of the processes taking place and are based on testing results. E.g. the partitioning coefficient are based on LogPow values and the ecotoxicity data is also based on tests conducted for different trophic levels. These data is also attached with uncertainties and thus an assessment factor is applied in the magnitude of a factor 10-1000.

The model is likewise attached with uncertainties e.g. the concentration in the sea is attached with uncertainties due to fluctuations in the discharge and variations in the sea current. Thus, the model includes conservative calculations of the conditions.

As described above the results are attached with a whole range of uncertainties ranging from a factor min. 10-1000, which added together could impact the results. However, conservative estimates are incorporated and thus the results are highly conservative.

20.4 Environmental assessment of accidental discharges

The distribution of a potential oil spill from the Hejre re-development is projected by the OSCAR model, which is regarded as a highly reliable model that has been in use for many years.

20.5 Environmental assessment of pipeline laying, noise and light

The environmental impact of pipeline laying is well documented from several studies. Likewise, environmental impacts of machinery and ship noise on marine mammals and the impact of light on birds are well documented.

20.6 Socio-economic assessments

The socio-economic assessments are based on up-to-date fisheries data from the Danish AgriFish Agency covering the years 2014-2018.

20.7 Cumulative effects

The cumulative effects are based on the strategic environmental assessment for the project area carried out in 2012 (Danish Energy Agency, 2012) and the technical report from DCE on the human uses, pressures and impacts in the eastern North Sea (Andersen et al., 2013) and information from DEA.

In addition to the above-mentioned references the DEA has appointed several areas for future wind farms (Reservation of additional areas for national tendering of offshore wind farms according to the Energy agreement dated 29 June 2018. Reservation dated 28 August 2019).

Information on EU projects on common interest is published regularly on an EU homepage[10].

[10] https://energy.ec.europa.eu/topics/infrastructure/projects-common-interest/key-cross-border-infrastructure-projects_en

21. References

Andersson M.,H., Andersson, S., Ahlsèn J., Andersson B.D., Hammar J., Persson L.KG, Pihl J. Sigray P., Wikström A. (2017). A framework for regulating underwater noise during pile driving. Vindval.Report 6775 August 2017.

AzNIIRKH (1986). Refereret i Patin S. Gas impact on fish and other marine organisms. In Environmental impact of the offshore oil and gas industry. www.offshore-environment.com/gasimpact.html.

Bach S.S., H. Skov and W. Piper (2010). Acoustic Monitoring of Marine Mammals around Offshore Platforms in the North Sea and Impact Assessment of Noise from Drilling Activities. SPE International Conference on Health, Safety and Environmental Oil and Gas Exploration and Production. 12-14 April. Rio de Janeiro Brazil. Society of Petroleum Engineers.

Baptist, H.J.M., 2000. Ecosysteemdoelen Noordzee: Vogels. OS/RIKZ Report 2000.817x. RIKZ, Middelburg.

BERR (2008). Review of cabling techniques and environmental effects applicable to the offshore wind farm industry. Technical Report. January 2008.

BirdLife International (2014). Birdlife Seabirds Wikispace (http://seabird, wikispace.com).

Borisov et al (1995) Referred in Patin S. Gas impact on fish and other marine organisms. In Environmental impact of the offshore oil and gas industry. www.offshore-environment.com/gasimpact.html.

Bourne, W. R. P. (1979). "Birds and gas flares." Marine Pollution Bulletin 10(5): 124125.

BP Document No. BP261_r01g (2014). North West Hutton. Decommissioning Programme. Close-out Report.

Brasseur, S., Van Polanen-Petel, T., Aarts, G., Meesters, E., Dijkman, E. en Reijnders, P. (2010). Grey seals (Halichoerus grypus) in the Dutch North Sea: population ecology and effects of wind farms. IMARES Wageningen UR, rapportnr. C137/10.Bundesamt für Naturschutz (2008). Erhaltungsziele für das FFH-Gebiet "Doggerbank" (DE 1003-301) in der deutschen AWZ der Nordsee.

Bromley P.J. (2000). Growth, sexual maturation and spawning in Central North Sea plaice (*Pleuronectes platessa* L.) and the generation of maturity ogives from commercial catch data. Journal of Sea Research 44:27-43.

Callaway R., J Alsvåg, I. de Boois, J Cotter, A. Ford, H. Hinz, S. Jennings, I. Kröncke, J. Lancaster, G. Piet, P. Prince and S. Ehrich (2002). Diversity and community structure of epibenthic invertebrates and fish in the North Sea. ICES Journal of Marine Science 59: 1199-1214, 2002.

COWI/DHI Joint Venture (2001). The Great Belt Link. The monitoring programme 1987-2000. Report to Storebælt. Sund og Bælt.

Delefosse, M., Rahbek, LM.L., Roesen, L., Clausen, K.T. (2018) Marine mammals sightings around oil and gas installations in the central North Sea. J Mar Biol Ass. 98(5): 993-1001.

Däne M. et al (2013). Effects of pile driving on harbour porpoises (Phocoena phocoena) at the first offshore windfarm in Germany-Environmental Research letters 8: 025002.

Dansk Industri (DI), 2015: Beskæftigelsesanalyse for turisme

DCE (2021). Marine mammal species of relevance for assessment of impulsive noise sources in Danish waters. Background note to revision of guidelines from the Danish Energy Agency. Scientific note from DCE – Danish Centre for Environment and Energy. Aarhus University.

DEA (2022). Guideline for underwater noise. Installation of impact or vibratory driven piles. May 2022. Danish Energy Agency.

Deda P. et al. (2006). Light pollution and the impacts on biodiversity species and their habitats.

DCE (2021). Thresholds for noise induced hearing loss in marine mammals. Background note to revision of guidelines from the Danish Energy Agency. Aarhus University. Danish Centre for Environment and Energy (DCE).

DNV (2020), Oil spill modelling for Hejre oil field – surface blowout, DNV GL AS, Norway, Ineos E&P A/S, 2020

DONG E&P A/S (2013) Kemisk og biologisk baselineundersøgelse af havbunden ved Hejre-feltet samt Referencestation Nord i maj 2013. DHI

DONG E&P A/S (2011). Hejre Development Project. Vurdering af virkninger på miljøet (VVM) for Hejre Feltet-udbygning og production. Prepared by COWI for

E&P Forum (1994). Methods for estimating atmospheric emissions from E&P Operations, Report No. 2.59/197, The Oil Industry International Exploration & Production Forum.

Edelvang, K., Gislason, H., Bastardie, F., Christensen, A., Egekvist, .J, Dahl, K., Göke, C., Petersen, I.K., Sveegaard, S., Heinänen, S., Middelboe, A.L., AlHamdani, Z.K., Jensen, J.B. & Leth, J. (2017) Analysis of marine protected areas – in the Danish part of the North Sea and the Central Baltic around Bornholm: Part 1: The coherence of the present network of MPAs. DTU Aqua Report, no. 325-2017, National Institute of Aquatic Resources, Technical University of Denmark.

EEA (2018) Contaminants in Europe's Seas. Moving towards a clean, non toxic marine environment. EEA Report No 25 2018. European Environment Agency.

Egekvist, J., Mortensen, L.O. & Larsen, F. (2018) Gosht nets-A pilot project on derelict fishing gear. DTU Aqua Report No. 323-207. National Institute for Aquatic Resources, Technical University of Denmark, 46 pp. +apendicies.

Engell-Sørensen K & P.H Skyt (2000). Evaluation of the effect of sediment spill from offshore windfarm construction on marine fish. SEAS Doc. no. 1980-1-03-2-rev1.

Falk, K., Jensen, S.B. (1995). Fuglene i Internationale Beskyttelsesområder i Danmark. Miljøministeriet. Skov- og Naturstyrelsen.

Falk-Petersen I.B & E. Kjørsvik (1987). Acute toxicity tests of the effects of oils and dispersants on marine fish embryos and larvae-A review. Sarsia.

French-McCay D. (2009) State-of-the-art and research needs for oil spill impact assessment modeling. Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response.

Freon P., F. Gerlotto and O.A. Misund (1993). Consequences of fish behaviour for stock assessment. ICES mar. Sci. Symp, 196: 190-195. 1993.

Garcia, E., Zamotra-Ledezma and Agilar, K. (2014). Environmental performance of drilling fluids selected for offshore operations in Venezuela. Wold.Appl.Sci.J. 9:1310-1314.

Geelhoed S.C.V., Janninhoff N, Lagerveld S., Lehnert L.S., Verdaat Wageningen H.J.P. (2017) Marine mammal surveys in Dutch North Sea waters in 2017. University & Research Report C030/18

Geelhoed SCV., Bemmelen RSA van, Verdaat JP. (2014). Marine mammal surveys in the wider Dogger Bank area summer 2013. IMARES, Report number C016/14.

GEUS 2019. Marine raw materials database. https://data.geus.dk/geusmap/

Gilles, A., S. Viquerat, E.A. Becker, K.A. Forney, S.C.V. Geelhoed. J. Haelters, J. Nabe-Nielsen, M. Scheidat, U. Siebert, S. Sveegaard, F.M. van Beest, R. van Bemmelen and G. Aarts (2016). Seasonal habitat-based density models for a marine top predator, the harbour porpoise. Ecosphere Vol. 7(6). June 2016.

Glabrybvod (1983). Referred in Patin S. Gas impact on fish and other marine organisms. In Environmental impact of the offshore oil and gas industry. www.offshore-environment.com/gasimpact.html.

Haelters J. & C.J. Camphuysen (2010). The harbour porpoise in the southern North Sea: Abundance, threats and research- & management proposals. http://wwwold.nioz.nl/public/latest_news/1391.pdf

Hammond, P. S., et al. 2013. Cetacean abundance and distribution in European shelf waters to inform conservation and management. Biological Conservation 164:107–122

Helm R.C., D.P. Costa, T.D. DeBruyn, T.J. O`Shea, R.S. Wells and T.M. Williams (2015). Chapter 18. Overview of effects of oil spills on marine mammals. In Handbook of Oil Spill Science and Technology. First Edition. Edited by Merv Fingas 2015 John Wiley & Sons. Inc. Published 2015 by John Wiley & Sons Inc.

Herr H, Scheidate, M., Lehnert, K. and Sieberst, U. (2009). Seals at sea: modelling seal distribution in the German Bight based on aerial survey data. Biomedical and Life sciences Vol 156, No 5 April 2009.

Herr H. et al. (2005). Distribution of harbour porpoise (Phocoena phocoena) in the German North Sea in relation to density of sea traffic. ASCOBANS. 12th Advisory Committee Meeting Document AC12/Doc.8 (P). Brest, France, 12 – 14 April 2005 Dist. 18 March 2005.

Hess Danmark (2006). VVM for Syd Arne – feltudbygning og produktion. By COWI.

ICES (2019a) Fish Maps https://www.ices.dk/marine-data/maps/Pages/ICES-FishMap.aspx

ICES (2019b). Advice on fishing opportunities, catch and effort. Herring (*Clupea harengus*) in Subarea 4 and divisions 3a and 7d, autumn spawners (North, Skagerrak and Kattegat, eastern English Channel).

ICES (2019c). Advice on fishing opportunities, catch and effort. Sprat (Sprattus sprattus) in Division 3a and Subarea 4 (Skagerrak, Kattegat and North Sea).

ICES (2019d). Advice on fishing opportunities, catch and effort. Norway special request for revised 2019 advice on mackerel (Scomber scombrus) in subareas 1-8 and 14, and in Division 9a (The northeast Atlantic and adjacent waters).

ICES (2019e). Advice on fishing opportunities, catch and effort. Cod (*Gadus morhua*) in Subarea 4, Division 7d and Subdivision 20 (North Sea, eastern English Channel, Skagerrak).

ICES (2019f). Advice on fishing opportunities, catch and effort. Haddock (*Melanogrammus aeglefinus*) in Subarea 4, Division 6a and Subdivision 20 (North Sea, West of Scotland, Skagerrak.

ICES (2019g). Advice on fishing opportunities, catch and effort. Whiting (*Merlangius merlangus*) in subarea 4 and Division 7 (North Sea and eastern English Channel)

ICES (2019h). Advice on fishing opportunities, catch and effort. Plaice (*Pleuronectes platessa*) in Subarea 4 (North Sea) and Subdivision 20 (Skagerrak).

ICES (2019i). Advice on fishing opportunities, catch and effort. Dab (*Limanda limanda*) in Subarea 4 and Division 3a (North Sea, Skagerrak and Kattegat).

ICES (2019j). Advice on fishing opportunities, catch and effort. Sandeel (*Ammodytes* spp). In division 4b-c, Sandeel Area 1r (central and southern and southern North Sea, Dogger Bank.

INEOS Oil & Gas DK (2019). Oil Spill Contingency Plan for INEOS Oil & Gas DK offshore operations in the Danish Sector.

INEOS Oil & Gas DK (2020). NO_X emissions correlation with effect of turbine, send by e-mail by Malene Rahbek 1/7-2020.

INEOS Oil & Gas Scandinavia (2020a). SELECT – Environmental Assessment of Pipeline Route Survey. Hejre & Solsort Development Project.

INEOS Oil & Gas, oil spill contingency plan for INEOS Energy DK offshore installations, 2/3-2022

INEOS E&P A/S (2022). North Sea Seabed Monitoring 2021. South Arne Platform. Macrofauna and Sediment Chemistry. Report. Project No: 11826426. 01 June 2022IPIECA (2000). Biological impacts of oil pollution. Sedimentary shores. IPIECA Report Series Volume 9.

IPIECA 1996. Sensitivity mapping for oil spill response. IMO/IPIECA Report Series Volume 1.

ITOPF (2002). Fate of Marine Oil Spills. Technical Information Paper No. 2 2002.

ITOPF (2019). Handbook 2019/20.

Kinze C. C. (2007). Hvaler s. 262 - 311. In: Dansk Pattedyr Atlas. Baagøe, H.J. & T. S. Jensen (red.) (2007) Gyldendal, København, 392 pp.

Knutsen H., C. Andrè, P.E. Jorde, M.D. Skogen, E. Thuròczy and N.C. Stenseth (2004). Transport of North Sea cod 'Larvae into the Skagerrak coastal populations. Proc. R. Soc. Lond. B 2004 pp 1338-1344.

Lack D (1960), Migration across the North Sea studied by radar Part 2. The spring departure 1956–59. Ibis, 102: 26–57.

Lack, D. (1959), Migration across the North Sea studied by radar Part 1. Survey throughout the year. Ibis, 101: 209–234.

Lack, D. (1963), Migration across the southern North Sea studied by radar Part 4 Autumn Ibis, 105: 1–54

van Leeuwen S., Tett P., Mills D., van der Molen J. (2015) Stratified and nonstratified areas in the North Sea: Long-term variability and biological and policy implications. JGR Oceans. 120 (7): 4670-4686

Love, M.S., J. E. Caselle and L. Snook (2000). Fish assemblages around seven platforms in the Santa Barbara Channel area. Fish Bull 98:96-117.

Maersk oil 2015. Danish offshore chemical and biological seabed monitoring around oil and gas platforms. Monitoring around the Harald platform -2015. DHI

McConnell, B.J., Fedak, M.A., Lowell, B. & Hammond, P.S. (1999): Movements and foraging areas of grey seals in the North Sea. Journal of Applied Ecology 36: pp. 573-590.

McConnell, B.J., Fedak, M.A., Lowell, B. & Hammond, P.S. (1999): Movements and foraging areas of grey seals in the North Sea. Journal of Applied Ecology 36: pp. 573-590.

Ministry of Environment and Food (2019) Danmarks havstrategi II, Første del. God miljøtilstand, basisanalyse, miljømål. Ministry of Environment and Food. ISBN: 978-87-93593-73-2

Ministry of Environment (2021): Nye beskyttede havstrategiområder I Nordsøen og Østersøen omkring Bornholm. Miljøministeriet, Marts 2021.

Mueller –Blenke, C., Gill, A.B., McGregor, P.K., Metcalfe, J., Bendall, V., Wood, D., Andersson, M.H., Sigray, P., Thomsen, F. (2010). Behavioural reactions of cod and sole to playback of pile driving sound. J. Acoust. Soc. Am. 128, 2332.

Munk P., P.J. Wright & N.J., Pihl (2002). Distribution of the early larval stages of cod, plaice and lesser sandeel across haline fronts in the North Sea. Estuarine and Coastal Marine Science 55: 139-149.

Munk P., P.O. Larsson, D. Danielsen & E. Moksness (1995). Larval and small juvenile cod *Gadus morhua* concentrated in the highly productive areas of a shelf-break front. Marine Ecology Progress Series 125: 21-30.

Munk P., P.O. Larsson, D. Danielsen & E. Moksness (1999). Variability of frontal zone formation and distribution of gadoid fish larvae at the shelf break in the north-eastern North Sea. Marine Ecology Progress Series 177: 221-233.

Nedwell J.R., Edwards B., Turnpenny A.W.H. & Gordon J. (2004). Fish and marine mammal audiograms: A summary of available information. Report ref: 534R0214.

NIRAS (2019) Miljøkonsekvensrapport, Baltic Pipe. Gasrørledning i Nordsøen. Energinet 7. februar 2019.

NOGA (2022) Recommended guidelines for discharge and emission reporting. The Norwegian Oil and Gas Association. guideline-044---yearly-reporting-ver-20--english_januar-2022.pdf (offshorenorge.no)

NORCE (2022) Risk Based Approach to Produced Water Management - EIF Calculations INEOS Energy 2021, Report no. 34-2022, NORCE Climate & Environment, June 2022.

OSPAR (2000). Quality Status Report 2000 Region II, Greater North Sea. OSPAR Commission, London 2000. ISBN 0946956480

OSPAR (2017). Abundance and Distribution of Cetaceans. https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-mammals/abundance-distribution-cetaceans/abundance-and-distribution-cetaceans/

Otto L., Zimmerman J.T.E., Furnes G.K., Mork R., Saetre R., Becker G. (1990). Review of the physical oceanography of the North Sea. Netherlands Journal of Sea Research. 26 ()2-4: 161-238

Paffenõfer G.A. (1972). The effects of suspended "red mud" on mortality, body weight and growth of the marine planktonic copepod Calanus helgolandicus. Water. Air and Soil Pollution 1 pp 314-321.

Patin (1993). Gas impact on fish and other marine organisms. In Environmental impact of the offshore oil and gas industry. www.offshore-environment.com/gasimpact.html.

Peeters, J.C.H.; Peperzak, L. (1990) Nutrient limitation in the North Sea: A bioassay approach. Netherlands Journal of Sea Research, 26(1): 61-73.

Pohlmann, E. Rachor, M. Robertson, E. V, Berghe, G. van Hoey and H.L. Rees (2010). Spatial patterns of infauna, epifauna and demersal fish communities in the North Sea. ICES J. Mar. Sci. 67 (2) 278-293.

Rambøll (2016) Environmental and social impact statement -Harald. Intended for Maersk Oil.

Reid J.B. P.G.H. Evans and S.P Northridge (2003). Atlas of Cetacean distribution in North-West European waters. Joint Nature Conservation Committee.

Reiss, H., Degraer, S., Duineveld, G., Kröncke, I., Craeymeersch, J., Aldridge, .N., Eggleton, J., Hillewaert, H., Lavaleye, M., Moll, A., Pohlmann, T., Rachor, E., Robertson,M.,Vanden-Berghe,E.,VanHoey,G.,Rees,H.L. (2010) Spatial patterns of infauna, epifauna and demersal fish communities and underlying processes in the North Sea. ICES Journal Marine Sciences 67, 278e293.

Richardson, W.J., Greene, C.R.G., Malme, C.I. & Thomson, D.H. (1995). “Marine Mammals and Noise”. Academic Press, San Diego. 576 pp.

Ronconi R.A., K. A. Allard, P. D. Taylor (2015). Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. Journal of Environmental Management 147 (2015) 34-45.

SCANS-II (2006). Small Cetaceans in the European Atlantic and North Sea. LIFE04NAT/GB/000245.

Schmidt J.O. C.J.G. Van Damme, C. Röckmann and M. Collas (2010). Recolonisation of spawning grounds in a recovering fish stock: recent changes in North Sea herring. Scientia Marina October 2009 153-157 Barcelona (Spain).

Serigstad B & G.R. Adoff (1985). Effects of oil exposure on oxygen consumption of cod eggs and larvae. Marine Environmental Research 17: 266 – 268.

Shell Report Number: BDE-D-TOP-AA-6945-00002 (2019). Brent Delta Topside Decommissioning Close-out Report.

References nos. 74-20 Natural Resources Institute University of Maryland, Prince Frederick p 166-200.

Skov H., J. Dürinck, M.F. Leopolds & M.L.Tasker (1995). Important Bird Areas in the North Sea--BirdLife International Cambridge.

Skov H., J. Dürinck, M.F. Leopolds & M.L.Tasker (2007) A quantitative method for evaluating the importance of marine areas for conservation of birds. Scioence Direct

Sokolov og Vinogradov (1991). Referred in Patin S. Gas impact on fish and other marine organisms. In Environmental impact of the offshore oil and gas industry. www.offshore-environment.com/gasimpact.html.

Soldal A.V.et al. (2002). Rigs-to Reefs in the North Sea: Hydrostatic quantification of fish in the vicinity of a "semi-cold" platform. ICES Journal of Marine Science. Vol. 59, Supplement 1, October 2002, pp S281-S287.

Southall, B.L., et al.(2007). Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33, 411–521.

Stanley D.R. og C.A. Wilson (1997). Seasonal and spatial variation in the abundance and size distribution of fishes associated with a petroleum platform in the northern Gulf of Mexico. Can. J. Fish. Aqat. Sci. /J. Can Sci. Haliet. Aquat. 54 (5): 1166-1176.

Steward D.B (2003). Possible Impacts on overwintering Fish of Trucking Granular Materials Over Lake and River Ice in the Mackenzie Delta Area. Canada/Inuvialuit Fisheries Joint Management Committee Report 2003-1 v+12p.

Stone, C J (2003). The effects of seismic activity on marine mammals in UK waters, 1998-2000. JNCC Report No. 323.

Sundby S., T. Kristiansen, R. Nash and T. Johannesen (2017). Dynamic Mapping of North Sea spawning. Report of the KINO Project. Fisken og Havet nr. 2-2017.

Sveegaard, S. Nabe-Nielsen J. and Teilmann J. (2018). Marsvins udbredelse og status for de marine habitatområder i danske farvande. Aahus Universitet, DCE -Nationals Center for Miljø og Energi, 36 s. -Videnskabelig rapport nr. 284

Tasker M.L., P.H. Jones, B.F. Blake, T.J. Dixon & A.W. Wallis (1986). Seabirds associated with oil production platforms in the North Sea. Ringing & Migration, 7:7-14.

Thatcher M., Robson M., Henriquez L.R., Karmann C.C., Payne G. and Robinson N. (2017). CHARM Chemical Hazard Assessment and Risk Management - A user guide for the evaluation of chemicals used and discharged offshore, User Guide Version 1.5.

Thomas Kiørboe; Flemming Møhlenberg Sletter havet sporene? : en biologisk undersøgelse af miljøpåvirk-ninger ved ral- og sandsugning. Miljøministeriet, Fredningsstyrelsen

Thompson et al. (2010). Assessing the responses of coastal cetaceans to the construction of offshore wind turbines. Marine Pollution Bulletin 60: 1200-1208.

Todd et al (2009). Echolocation activity of harbour porpoises (*Phocoena phocoena*) around an offshore gas-production platform drilling rig complex. In: Fifth International Conference on Bioacoustics 2009, 31st March-2nd April 2009.

Todd V.L.G., P.A. Lepper & I.B. Todd (2007) Do harbour porpoises target offshore installations as feeding stations? 2007 IADC Environmental Conference & Exhibition 3rd April 2007, Amsterdam, Netherlands.

Tougaard S. (2007). Spættet sæl s 252-257 og gråsæl s. 258-261. In: Dansk Pattedyr Atlas, Baagøe, H.J. & T. S. Jensen (red.) Gyldendal, København, 392 pp.

Tougaard, J. (2014). Vurdering af effekter af undervandsstøj på marine organismer. Del 2 – Påvirkninger. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 51 s. - Teknisk rapport fra DCE - Nationalt Center for Miljø og Energi nr. 45.

Tougaard, J. et al. (2003): Satellite tracking of Habour Seals on Horns Reef. Use of the Horns Reef wind farm area and the North Sea. Report to Techwise A/S March 2003. Syddansk Universitet.

Trosi G., S. Barton, S. Bexton (2016). Impacts of oil spills on seabirds: Unsustainable impacts of non-re-newable energy. International Journal of hydrogen Energy. Vol. 41 Issue 37, 5 October 2016, Pagges 16549-16555.

Van De Laar F.J.T. (2007). Green light to birds. Investigation into the effect of bird-friendly lightning. NAM Locatie L15-FA-1. December 2007.

VisitDenmark, 2019: Turismen i Danmark – skaber vækst og arbejdspladser i hele Danmark. Juni 2019.

Waggitt, J. J., Evans, P. G. H., Andrade, J., Banks, A. N., Boisseau, O., Bolton, M., Bradbury, G., Brereton, T., Camphuysen, C. J., Durinck, J., Felce, T., Fijn, R. C., Garcia-Baron, I., Garthe, S., Geelhoed, S. C. V., Gilles, A., Goodall, M., Haelters, J., Hamilton, S. Hiddink, J. G. (2020). Distribution maps of cetacean and seabird populations in the North-East Atlantic. Journal of Applied Ecology, 57(2), 253-269. https://doi.org/10.1111/1365-2664.13525.

Warnar T., B., Huwer, M., Vinther, J., Egekvist, C. R, Sparrevohn, E. Kirkegaard, P. Dolmer, P. Munk og T. K. Sørensen (2012). Fiskebestandenes struktur. Fagligt baggrundsnotat til den danske implementering af EUs havstrategidirektiv. DTU Aqua-rapport nr. 254-2012.

Weilgart, L.S. A (2007). Brief Review of Known Effects of Noise on Marine Mammals. International Journal of Comparative Psychology, 20(2), 159-168.

Wildish, D.J. & J. Power (1985). Avoidance of suspended sediments by smelt as determined by a new "single fish" behavioural bioassay. Bull. Environ. Contam. Toxicol. 34: 770-774.

Wildish, et al. (1977). Avoidance by herring of suspended sediments from dredge spoil dumping. ICES Fisheries Improvement Committee, C.M.1077/E:11, 1-6.

Worsøe L.A., M.B. Horsten & E. Hoffman (2002). Gyde-og opvækstpladser for kommercielle fiskearter i Nordsøen, Skagerrak og Kattegat. Danmarks Fiskeriundersøgelser. DFU-rapport nr 118-02.

Aarhus Universitet, DEC – Nationalt Center for Miljø og Energi (2019). Identifikation af mulige beskyttelsede havområder I Nordsøen, Skagerak og Østersøen omkring Bornholm, DCE rapport nr. 362.

APPENDIX A FATE AND EFFECT OF OIL SPILL

Introduction

This appendix briefly describes the fate and effects of oil spilled at sea.

Fate of oil

Oil released during a blow out or other types of spill undergoes the following processes: (Figure 1 Processes affecting oil spilled at the surface (Source: Flowing data 2010):

- Spreading
- Evaporation
- Dispersion
- Dissolution
- Emulsification
- Oxidation
- Sedimentation and
- Biodegradation

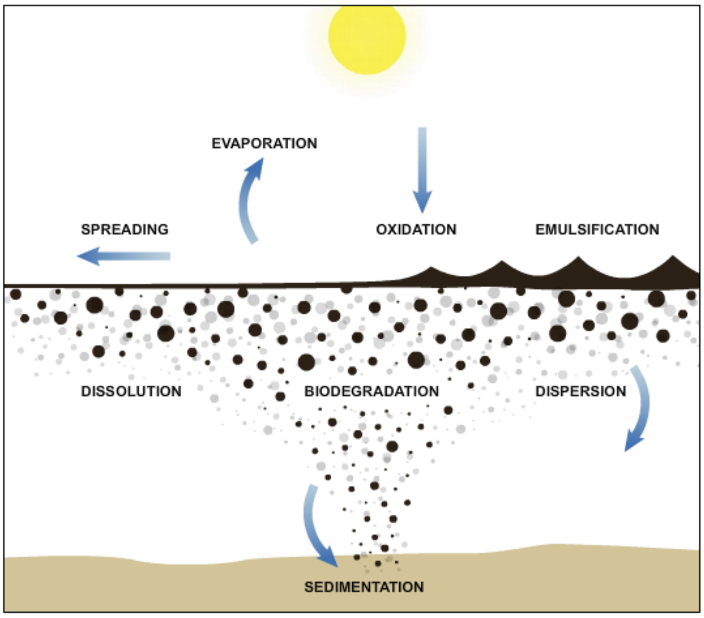


Figure 1 Processes affecting oil spilled at the surface (Source: Flowing data 2010)

The processes of spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill whilst oxidation, sedimentation and biodegradation are more important later on and determine the ultimate fate of the oil Figure 2.

Rate and scale of the different processes are dependent on:

- The physical and chemical characteristics of the oil;
- Temperature, wind and currents and
- Whether the oil is spilled beneath or on the surface of the water

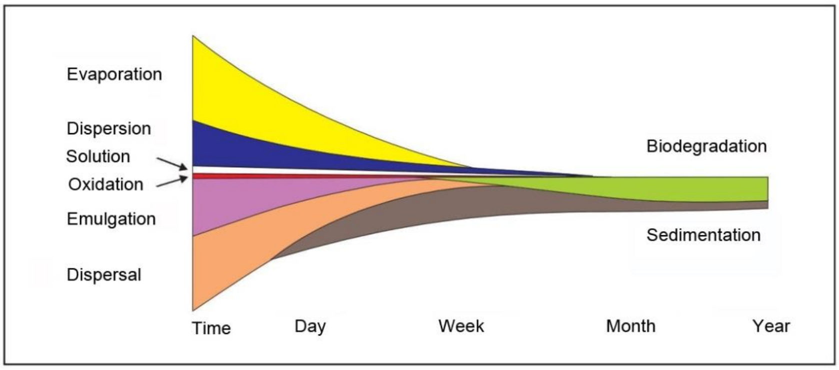


Figure 2 Overview of the relative significance of the different physical and chemical processes that affects spilled oil at sea as a function of time (after ITOPF 2002).

Tabel 1 Processes that affects oil spills (ITOPF 2019 and 2002)

Description of processes
Spreading. On the sea surface the oil will quickly be spread by wind and currents in a film of thin, narrow slicks parallel to the wind and current direction and will cover extensive areas of the sea surface. **Evaporation.** The volatile components of the oil will evaporate to the atmosphere within a short period of time. The rate of evaporation is dependent on temperature, atmospheric pressure and the surface area of the oil film, the rate increasing with increasing temperature, decreasing atmospheric pressure and increasing surface area. **Dispersion.** Waves and turbulence can break all or part of the oil slick into fragments and droplets of varying size that will be mixed into the upper layers of the water column. Some of the smaller droplets will remain suspended in the water column while the larger ones will tend to rise back to the surface, where they may either coalesce with other droplets to reform a slick or spread out to form a very thin film. **Dissolution**. The lighter water-soluble components of the oil, such as light aromatic hydrocarbons compounds like benzene and toluene, may dissolve into the surrounding water but most of these components will evaporate **Emulsification**. Due to wave action sea water droplets may become suspended in the oil, forming water-in oil emulsions (of-ten called chocolate mousse), which is usually very viscous and quite persistent. **Oxidation**. Hydrocarbons can react chemically with oxygen forming either soluble compounds or persistent tar balls with a solid outer crust surrounding a softer, less weathered interior. Such tar balls, are often found on shorelines **Sedimentation**. Some heavy refined products or dispersed oil that mix with suspended solids have a higher density than seawater and may sink to the bottom. This process mainly takes place on shallow waters that are often laden with suspended solids providing favourable conditions for sedimentation. **Biodegradation**. Seawater contains a range of microorganisms that can degrade oil components to water soluble com-pounds and eventually to carbon dioxide and water. However, some compounds in oil are very resistant to attack and may not degrade.

Potential biological impacts of oil spill

In the unlikely event of a blowout of oil and in a situation when oil-spill response measures not can be activated, the environmental impacts may be severe. The sensitivity of different groups of organisms and habitats vary markedly. Table 1 and table 2 give overviews of the vulnerability of different groups of species and habitats in open waters and on shallow coastal waters and shorelines, respectively.

In general, environmental impacts of oil spill are most severe if the slick of petroleum hydrocarbons reaches shallow coastal waters and the shore, or if the slick passes concentrations of seabirds which are particularly sensitive to oil spills.

Table 2 Overview of potential impacts of oil spills on different groups of organism and habitats in open waters.

Potential impacts in open waters.
Impacts on plankton. Plankton populations are not particularly vulnerable to oil spills. It is well established that plankton is sensitive to oil exposure and consequently short-term impacts would be expected in the immediate vicinity of the oil. However, plankton is abundant, will naturally suffer very high levels of mortality and has an enormous regeneration capacity. As a result, long lasting effects on plankton is not expected and long-term effects of oil spills on phyto - or zooplankton communities have not been observed to date (ITOPF 2002, Khalaf 2006, Anon 1985, Falk Petersen et al. 1998 and Kühnholt 1977). **Impacts on pelagic fish, fish eggs and fish larvae.** There is no evidence to date that any oil spill in open offshore waters has affected the size of fish populations. Laboratory experiments have shown that oil is very toxic to fish eggs and larvae (Falk-Petersen & Kjørsvik 1987, Serigstad & Adoff 1985, Tilseth, Solberg & Westrheim 1984). However, in several studies effects on pelagic fish eggs and larvae were not observed in the field following oil spills. One reason for this may be that toxic concentrations of oil components are generally confined to the uppermost parts of the water column immediately beneath an oil slick and that fish eggs and larvae are encountered below the toxic water layers. Other studies have demonstrated massive kills of fish eggs and larvae in the vicinity of oil spills without causing any effect on fish populations. The lack of effects on numbers in subsequent adult populations following massive kills of eggs and larvae is probably because most fish species produce vast numbers of eggs and larvae and because most species have extensive spawning grounds (IPIECA 2000). Impacts on adult offshore pelagic fish have not been demonstrated. Fish eggs or larvae are not considered particularly sensitive to oil. This is because they do not surface. Hence contact with floating oil is usually minimal (see Neff, 1991), certainly compared to seabirds, marine mammals and turtles. Hydrocarbon levels that effect fish are considerably higher than levels contained in surface oil slicks (see Volkman et al., 1994). **Impacts on seabirds**. In open waters, mainly seabirds are threatened by oil spills. It is well-documented that seabirds are extremely vulnerable to oil spills and that large amounts of seabirds are often killed in connection with an oil spill in areas where seabirds are concentrated. The reason for seabirds being especially vulnerable is that they are often in contact with surface water and that the oil destroys the buoyancy and the isolating quality of the plumage. Birds smothered in oil will usually die of cold or starvation or drown. Event very small spots of oil may be fatal, especially during winter. Mainly seabirds that stay on the sea surface for longer periods are at risk, but all types of seabird may be affected (Trosi et al 2016, Garcia 2003, Peterson et al. 2003, Exxon Valdez Oil Spill Trustee Council 1994, Burger 1993). **Impacts on cetaceans and seals**. Whales, dolphins and seals are less vulnerable than birds, but they may be affected due to evaporation of volatile toxic components from the oils slick on the sea surface. If they emerge at the surface to breathe in the middle of an oil slick, they may inhale toxic vapours. Exposure to toxic petroleum hydrocarbon fumes may irritate eyes and lungs, cause drowsiness, impairs coordination or breathing which in turn may bring about drowning (Trosi et al 2016, Hammond et al. 2004).

Table 3 Overview of potential impacts of oil spills on different groups of organism and habitats on shallow coastal waters and shoreline.

Potential impacts on shallow coastal waters and shoreline.
Impacts on sea grasses. In most cases, oil will flow above the seagrass without causing damage. However, sea-grass beds may be affected if oil is brought in contact with seagrass as described for corals above (Durakoet al. 1993). **Impacts on shallow water benthic fauna and demersal fish**. Benthic fauna organisms are generally very sensitive to oil spill and elevated concentrations of toxic oil components in the water. There are numerous examples of severe impacts on benthic fauna following oil spills. However, impacts have only been observed on shallow water along the coasts where toxic concentrations may reach the seabed. In general, benthic fauna has a high recovery potential. Recolonization by most species is quite rapid but the recovery of certain sensitive species may be prolonged (such as species of crustaceans and mussels) (Basque Research 2009, SEEEC 1998, Dyrynda 1996, IPIECA 2000, Kingston, et al. 1995, Kingston et al. 1997, Dauvin 1998). There are also examples of demersal fish and spawning grounds for fish with demersal eggs on shallow waters have been affected by oil spills (Exxon Valdez Oil Spill Trustee Council 2009, Brown and Carls 1998, Peterson et al. 2003, Wright et al. 1997) **Impacts on waterfowl and shorebirds**. Shorebirds and waterfowl are often concentrated on tidal flats and are very vulnerable to oil spills. Apart from the impacts on plumage described for the offshore birds waterfowl and shorebirds may be affected as a result of toxic effects after the ingestion of oil during preening, ingestion of oiled prey, inhalation of oil fumes or absorption of oil through skin or eggs and indirect effects resulting from destruction of bird habitats or food resources (Evans et al. 1993) **Impacts on shorelines**. Shorelines, more than any other part of the coastal environment, are exposed to the effects of floating oil. Oil stranded on beaches often gives rise to concern because it may affect several ecological and social conditions. Further, the cleaning of oiled beaches may be costly. The vulnerability of shorelines differs considerably depending on the type of habitat with respect to how easy they are to clean up after an oil spill. The sensitivity of different coastal habitat can be ranked as follows (with increasing sensitivity: 1) Exposed headlands and wave-cut rocky platforms, 2) Fine grained sandy beaches, 3) Beaches of mixed sand and coarser sediments (gravel, pebbles and boulders) 4) Beaches of a range of gravel, pebbles and boulders, 5) Sheltered rocky shores, 6) Sheltered tidal flats, 7) saltmarshes (IPIECA 1996).

References

Anon (1985) Oil in the sea. Inputs, fates and effects. National Academy Press, Washington D.C 1985.Basque Research 2009.

Brown E.D. and M.G. Carls (1998). Pacific Herring (Clupea pallasi) Restoration? notebook. Exxon Valdez Oil Spill Trustee Council. September 1998.

Burger A.E. (1993). Estimating the mortality of seabirds following oil spills: Effects of spill volume. Marine Pollution Bulletin Vol. 26, 140-143.

Danish Energy Agency: https://ens.dk/ansvarsomraader/olie-gas/oekonomi-olie-og-gas

Danish Fisheries Agency (2014).). https://fiskeristyrelsen.dk/english/fishery-statistics/employment-statistics/

Danish Fisheries Agency (2019). Fiskeristyrelsens logbogs- og afregningsregister 26. juni 2019

Danmarks Pelagiske Producentorganisation, Danmarks Fiskeriforening Producent Organisation, Danish Seafood Association, Marine Ingredients Denmark Danske Havne (2018). Dansk fiskeri og fiskeindustris økonomiske fodaftryk. Januar 2018. (Copenhagen Economics).

Dauvin J.C. (1998). The fine sand Abra alba community of the Bay of Moriax twenty years after the Amoco cadiz oil spill. Mar. Poll. Bull. 36 pp 669-676

Dyrynda (1996). An appraisal of the early impacts of the "Sea Empress" oil spill on shore ecology within south-west Wales.

Exxon Valdez Oil Spill Trustee Council (2009). 2009 Status Report.

Exxon Valdez Oil Spill Trustee Council (1994). Final Environmental Impact Statement for the Exxon Valdez Oil Spill Restoration Plan. Anchorage, Ala.: The Council, 1994.

Falk-Petersen I.B & E. Kjørsvik (1987). Acute toxicity tests of the effects of oils and dispersants on marine fish embryos and larvae-A review. Sarsia.

Falk Petersen I. B.et al. (1982). Toxic effects of naphthalene and methylnaphtahlene on marine plankton organisms. Sarsia 67: 171-178

Fiskeridirektoratet (2010). Bestilte særudtræk af fiskefangstdata fra Fiskeridirektoratet

Flowingdata (2010). Physics of oil spills explained. http://flowingdata.com.

Hammond et al. (2004). Background information on marine mammals relevant to Strategic Environmental Assessments 2 and 3. Sea Mammal Research Unit, Gatty Marine Laboratory University of St Andrews. DTI.IPIECA 2000a

IPIECA (2000). Biological impacts of oil pollution. Sedimentary shores. IPIECA Report Series Volume 9.

IPIECA (1996). Sensitivity mapping for oil spill response. IMO/IPIECA Report Series Volume 1.

ITOPF (2019). Handbook 2019/20.

ITOPF (2002). Fate of Marine Oil Spills. Technical Information Paper No. 2 2002.

Khalaf G,et al. (2006). Preliminary results of the oil spill impact on Lebanese water. Lebanese Science Journal, Vol. 7, No. 2, 2006 135.

Kingston, P.F at al. (1995). The impact of the Braer oil spill on the macrobenthic infauna of the sediments off the Shetland Islands. Marine pollution bulletin 1995, vol. 30, no7, pp. 445-459

Kingston P.F. et al. (1997). Studies on the response of intertidal and subtidal marine benthic communities to the Braer oil spill. In: The impacts of an oil spill in turbulent waters: The Braer. Proceedings of a Sympo-sium held at the Royal Society of Edinburgh 7-8. September 1985. Eds J.M. Davies and G. Topping. The Stationary Office.

Kühnholt W. W. (1977). The effect of mineral oils on the development of eggs and larvae of marine spe-cies. A review and comparison of experimental data in regard to damage at se Rapp. P.-v Réun. Cons. int. Explor. Mar 171:175-183.

NORCE (2022), Risk Based Approach to Produced Water Management EIF Calculations INEOS Energy 2021, report no. 34-2022, Norwegian Research Centre, June 2022

Quartz & co (2012): Den danske olie- og gassektors udvikling og samfundsmæssig betydning (1992-2022).

Region Syddanmark (2017). Den danske Offshorebranche. National kortlægning af forretningsområdet.

SEEEC (1998). The Environmental Impacts of the Sea Empress Oil Spill. Final Report of the Sea Empress Environmental Evaluation Committee. The Stationary Office, London.

Serigstad B & G.R. Adoff (1985). Effects of oil exposure on oxygen consumption of cod eggs and larvae. Marine Environmental Research 17: 266 – 268.

Statistikbanken.dk (2020). The statistic (number of employed in the fishery sector) is found in Statisti-kbanken.dk and here in the matrix RAS311.

Tilseth S., T.S. Solberg & K. Westrheim (1984). Sublethal effects of the Water-Soluble Fraction of ekofisk Crude Oil on the early Larval Stages of Cod (Gadus morhua). Marine Environmental Research 11 (1984) 1-16.

Trosi G., S. Barton, S. Bexton (2016). Impacts of oil spills on seabirds: Unsustainable impacts of non-re-newable energy. International Journal of hydrogen Energy. Vol. 41 Issue 37, 5 October 2016, Pagges 16549-16555.

Wright et al. (1997). The impact of the Braer oil spill on sandeels around Shet-land. In:"The impact of an oil spill in turbulent waters: The Braer." Proceedings of a Symposium held at the Royal Society of Edinburgh 7-8-September 1995 (eds. J.M. Davies and G. Topping). The Stationary Office.