Nautical Risk Assessment of Halla OWF

Comparison between layout 120 WTGs and layout 160 WTGs

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Table of contents

Abbreviations and concepts

AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable (area where risks can be tolerated if all reasonable measures are taken)
Allision	IWRAP distinguishes between collision (where two moving vessels collide) and allision where a moving vessel bumps into a stationary object – a bridge, pier, dock or oil platform. Two types of allision are covered by IWRAP: • Powered allision (manoeuvrable vessel bumps into a stationary object). Occurs either in the absence of a ship's manoeuvre when the fairway turns, or for vessels positioning themselves outside the fairway. • Drifting allision (drifting ship bumps into a stationary object).
Causation factor	Assumption in IWRAP of the probability of causality falling out. A causation factor is the conditional probability of a human error or technical error in an accident that could otherwise have stopped the accident
Collision	For the purposes of this report, collision refers to collisions between ships unless otherwise stated. IWRAP distinguishes between collision (where two moving vessels collide) and allision where a moving vessel bumps into a stationary object – a bridge, pier, dock or oil platform. Five types of collision are covered in IWRAP: • Head-on collision • Overtaking collision • Crossing collision • Merging collision • Bend collision
Concept design	Includes preliminary design of windfarm and navigation areas layout using data and formulae given in design guidelines together with other relevant data relating to ships and environment. At the very first design stage only rough estimates of the safety distance are determined. The process is intended to be rapid in execution and not require excessive input data, so that alternative options (for trade-off studies) can be evaluated rapidly (PIANC, 2018)
Detailed design	Is a more rigorous process intended to validate, develop, and refine the Concept Design. The methods used in Detailed Design rely on numerical analysis (for example simulation) and therefore require more extensive and detailed input, as well as proper judgement and experience in the interpretation of their output. The outputs of the Detailed Design may be subjected to further checking for acceptability by means of marine traffic analysis, risk analysis and cost/benefit estimates. The results of these checks may lead to adjustments and a further cycle of Detailed Design (PIANC, 2018)
EEZ	Exclusive Economic Zone
Fairway	Seaway in inland waters, inland or near the coast, designated by maritime safety devices or marked on a chart or in a nautical publication
FI	Frequency Index, a number representing the accident frequency (Maritime Safety Committee, 2018)
FSA	Formal Safety Assessment
Gross tonnage (GRT)	Measure of the size of a vessel (the total internal volume of a vessel)

GW	gigawatt
HEP	Human Error Probability
HRA	Human Reliability Assessment
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
IWRAP	IALA Waterway Risk Assessment Program (modelling tool for calculating accident frequencies for ships)
kV	kilovolt
leg	sailing segment between two waypoints
M	nautical mile (1,852 meters)
MW	megawatt
OWF	Offshore Wind Farm
Platform	Hub for collecting and transforming the electricity generated by the WTGs. It typically houses transformers, switchgear, and, if applicable, hydrogen and necessary infrastructure.
RI	Risk Index, a number that represents the magnitude of the risk (Maritime Safety Committee, 2018)
SI	Severity Index; a number that represents the severity of the consequence of an accident (Maritime Safety Committee, 2018)
Shipping area	The maritime spatial planning identifies significant trafficked areas as seafaring areas. Seafaring areas play a crucial role in the current and future use of the marine areas (Maritime Spatial Plan 2030). In this report, the term shipping area is used synonymously with seafaring area.
TSS	Traffic Separation System – an area where oncoming traffic is separated into different traffic routes
Traffic lane	A traffic lane is a defined area where one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary (IMO, n.d.)
waypoint	Reference point in navigation; node point in IWRAP
WTG	Wind Turbine Generator

1. Introduction

OX2 plans to apply for a permit for the construction of an offshore wind farm, Halla, located about 60 km off the coast of Oulu in the region of North Ostrobothnia in Finland. Between the coast and the wind farm the island Hailuoto is located. The distance from the island is about 20 km to the wind farm. The wind farm area is about 550-575 km^2 in size and is planned for approximately 120-160 wind turbines (WTGs) with a total height of 370 metres.

Risk analysis and assessment for two alternative layouts, 120 WTGs and 160 WTGs, have been carried out. In this report, a comparison of the level of risk between the two layouts is made.

The layout with 120 WTGs is illustrated in Figure 1 and the layout with 160 WTGs is illustrated in Figure 2.

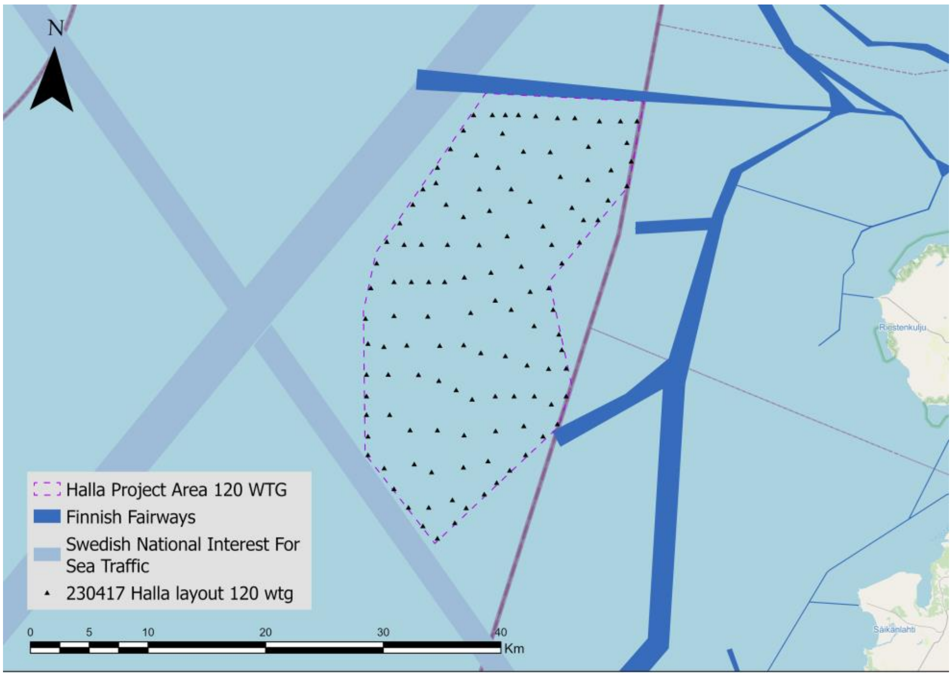

Figure 1. Halla project area, layout with 120 WTGs.

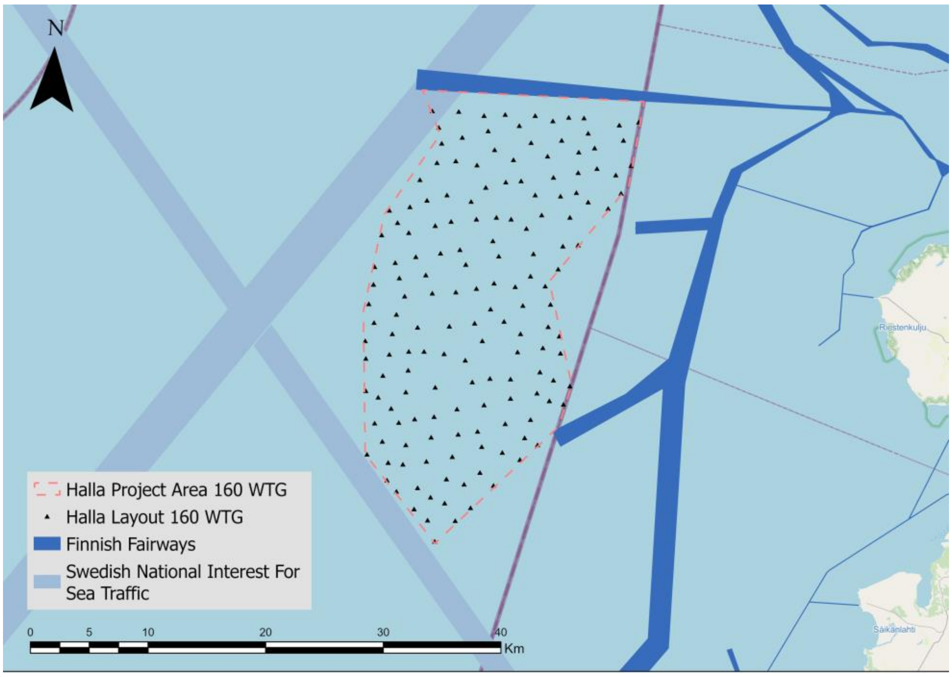

Figure 2. Halla project area, layout with 160 WTGs.

The layout with 160 WTGs occupy a slightly larger area than the layout with 120 WTGs. The difference is that for layout 160 WTGs the area expands further in a north-westerly direction, overlapping the shipping area Nordvalen – Kemi/Tornio slightly in the north-western corner of the project area. In the layout with 160 WTGs, the turbines are placed more closely inside the project area. Along the edges, however, the turbines stand somewhat more sparsely than they do in the layout with 120 WTGs.

In the 120 WTGs layout the turbines are arranged more in a row-like way while in the 160 layout they are more irregularly placed within the project area.

2. Comparison of risk levels, 120 and 160 WTGs

In this chapter, a comparison is made between the two layouts for Halla with 120 and 160 WTGs. Only significant results and differences between the layouts are compared regarding allision, collision, grounding and winter navigation.

The calculations in IWRAP of the nautical risks have been carried out for vessel traffic during months with and without sea ice. Only the scenario with the highest risk level is presented in this report.

2.1 Allision

When Halla OWF is established, there is an increase of frequency of different types of allision. Allision refers to a ship navigating or drifting into a stationary object. Stationary objects associated with Halla OWF include platforms, Wind Turbine Generators (WTG) and the rotating blades.

The risk of allision with hydrogen platforms is analysed further in the Seveso assessment and is therefore not presented in this document. The risk of colliding with a rotor blade has been assessed as acceptable for both layouts, 120 and 160 WTGs. Therefore, only the risks for powered and drifting allision with the WTGs themselves are presented here.

When the frequencies for the turbine layout with 160 WTGs are calculated, the traffic west of Halla is assessed to move slightly in a north-westerly direction as well as become a bit more congested. This mainly due to the WTGs in the northwest corner of the OWF and that the Halla project area takes up a larger part of the shipping area (Nordvalen – Kemi/Tornio), see Figure 2. The effect of this is that the risk of allision remains unchanged or even slightly lower for Halla 160 WTGs compared to Halla 120 WTGs.

However, the risk of collision increases, which is further described in section 2.1.

The change of risk level between Halla 120 WTGs and Halla 160 WTGs is illustrated in Table 1, Table 2 and Table 3 below. For powered and drifting allision, the risk has also been calculated for scenarios with establishment of Polargrund OWF and Omega OWF.

Table 1. Calculated risks of powered allision with WTG (ship navigates into a WTG) for Halla 120 WTGs and Halla 160 WTGs.

No. WTGs	Scenario	Hazard	Frequency (FI)	Severity (SI)		Risk (RI)	
				Human safety	Environment	Human safety	Environment
120	Halla	Ship navigates into a WTG (powered allision)	1.8	3	2.9	4.8	3.7
160	Halla	Ship navigates into a WTG (powered allision)	1.6	3	2.9	4.6	3.5
120	Halla, Omega and Polargrund	Ship navigates into a WTG (powered allision)	1.9	3	2.9	4.9	3.8
160	Halla, Omega and Polargrund	Ship navigates into a WTG (powered allision)	1.6	3	2.9	4.6	3.5

Table 2. Calculated risks of drifting allision with WTG (inoperable ship drifts into a WTG) for Halla 120 WTGs and Halla 160 WTGs.

No. WTGs	Scenario	Hazard	Frequency (FI)	Severity (SI)		Risk (RI)	
				Human safety	Environment	Human safety	Environment
120	Halla	Inoperable ship drifts into a WTG (drifting allision)	2.5	2	2.3	4.5	3.8
160	Halla	Inoperable ship drifts into a WTG (drifting allision)	2.5	2	2.3	4.5	3.8
120	Halla, Omega and Polargrund	Inoperable ship drifts into a WTG (drifting allision)	3.2	2	2.4	5.2	4.6
160	Halla, Omega and Polargrund	Inoperable ship drifts into a WTG (drifting allision)	3.1	2	2.4	5.1	4.5

Table 3. Calculated risks of drifting allision with WTG in ice condition (vessel caught in ice and drifts with the ice field into a WTG) for Halla 120 and Halla 160.

No. WTGs	Scenario	Hazard	Frequency (FI)	Severity (SI)		Risk (RI)	
				Human safety	Environment	Human safety	Environment
120	Halla	Vessel caught in the ice and drifts with the ice field into a WTG (drifting allision)	4.2	2	2.3	6.2	5.4
160	Halla	Vessel caught in the ice and drifts with the ice field into a WTG (drifting allision)	4.1	2	2.3	6.1	5.4

The results above are based on and calculated on the assumption that the traffic pattern west of Halla OWF will change depending on which layout is studied. In order to better understand the effect that more WTGs have on the risk, a sensitivity analysis was carried out where the traffic pattern used for Halla 120 WTGs was also used for Halla 160 WTGs. Since Halla 160 WTGs occupies a larger part of the shipping area west of Halla, this analysis means that more ships are expected to pass very close to or even within the project area. Note that the sensitivity analysis is regarded as conservative compared to the more realistic scenario calculated for and presented in Table 1 and Table 2.

The sensitivity analysis indicates that the risk of powered allision is higher for Halla 160 WTGs compared to Halla 120 WTGs (see Table 4). It is especially the two northwesternmost WTGs that in this case cause an increased risk of powered allision. A further study of this result shows that these two northwesternmost WTGs constitutes approximately 92% of the total powered allision frequency in the analysis area. If you only study the traffic in the shipping area Nordvalen Kemi/Tornio, these two WTGs constitutes of approximately 99% of the powered allision. Note that this is a conservative sensitivity analysis. However, for comparison, these two WTGs also constitutes approximately 24% of the total powered allision for the more realistic traffic scenario in the baseline calculation, referred to in Table 1, on page 7.

Table 4. Sensitivity analysis for calculated risks of powered allision with 160 WTG (ship navigates into a WTG) in comparison of Halla 120 WTGs, where the traffic pattern for 120 WTGs have been used for both layouts.

No. WTGs	Scenario	Hazard	Frequency (FI)	Severity (SI)		Risk (RI)	
				Human safety	Environment	Human safety	Environment
120	Halla	Ship navigates into a WTG (powered allision)	1.8	3	2.9	4.8	3.7
160	Halla	Ship navigates into a WTG (powered allision)	2.8	3	3.1	5.8	4.9

The drifting allision frequency of the two layouts, Halla 120 WTGs and Halla 160 WTGs, are not noticeably different from each other. This means that if the two northwesternmost WTGs in the layout for Halla 160 WTG are removed, both the risk of collision (ship-to-ship collision) and allision (ship-to-WTG collision) for Halla 120 WTGs and Halla 160 WTGs will be approximately the same.

Table 5. Sensitivity analysis for calculated risks of drifting allision with 160 WTG (ship navigates into a WTG) in comparison of Halla 120 WTGs, where the traffic pattern for 120 WTGs have been used for both layouts.

No. WTGs	Scenario	Hazard	Frequency	Severity (SI)		Risk (RI)	
			(FI)	Human safety	Environment	Human safety	Environment
120	Halla	Inoperable ship drifts into a WTG (drifting allision)	2.5	2	2.3	4.5	3.8
160	Halla	Inoperable ship drifts into a WTG (drifting allision)	2.5	2	2.3	4.5	3.8

In summary, the layout with 158 WTGs according to Figure 2, but where the two highlighted WTGs in Figure 3 are excluded, will pose about as much risk as the layout with 120 WTGs in Figure 1 does.

Figure 3 illustrates the shipping areas assumed in the accident frequency calculations for Halla 120 WTGs and Halla 160 WTGs. For Halla 160 WTGs a smaller area has been reserved for vessel traffic compared to Halla 120 WTGs, as can be seen in Figure 3. This is because the Halla 160 WTGs project area interfere with parts of the original shipping area (green area in the figure). The green area illustrates the area reserved for vessel traffic in the layout for 120 WTGs. Also illustrated in the figure is that only two WTGs in the 160 WTGs layout interfere on the larger shipping area (green area).

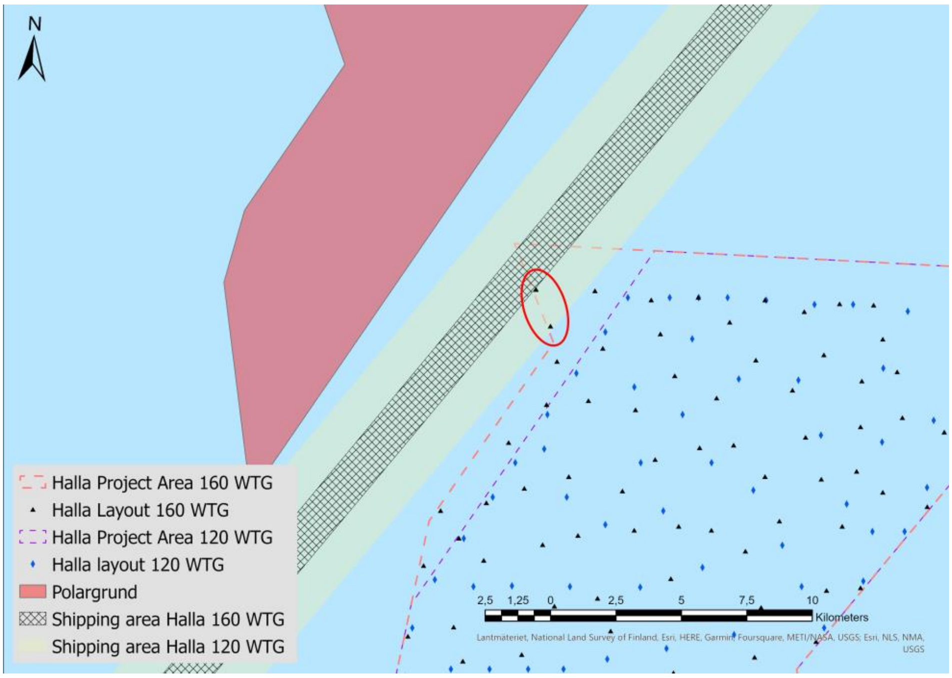

Figure 3. Illustration of which areas the different park layouts leave as space for vessel traffic and which two WTGs in Halla 160 WTGs cause the greatest increase in risk of powered allision between the two layouts (WTGs within red circle).

In summary, the two WTGs make up for the majority of the powered allision frequency for Halla 160 WTGs (marked with a red circle in the figure below). If these two WTGs are removed, the risk of powered allision decreases significantly (to one tenth of the original risk with 160 WTGs). This change also decreases the risk of collisions since the vessels have a larger area to navigate within. Note that the resulting risk of allision is still acceptable in the baseline calculation and ALARP in the conservative sensitivity analysis, even if the two WTGs are still established. However, the positioning of these WTGs should be questioned out of a navigational perspective.

2.2 Collision

Collision frequencies have been calculated for vessels in shipping lanes around the Halla OWF based on available AIS data. The calculations are based on the traffic model for months with and without sea ice, where the most conservative ("worst") results are presented. Frequencies for different collision categories are calculated and compared for two different modelling scenarios: Halla OWF, and Halla, Omega and Polargrund OWF (surrounding OWFs).

The total collision risk for Halla 120 WTGs and Halla 160 WTGs, as well as for Halla including nearby OWFs, is illustrated in Table 6.

Table 6. Calculated risk on effects on human safety and environment for total collision (all collision types). The indices and colour codes are described in the main reports. The table compares risk levels for Halla 120 WTGs and Halla 160 WTGs.

No. WTGs	Scenario	Hazard	Frequency (FI)	Severity (SI)		Risk (RI)	
				Human safety	Environment	Human safety	Environment
120	Halla	Total collisions, windfarm induced	2.5	3	3	5.5	5.5
160	Halla	Total collisions, windfarm induced	2.7	3	3	5.7	5.7
120	Halla, Omega and Polargrund	Total collisions, windfarms induced	2.8	3	3.2	5.8	6.0
160	Halla, Omega and Polargrund	Total collisions, windfarms induced	3.0	3	3.2	6.0	6.2

According to the calculations for both layouts, the risk of collision increases as a result of the establishment of the larger OWF layout, Halla 160 WTGs. This is mainly due to the fact that traffic is likely to become more congested west of Halla because the project area is being expanded in a western direction. This becomes particularly clear if Polargrund is also established. Then the available corridor between the project areas of Halla and Polargrund is reduced from a width of about 7.5 km (120 WTGs) to about 3 km (160 WTGs), see Figure 4. Between Polargrund and Hallas nearest WTGs in the 160 WTGs layout, the distance is approximately 4,5 km.

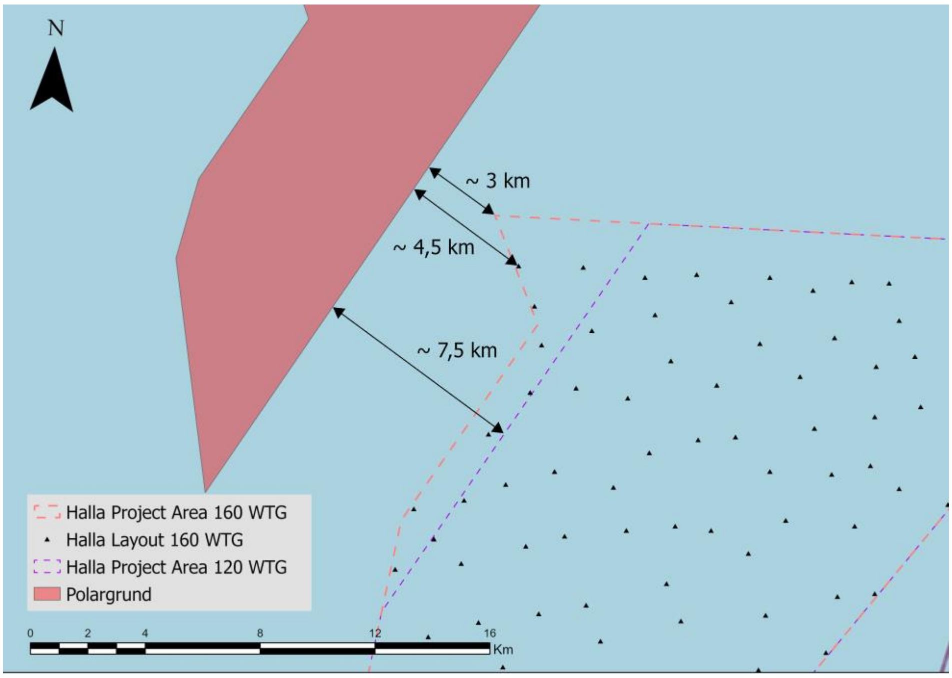

Figure 4. Distance between Polargrund and Halla 120 WTGs and Halla 160 WTGs. The picture also illustrates the distance between the nearest WTGs in the 160 WTGs layout and Polargrund.

Even without the establishment of Polargrund OWF, it is likely that ship traffic will pass Halla within a narrower path because vessels tend to choose the shortest possible route. Therefore, an increase of traffic congestion is assumed for Halla 160 WTG even in the scenario without establishment of Polargrund.

However, the frequency difference for collision is relatively low between the two alternatives mainly due to the low traffic volume in the shipping area (2-3 vessels per day). The collision return time for Halla 120 WTG has been calculated to one collision in approximately 880 years and the collision return time for Halla 160 WTG has been calculated to one collision in approximately 810 years.

2.3 Grounding

The risk of grounding is generally not affected that much as a result of the establishment of Halla. According to the calculations, it is even the case that the risk of grounding is somewhat reduced. The reason for this is not that intuitive, but a theory is that the WTGs have a mitigating effect for the risk of grounding as some vessels will collide with WTGs instead of running aground.

Establishment of Halla 160 WTG entails a reduced risk for both powered and drifting grounding, while establishment of Halla 120 WTG entails a slightly increased risk for powered grounding but reduced risk for drifting grounding. The reason why the layout with more WTGs entails a lower risk could be the fact that there are more WTGs that can prevent grounding from happening, in short, allision occurs before vessels reaches a ground.

Note, however, that the difference in grounding between Halla 160 WTG and Halla 120 WTG is very small. The difference between grounding risk if no OWF is established and if Halla is established is also very small.

2.4 Winter navigation

Halla project area and its surroundings is covered in ice every winter. In general, the ice conditions are such that drift ice are common and ice ridges occur occasionally. Vessels frequently become dependent on icebreaker assistance. Ice buildup and coverage during winter and spring months often forces ships to take different routes than during months without sea ice. Different types of ice cover can also affect sea traffic in different ways. In harsh weather conditions, the role of ice management becomes important to ensure the safety of navigation and fluent flow of traffic calling at ports.

Physical ice management by icebreakers allows operations to be conducted safely throughout the ice season. Ice monitoring and evaluating the ice conditions of local areas provide crucial decision-making support for the icebreaker operations[1]. Icebreakers operating in the area are hence a prerequisite for the continuation and safety of shipping in the area.

When establishing offshore wind power, the ice formation in the area may change. However, it is not yet known what the change in ice formation and ice

[1] Icebreakers have the monitoring tools to analyse existing ice conditions and predictions for future ice situations based on satellite images, weather predictions and shipping traffic predictions. There are a variety of ways to break or deflect ice, with the optimal of which depends on the specifics of the operation being supported and the available vessels.

coverage may look like. No studies of how offshore wind power may change the forming of sea ice have been identified.

The following assessment has been made of the consequences and resulting risk of the OWF changing ice formation:

- **The OWF affects ice buildup:** When an OWF is established it leads to more fixed points in the sea where ice can build up at the surface on the WTGs. At the same time, establishment of WTGs could lead to drifting ice breaking up against the foundations of the WTGs.

The Swedish Transport Agency and the Swedish Maritime Administration (2023) lists the following scenario regarding sea ice and the establishment of a OWF that could potentially be featured:

- The ice may be broken by the foundations of the WTGs and drift ice could get stuck in the area. Ice ridges could form when the ice sheet pushes on from behind and compresses the ice.
- The ice may be broken by the foundations of the WTGs and passes the wind farm, which lead to ice being compressed and form large areas with ice ridges.
- Ice could drift back and forth in the area of the wind farm, leading to ice being broken and compressed on several occasions, forming a thick ice barrier which gets stuck in the area.

Furthermore, ice that has been affected by the OWF can also drift and hamper ship traffic at other locations. This can lead to aggravated ice conditions elsewhere and pose limitations in shipping and calling at ports in the Gulf of Bothnia.

In summary, the risk is regarded as an aggravating circumstance for some of the other accident scenarios brought up in the NRAs. It cannot easily be evaluated on the same scale as other risks but is classified as risk level *ALARP* to be addressed further, see summary of risk in Table 7. This applies for both Halla 120 WTG and Halla 160 WTG. It has not been possible to identify any major differences in this risk between the two layouts. However, since the Halla 160 WTG involves the establishment of more fixed objects at sea, there are more points for ice to break up against. This can have a greater impact on the ice conditions in the area compared to the Halla 120 WTG.

However, the differences in risk level between the two layouts are expected to be minimal and both layouts are still considered to be within the criteria for ALARP.

Table 7. Estimated risk of how the OWF affects ice buildup.

No. WTGs	Scenario	Hazard	Frequency	Severity (SI)		Risk (RI)	
			(FI)	Human safety	Environment	Human safety	Environment
120	Halla	The OWF affects ice buildup	-			ALARP	
160	Halla	The OWF affects ice buildup	-			ALARP	

Establishment of offshore wind power may also affect the ability of vessels to navigate during winter, as the park may block normal winter navigation routes. If the OWF blocks the fastest and easiest winter navigation routes, icebreakers or other tugboats will need to take a different route, potentially delaying or complicating assistance to vessels. This risk is primary a risk with administrative and economic consequences, not included in this nautical risk assessment. Note that the risk of a vessel caught in the ice and drifting into a WTG is calculated and classified as ALARP, see section 2.1, Table 3.

However, there are also potential consequences for human safety and the environment. Vessels that must travel longer distances in winter conditions might be more exposed to the risks of grounding, collision and allision since the travelled distance is longer. The likelihood of encountering massive ice ridges becomes bigger and stationary vessels waiting for assistance are subject to forces in the ice and the risk of hull damage. How much blocked routes contribute to the overall winter risks cannot be easily quantified, but the risk is conservatively classified as *ALARP* to be addressed further.

No. WTGs	Scenario	Hazard	Frequency (FI)	Severity (SI)		Risk (RI)	
				Human safety	Environment	Human safety	Environment
120	Halla	The OWF blocks winter navigation routes (longer routes resulting in grounding, collision and allision)	-			ALARP	
160	Halla	The OWF blocks winter navigation routes (longer routes resulting in grounding, collision and allision)	-			ALARP	

Although both layouts have been classified as ALARP, it is likely that the risk of blocked winter navigation routes is slightly higher for the Halla 160 WTG. This is mainly due to the fact that the project area is larger and thus takes up a larger navigable surface for vessel traffic. Primarily, this can have an impact on the icebreaker assistance's ability to get ahead. If Polargrund OWF is also established, the available corridor between Halla and Polargrund is narrower, which has an impact on the possibility of choosing a suitable route in winter conditions at sea.

2.5 Search and rescue

Only smaller vessels and working vessels are allowed inside the OWF area, but that does not mean that large vessel by accident can enter the OWF area. Either by navigating wrongly or drifting inside the OWF area. Rescue operations in the event of an accident inside the OWF area can become somewhat more complicated and difficult to manoeuvre if 160 WTGs are established instead of 120. This is because the WTGs are placed more closely in the scenario with 160 WTGs. Navigation inside a OWF can be difficult and neither of the layouts are laid out in a regular grid pattern which would facilitate navigation and search and rescue. In the layout with 120 WTGs the turbines are more aligned, compared to the layout with 160 WTGs, making it easier for vessels and helicopters to navigate within.

Neither of the layouts have optimal conditions for search and rescue and other vessels to navigate within the OWF area. In order to maximize the energy production, wind turbines could not be placed in straight lines. It would increase the wake effect remarkably and reduce the annual energy production as well as shorten the WTG lifetime. It is still recommended to examine the possibility to get the WTGs more aligned and discuss the matter with search and rescue actors before deciding the finalized layout.

3. Discussion and conclusion

In the comparison between Halla 120 WTGs and Halla 160 WTGs, there are no major differences in risk level. What can be ascertained is that primarily the risk of collision increases with the establishment of Halla 160 WTGs. This is because the vessel traffic west of Halla has a smaller navigable area.

The difference in risk of allision between the two WTG layouts is very small. It may seem strange since Halla 160 WTGs consists of more WTGs and thus implies more fixed points for a vessel to collide with. The reason why the allision risk is almost unchanged is that the vessel traffic, regardless of layout, has been assumed to go outside the project area. In addition, there are more WTGs near the edges of the project area in the layout with 120 WTGs. In Halla 120 WTGs, the WTGs are placed closer to each other near the edges and further away from each other in the middle of the project area. This means that there are more WTGs within a shorter distance that the vessels west of the project area can collide with. In Halla 160 WTGs, the WTGs are more spread out along the edges. Therefore, the risk of allision is even somewhat lower for Halla 160 WTGs, despite more WTGs being established. The conclusion of this is that the placement of WTGs is more significant to the level of risk than the number of WTGs is.

A sensitivity analysis with unchanged traffic pattern (and thus also unchanged collision risk) between Halla 120 WTGs and Halla 160 WTGs has also been carried out. In this analysis, the allision risk increases for Halla 160 WTGs, because traffic has been modelled through the northwest corner of the project area. This analysis indicates that it is the two WTGs that are placed in this corner that account for almost the entire increase in risk of allision that Halla 160 WTGs entails, in the analysis case with the same traffic pattern as for Halla 120 WTGs. If these two WTGs are removed or relocated, both the risk of allision and collision become similar for Halla 120 WTGs and Halla 160 WTGs. This means that the layout of Halla 160 WTGs excluded the two northwesternmost WTGs results in approximately the same risk as the layout of Halla 120 WTGs does.

It can also be stated that Halla 160 WTGs may entail a slightly higher level of risk with respect to winter navigation since a larger project area blocks more possible winter navigation routes. The area west of Halla OWF available for navigation also decreases, especially if Polargrund OWF is also established, which reduces the area for winter traffic to pass safely. A less navigable area also reduces the opportunities for the icebreakers to choose good pilotage routes. Once again, the northwest corner of Halla 160 WTGs takes up the largest navigable area. If the WTGs within this corner can be removed or relocated, the possibilities for winter traffic and for icebreakers to pass in a safe manner increases.

More wind turbines can also have a greater impact on certain risks during the winter months, when the sea is covered with ice. More WTGs means more points for the ice to break up against which can have a greater impact on the ice conditions in the area. More turbines on the same area can also complicate any emergency situations inside the project area since there are more fixed points around which assistance and safety vessels need to navigate. In addition, neither of the layouts are laid out in a regular grid pattern which would facilitates navigation and search and rescue. In the layout with 120 WTGs the turbines are more aligned, compared to the layout with 160 WTGs, making it easier for vessels and helicopters to navigate within. It is recommended to examine the possibility to get the WTGs more aligned and discuss the matter with search and rescue actors before deciding the finalized layout.

Finally, it can be stated that the risk level does not change in the comparison between Halla 120 WTGs and 160 WTGs. To clarify, if the risk is classified as acceptable for 120 WTGs it is also acceptable for 160 WTGs. This is the same for risks classified as ALARP. Note that this includes the two northwesternmost WTGs. However, the positioning of these WTGs should be questioned out of a navigational perspective.

No risk is classified as unacceptable for either Halla 120 WTGs or 160 WTGs. However, there are several risks that have been classified as ALARP for both layouts (see chapter 7 in main report). The mitigating measures for these risked are assessed to be of such a nature that they are justified to implement. The extent and exact design of the technical and physical measures (K, L, M, N, O, P, Q, R, S and T) are specified when the final layout of the park is decided. The exception is the mitigating measure Q where a study of possible radar interference will be conducted when the park is established to determine if there is a need to take measures to counter radar interference.

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Together with our clients and the collective knowledge of our 18,500 architects, engineers and other specialists, we co-create solutions that address urbanisation, capture the power of digitalisation, and make our societies more sustainable.

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