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NAVIGATIONAL RISK – JAMMERLAND BUGT WIND FARM

Hazard Identification and Qualitative Risk Evaluation of the Navigational risk for the Jammerland Bugt Wind Farm

Orbicon A/S

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1 SUMMARY

DNV GL has been contracted to perform a navigational safety analysis in connection with the preparation of the environmental impact assessment (EIA) for the Jammerland Bugt wind farm project.

The analysis follows the IMO "Guidelines for Formal Safety Assessment", where the first step, following the guidelines, is to identify the potential hazards (adverse events) that may result in injury, damage to the environment, economic loss, etc. As background for the HAZID analysis the ship traffic in the area has been mapped based on AIS received from the Danish maritime authority (DMA). The AIS data is covering a period of twelve months from October 1, 2013 to September 30, 2014. Apart from leasure and fishing traffic the AIS data has in the hazard identification been found representative for the assessment of the traffic around Jammerland Bugt wind farm.

The HAZID was conducted at the premises of DNV GL in Hellerup on November 28, 2014.

The hazard group reflected the relevant stakeholders and individuals with extensive experience and skills in navigational safety. The hazard group identified hazards related to commercial traffic, ferry traffic, fishing, leisure sailors and maritime pilots. Most vessels are found covered by AIS apart from small fishing vessels and leisure boats. In these cases the traffic was assessed by the HAZID participants.

For each identified hazard, frequencies and consequences were estimated based on expert elicitation, which in turn are used to evaluate the risk based on the established risk matrix. However, collision and grounding frequencies are calculated using the collision and grounding analysis tool, IWRAP.

It should be noted that the final location of the turbines is not known at this time. The wind farm can either consist of 80 3MW or 35 6MW turbines.

The actual number of turbines is thus currently not decided, but will not have an impact on the identified hazards. For the navigational risk assessment the analysis assumes the worst case scenario of 80 3MW turbines.

Because of the short distance to land no substation is expected to be built offshore.

No hazards have been found to lie above the ALARP range and potential risk reducing measures are thus not identified.

2 BACKGROUND

On February 22 2012 European Energy A/S applied for a permit for feasibility studies and preparation of an EIA for the establishment of an offshore wind farm at Omø Syd. The permit was given by Energistyrelsen on March 3 2014. In connection with the feasibility studies a navigational risk analysis shall be carried out.

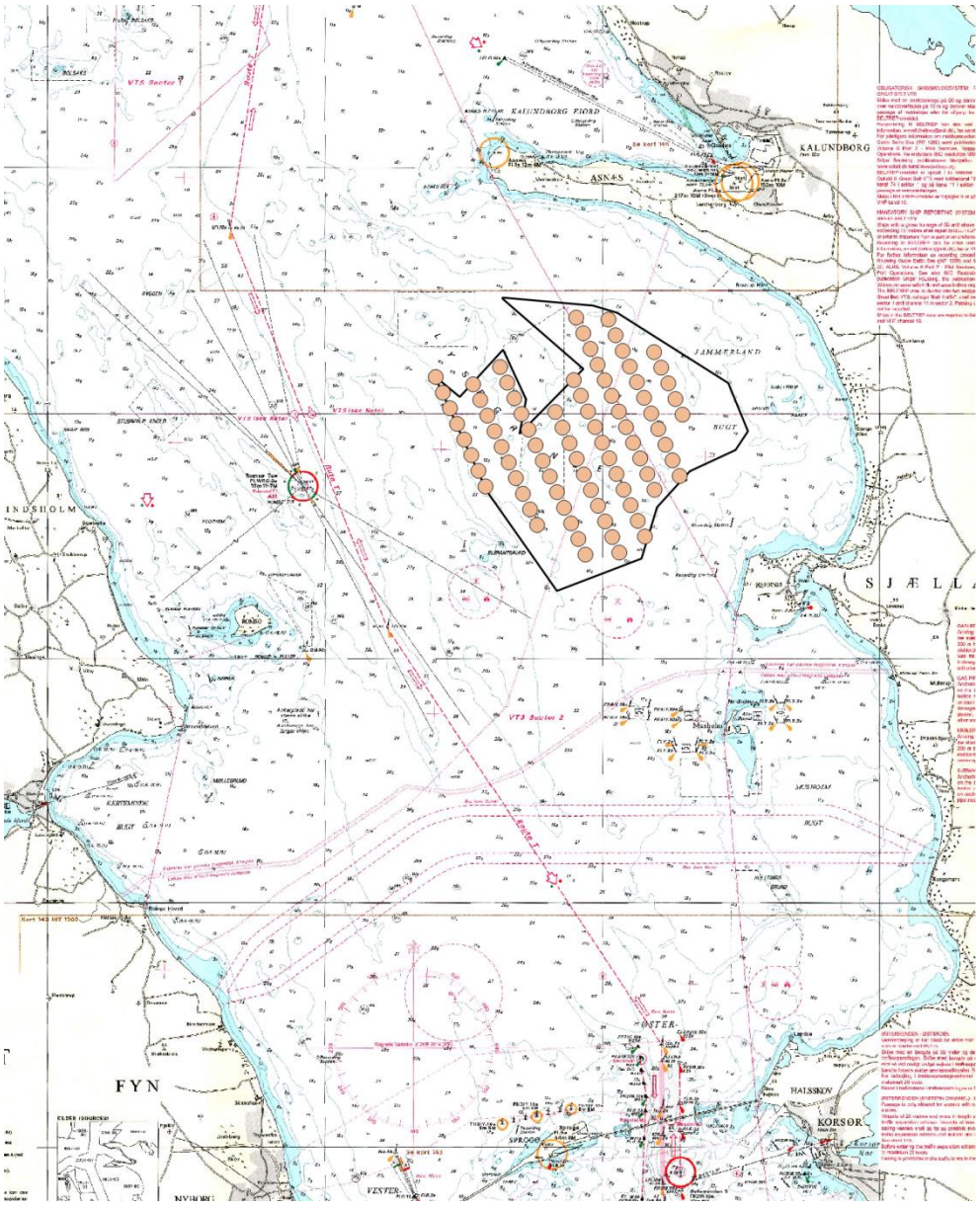

Figure 1: Investigation area and worst case turbine configuration

DNV GL has been contracted to perform a navigational safety analysis in connection with the preparation of the environmental impact assessment (EIA) for the Jammerland Bugt wind farm project.

The worst case hazards are evaluated based on the mapped AIS traffic around the investigation area, which were presented at the HAZID. The mapped traffic intensities in the area are shown in Figure 2

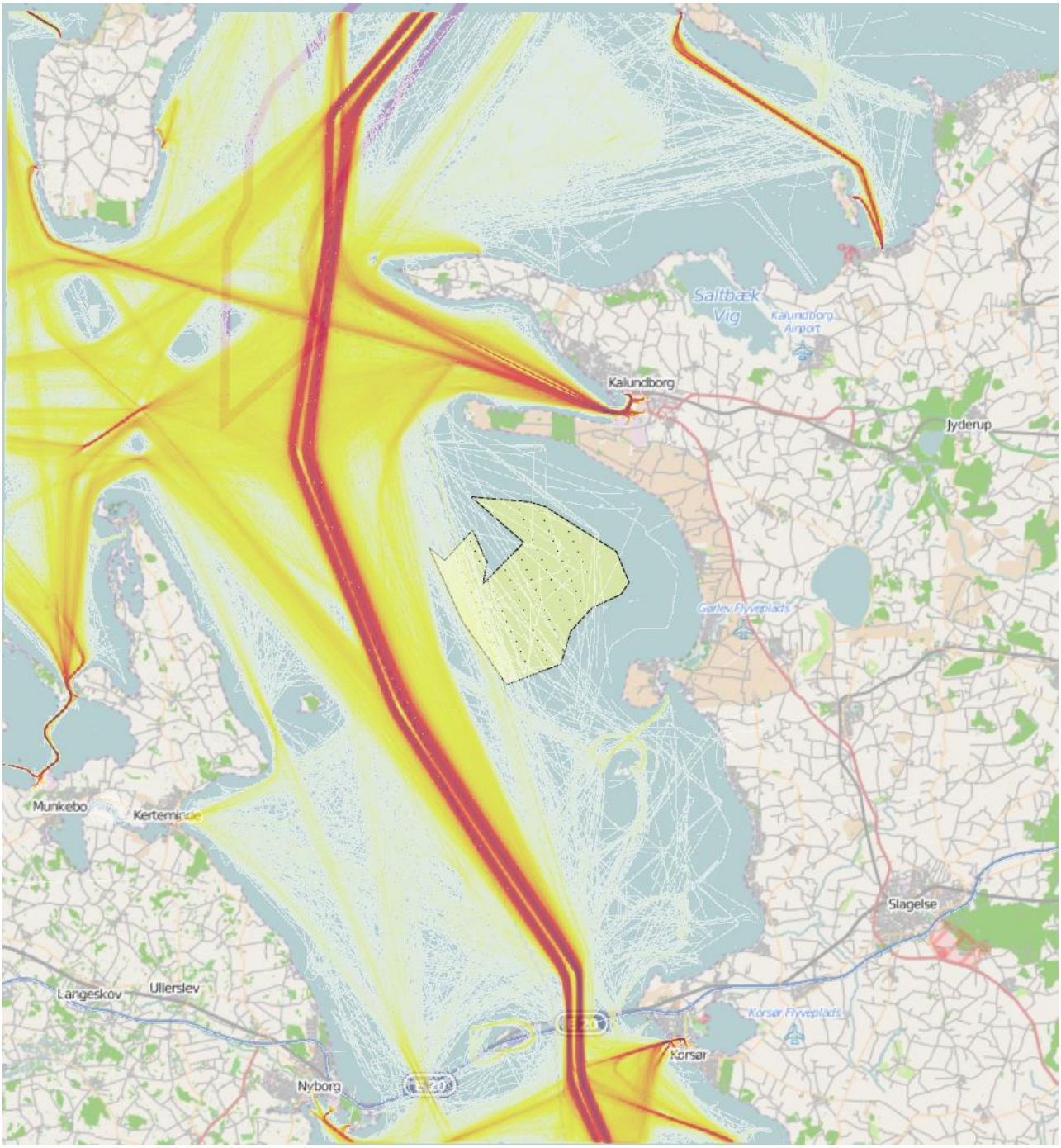

Figure 2: Mapped traffic based on AIS

3 STRUCTURE OF THE HAZID STUDY

3.1 The HAZID workshop

The HAZID workshop was carried out November 28, 2014 at DNV GL Hellerup. The participants and their field of expertise are listed in section 3.2.

Since this is a first overall assessment of the safety in the area, standard question words often used in HAZID's were not applied. Instead, there was a "systematic brainstorming" where each hazard was examined in the operational phase.

The main objective was to identify risk scenarios caused by the presence of the Jammerland Bugt wind farm in the operational phase. The current navigational risk in the area is not covered, and thus only the increased risk caused by the new wind farm.

The ship traffic was grouped into following categories:

- Fishing ships
- Oil products tanker
- General cargo ships
- Passenger ships
- Leisure boats
- Support ships
- Other ships

Although there will be no passage restrictions through the park area, it is expected that the entire area automatically will be kept free of commercial traffic and only fishing and leisure boats will sail through the park area.

The information of fishing in the area is based on AIS and does not cover small vessels without AIS. A qualitative assessment of fishing vessels without AIS have been included based on information from HAZID participants.

3.2 The HAZID group

The composition of the HAZID group reflected the various stakeholders in the area, as well as various professions, thus ensuring that all relevant risks were identified.

NAME	COMPANY / ORGINISATION / PROFESSION
Jens Chr. Eskjær Jensen	Bisserup Sejlklub
Henrik S. Lund	Danmarks Fiskeriforening
Morten Glamsø	Danmarks Rederiforening
Steen Wintlev	Dansk Sejlunion
Bjarne Cæsar	Danske Lodser
Peter Friis Hansen	DNV GL
Lasse Sahlberg-Nielsen	DNV GL
Jonathan Rahbek	DNV GL
Christina Andersen	European Energy
Ian Wallentin	European Energy
Arne Rydahl	Kalundborg Havn
Thorbjørn Kragesteen	Langelandsfærgen
Birgitte Nielsen	Orbicon
Flemming S. Sørensen	Søfartsstyrelsen
Erik Ravn	Søfartsstyrelsen

Figure 3: HAZID participants

3.3 Risk evaluation

The consequences are grouped into the following categories:

label		None	Negligible	Significant	Serious	Critical	Catastrophic
Consequence Class	Abbreviation	2	3	4	5	6	7
Health	H	Bruises and minor damages that do not require hospital treatment	1 injury requiring hospital treatment	Several incidents requiring hospital treatment	Several incidents requiring hospital treatment. 1 disabled	1-2 killed	More than 2 killed
Material	M	Costs due to ship-ship or ship-turbine collision	Costs due to ship-ship or ship-turbine collision	Costs due to ship-ship or ship-turbine collision	Costs due to ship-ship or ship-turbine collision	Costs due to ship-ship or ship-turbine collision	Costs due to ship-ship or ship-turbine collision
Environment	E	None/negligible	Minor environmental damages. Restored within days	Serious environmental damages. Restored within weeks	Serious environmental damages. Oilspill larger than 3 tons	Critical environmental damages. Oilspil larger than 30 tons	Catastrophic environmental damages. Oilspill larger than 300 tons
Monetary value	€	100	1,000	10,000	100,000	1,000,000	10,000,000
Acceptability per year		Negligible	Tolerable	Unwanted	Unwanted	Unacceptable	Unacceptable

Table 1: Consequence classes

Likewise the probability is grouped into the following categories:

Frequency class	Label	More than X incidents per year
2	Dayli - Month	10
1	Month-year	1
0	1-10 year	0.1
-1	10-100 year	0.01
-2	100-1000 year	0.001
-3	1000-10.000 year	0.0001
-4	10.000-100.000 year	0.00001
-5	> 100.000 year	0.000001

Table 2: Probability classes

The risk for a particular hazard can be evaluated based on the estimated consequences and frequencies. A coarse risk analysis has been carried out based on the risk matrix shown in Table 3 where it can be judged whether the accumulated hazards are acceptable or unacceptable and risk reducing measures should be evaluated further.

			Consequence					
			(2) None	(3) Negligible	(4) Significant	(5) Serious	(6) Critical	(7) Catastrophic
			100 - 1.000	1.000 - 10.000	10.000 - 100.000	100.000 - 1.000.000	1.000.000 - 10.000.000	>10.000.000
Frequency (number per year)	(2) Dayli - Month	>10						
	(1) Month-year	1 - 10						
	(0) 1-10 year	0,1 - 1						
	(-1) 10-100 year	0,01 - 0,1						
	(-2) 100-1000 year	0,001 - 0,01						
	(-3) 1000-10.000 year	0,0001 - 0,001						
	(-4) 10.000-100.000 year	0,00001 - 0,0001						
	(-5) > 100.000 year	<0,00001						

Table 3: Risk matrix – Red area is unacceptable, yellow area is unwanted, bright yellow is tolerable and green area is negligible. Consequences in the yellow area shall be evaluated using ALARP (As low as reasonably possible)

4 REPORTING AND ITEMS NOT COVERED BY THE HAZARD LIST

The identified hazards, evaluated consequences and barrier factors regarding ship-turbine collision are shown in appendix A of this report. The ship-turbine collision frequencies for each hazard are taken from a frequency analysis /1/ performed by DNV GL based on the AIS data.

In addition to the hazards listed in appendix A, the following items were discussed in the HAZID.

- The shallow waters at "Elefantgrunde" (Northbound traffic) and "Lysegrunde" (Southbound traffic) can potentially shield the wind farm from northbound ships on route H. It is thus likely that e.g. large northbound oil tankers will ground before colliding with a turbine.
- Due to the shallow waters in "Jammerland Bugt" large fishing vessels will not be able to enter the area.
- In Great Belt almost all oil tankers are tugged by tug boats
- The registered AIS for fishery will not give a realistic picture since only larger vessels above 24 m carry an AIS transmitter. Danmarks Fiskeriforening evaluates that the typical size of the vessel is around 12 m and that 45 vessels is in the area around Jammerland Bugt.
- Fishing patterns tend to be different from year to year. It is suggested that AIS for 5 years may give a better picture. It is however mentioned that fishery in the northern part of "Great Belt" is almost vanished
- The wind farm foundations will act like an artificial reef which is favourable for some fish species. Hence the presence of the wind farm might tend to increase the fishery between the turbines.

5 RESULTS FROM COARSE RISK ANALYSIS

Using the identified hazards and evaluated consequences regarding ship-turbine collision it is possible to accumulate each item in appendix A of this report into a single risk. In table Table 1 it is thus seen that the notable risks involved with ship-turbine collisions is environmental damage. According to Table 1 the environmental risks lies below "none" classification. Risks involved with personal safety and damage to equipment also lies below the "none" classification.

All Sheets	Total Risk	Estimated loss
Health	.7	EUR 5
Material	.4	EUR 2
Environment	1.5	EUR 33
GrandTotal	1.6	EUR 41

Table 4: Accumulated risk based on hazards listed in appendix A

Table 5 summarizes the accumulated risks for "Health", "Material" and environment in a risk matrix. It is seen that the accumulated hazards does not lie in the ALARP range.

All Sheets			Consequence					
			(2) None	(3) Negligible	(4) Significant	(5) Serious	(6) Critical	(7) Catastrophic
			100 - 1.000	1.000 - 10.000	10.000 - 100.000	100.000 - 1.000.000	1.000.000 - 10.000.000	>10.000.000
Frequency (number per year)	(2) Dayli - Month	>10						
	(1) Month-year	1 - 10						
	(0) 1-10 year	0,1 - 1						
	(-1) 10-100 year	0,01 - 0,1						
	(-2) 100-1000 year	0,001 - 0,01						
	(-3) 1000-10.000 year	0,0001 - 0,001						
	(-4) 10.000-100.000 year	0,00001 - 0,0001			Material			
	(-5) > 100.000 year	<0,00001					Environment; TOTAL	

Table 5: Risk Matrix based on hazards listed in appendix A. Note that "Health" with an accumulated risk of 0.7 falls outside the plotting range of the table.

6 CONCLUSION

The HAZID covered hazards/incidents caused by the presence of Jammerland Bugt wind farm. The wind farm can consist of either 80 3MW turbines or 35 6MW turbines with a total capacity of maximum 240 MW. The actual number of turbines is currently not decided, but will not have an impact on the identified hazards, but can have an impact on the found frequencies.

The current legislation does require that small fishing and leisure vessels carry AIS. Based on input from the HAZID participants a more realistic number of vessels will be included in the navigational risk analysis.

No hazards have been found to be in the ALARP range.

7 REFERENCES

/1/ Navigational Risk Assesment Jammerland Bugt Offshore Wind Farm, DNV GL, Doc no. 1KNPOEP-6.

APPENDIX A
Identified Hazards

Abrv	Summary for	Total risk	Total estimated loss
H	Health	.7	5

1	*Ship - turbine collisions*	*Damages to persons*				.7	5	
ID	**Incident**	**Cause**	**Frequency. One incident per**	**Barrier factor**	**Consequence**	**Risk class**	**Estimated Loss**	**Comments**
H1.1	Fishing ship collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	2	(H2) Bruises and minor damages that do not require hospital treatment	-2.7	0	Barrier factor increased to incorporate the fishing vessels not covered by AIS
H1.2	Fishing ship collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	2	(H3) 1 injury requiring hospital treatment	-.7	0	Barrier factor increased to incorporate the fishing vessels not covered by AIS
H1.3	Oil products tanker collides with turbine	Drifting collision due to e.g. black out	(-4) 10.000-100.000 year	0.01	(H2) Bruises and minor damages that do not require hospital treatment	-4.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.4	Oil products tanker collides with turbine	Powered collision due to human or technical error	(-5) > 100.000 year	0.01	(H3) 1 injury requiring hospital treatment	-4.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.5	Cargo ship collides with turbine	Drifting collision due to e.g. black out	(-3) 1000-10.000 year	0.01	(H2) Bruises and minor damages that do not require hospital treatment	-3.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.6	Cargo ship collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	0.01	(H3) 1 injury requiring hospital treatment	-3.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.7	Passenger ship collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	10	(H2) Bruises and minor damages that do not require hospital treatment	-2.0	0	The vessel carries a large amount of crew and passengers. Estimated 10 people will be affected.
H1.8	Passenger ship collides with turbine	Powered collision due to human or technical error	(-5) > 100.000 year	10	(H3) 1 injury requiring hospital treatment	-1.0	0	The vessel carries a large amount of crew and passengers. Estimated 10 people will be affected.
H1.9	Pleasure boat collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	0.05	(H2) Bruises and minor damages that do not require hospital treatment	-4.3	0	Most leisure vessels are small and will bounce off the structure. The consequence is evaluated to occur 1 of 20 times

H1.10	Pleasure boat collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	0.05	(H6) 1-2 killed	.7	5	Most leisure vessels are small and will bounce off the structure. The consequence is evaluated to occur 1 of 20 times
H1.11	Support ship collides with turbine	Drifting collision due to e.g. black out	(-4) 10.000-100.000 year	0.01	(H2) Bruises and minor damages that do not require hospital treatment	-4.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.12	Support ship collides with turbine	Powered collision due to human or technical error	(-3) 1000-10.000 year	0.01	(H3) 1 injury requiring hospital treatment	-2.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.13	"Other ship" collides with turbine	Drifting collision due to e.g. black out	(-3) 1000-10.000 year	0.01	(H2) Bruises and minor damages that do not require hospital treatment	-3.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times
H1.14	"Other ship" collides with turbine	Powered collision due to human or technical error	(-3) 1000-10.000 year	0.01	(H3) 1 injury requiring hospital treatment	-2.0	0	The size of the ship and the low number of crewmen entails that the consequence will occour 1 of 100 times

Abrv	Summary for	Total risk	Total estimated loss
M	Material	.4	2

1	*Ship - turbine collisions*	*Damages to materials*				.4	2	
ID	**Incident**	**Cause**	**Frequency. One incident per**	**Barrier factor**	**Consequence**	**Risk class**	**Estimated Loss**	**Comments**
M1.1	Fishing ship collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	2	(M3) Costs due to ship-ship or ship-turbine collision	-1.7	0	Barrier factor increased to incorporate the fishing vessels not covered by AIS
M1.2	Fishing ship collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	2	(M4) Costs due to ship-ship or ship-turbine collision	.3	2	Barrier factor increased to incorporate the fishing vessels not covered by AIS
M1.3	Oil products tanker collides with turbine	Drifting collision due to e.g. black out	(-4) 10.000-100.000 year	0.01	(M3) Costs due to ship-ship or ship-turbine collision	-3.0	0	The consequence was evaluated to occur 1 of 100 times
M1.4	Oil products tanker collides with turbine	Powered collision due to human or technical error	(-5) > 100.000 year	0.01	(M5) Costs due to ship-ship or ship-turbine collision	-2.0	0	The consequence was evaluated to occur 1 of 100 times
M1.5	Cargo ship collides with turbine	Drifting collision due to e.g. black out	(-3) 1000-10.000 year	0.01	(M3) Costs due to ship-ship or ship-turbine collision	-2.0	0	The consequence was evaluated to occur 1 of 100 times
M1.6	Cargo ship collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	0.01	(M5) Costs due to ship-ship or ship-turbine collision	-1.0	0	The consequence was evaluated to occur 1 of 100 times

M1.7	Passenger ship collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	0.01	(M3) Costs due to ship-ship or ship-turbine collision	-4.0	0	The consequence was evaluated to occur 1 of 100 times
M1.8	Passenger ship collides with turbine	Powered collision due to human or technical error	(-5) > 100.000 year	0.01	(M5) Costs due to ship-ship or ship-turbine collision	-2.0	0	The consequence was evaluated to occur 1 of 100 times
M1.9	Pleasure boat collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	0.01	(M3) Costs due to ship-ship or ship-turbine collision	-4.0	0	The consequence was evaluated to occur 1 of 100 times
M1.10	Pleasure boat collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	0.01	(M4) Costs due to ship-ship or ship-turbine collision	-2.0	0	The consequence was evaluated to occur 1 of 100 times
M1.11	Support ship collides with turbine	Drifting collision due to e.g. black out	(-4) 10.000-100.000 year	0.01	(M3) Costs due to ship-ship or ship-turbine collision	-3.0	0	The consequence was evaluated to occur 1 of 100 times
M1.12	Support ship collides with turbine	Powered collision due to human or technical error	(-3) 1000-10.000 year	0.01	(M4) Costs due to ship-ship or ship-turbine collision	-1.0	0	The consequence was evaluated to occur 1 of 100 times
M1.13	"Other ship" collides with turbine	Drifting collision due to e.g. black out	(-3) 1000-10.000 year	0.01	(M3) Costs due to ship-ship or ship-turbine collision	-2.0	0	The consequence was evaluated to occur 1 of 100 times
M1.14	"Other ship" collides with turbine	Powered collision due to human or technical error	(-3) 1000-10.000 year	0.01	(M4) Costs due to ship-ship or ship-turbine collision	-1.0	0	The consequence was evaluated to occur 1 of 100 times

Abrv	Summary for	Total risk	Total estimated loss
E	Environment	1.5	33

1	*Ship - turbine collisions*	*Damages to environment*				1.5	33	
ID	**Incident**	**Cause**	**Frequency. One incident per**	**Barrier factor**	**Consequence**	**Risk class**	**Estimated Loss**	**Comments**
E1.1	Fishing ship collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	2	(E3) Minor environmental damages. Restored within days	-1.7	0	Barrier factor increased to incorporate the fishing vessels not covered by AIS
E1.2	Fishing ship collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	2	(E3) Minor environmental damages. Restored within days	-.7	0	Barrier factor increased to incorporate the fishing vessels not covered by AIS
E1.3	Oil products tanker collides with turbine	Drifting collision due to e.g. black out	(-4) 10.000-100.000 year	0.0005	(E7) Catastrophic environmental damages. Oilspill larger than 300 tons	-.3	1	Double hull tankers not likely to cause oilspill. Also the shallow waters in Jammerland Bugt will prevent the ship from colliding with a turbine
E1.4	Oil products tanker collides with turbine	Powered collision due to human or technical error	(-5) > 100.000 year	0.0005	(E7) Catastrophic environmental damages. Oilspill larger than 300 tons	-1.3	0	Double hull tankers not likely to cause oilspill. Also the shallow waters in Jammerland Bugt will prevent the ship from colliding with a turbine
E1.5	Cargo ship collides with turbine	Drifting collision due to e.g. black out	(-3) 1000-10.000 year	0.01	(E6) Critical environmental damages. Oilspil larger than 30 tons	1.0	10	Consequence evalutated to occur 1 of 100 times
E1.6	Cargo ship collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	0.2	(E6) Critical environmental damages. Oilspil larger than 30 tons	1.3	20	Consequence evalutated to occur 1 of 5 times to due the speed involved in a powered grounding. Sharp edges from the damaged windturbine may cut the ship hull open
E1.7	Passenger ship collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	0.01	(E6) Critical environmental damages. Oilspil larger than 30 tons	-1.0	0	Consequence evalutated to occur 1 of 100 times
E1.8	Passenger ship collides with turbine	Powered collision due to human or technical error	(-5) > 100.000 year	0.2	(E6) Critical environmental damages. Oilspil larger than 30 tons	.3	2	Consequence evalutated to occur 1 of 5 times to due the speed involved in a powered grounding. Sharp edges from the damaged windturbine may cut the ship hull open
E1.9	Pleasure boat collides with turbine	Drifting collision due to e.g. black out	(-5) > 100.000 year	0.01	(E2) None/negligible	-5.0	0	Consequence evalutated to occur 1 of 100 times

E1.10	Pleasure boat collides with turbine	Powered collision due to human or technical error	(-4) 10.000-100.000 year	0.2	(E2) None/negligible	-2.7	0	Consequence evalutated to occur 1 of 5 times to due the speed involved in a powered grounding. Sharp edges from the damaged windturbine may cut the ship hull open
E1.11	Support ship collides with turbine	Drifting collision due to e.g. black out	(-4) 10.000-100.000 year	0.01	(E3) Minor environmental damages. Restored within days	-3.0	0	Consequence evalutated to occur 1 of 100 times
E1.12	Support ship collides with turbine	Powered collision due to human or technical error	(-3) 1000-10.000 year	0.2	(E3) Minor environmental damages. Restored within days	-.7	0	Consequence evalutated to occur 1 of 5 times to due the speed involved in a powered grounding. Sharp edges from the damaged windturbine may cut the ship hull open
E1.13	"Other ship" collides with turbine	Drifting collision due to e.g. black out	(-3) 1000-10.000 year	0.01	(E3) Minor environmental damages. Restored within days	-2.0	0	Consequence evalutated to occur 1 of 100 times
E1.14	"Other ship" collides with turbine	Powered collision due to human or technical error	(-3) 1000-10.000 year	0.2	(E3) Minor environmental damages. Restored within days	-.7	0	Consequence evalutated to occur 1 of 5 times to due the speed involved in a powered grounding. Sharp edges from the damaged windturbine may cut the ship hull open

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