REVIEW ON RISK ASSESSMENT ON TRANSIT AND CO-USE OF OFFSHORE WIND FARMS IN DUTCH COASTAL WATER

COMMISSIONED BY THE DUTCH MINISTRY OF ECONOMIC AFFAIRS AND CLIMATE POLICY

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GLOSSARY OF TERMS

Below, in Table 1, the list of abbreviations and main definitions is printed. In Appendix A, a list of definitions is presented.

Table 1. Glossary of terms.

Abbreviation	Term and explanation
Active fishing	Fishing by means of dragging a net through the water
Co-use	Activities performed in the wind farm area, other than activities related to the operation of the wind farm itself. E.g. fishing, energy generation using tidal- or wave energy techniques
DoMe Vessel	Doorvaart (*Dutch for Transit)* en Medegebruik, (*Dutch for Co-use*) Vessel
EZK	Ministry of Economic Affairs and Climate Policy
IenW	Ministry of Infrastructure and Water Management
OWF	Offshore wind farm
O&M	Operations and maintenance
Passive fishing	Fishing using stationary nets, traps or pots. Either placed on the bottom or kept afloat using buoys
Recreational fishing	Fishing without a business model. Most common technique is line fishing and angling, performed from relative small boats, drifting on current and wind
Rijkswaterstaat	Rijkswaterstaat is part of the Dutch Ministry of Infrastructure and the Environment and as organization responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. This includes: • The main road network; • The main waterway network; • The main water systems.
Transit wind farm	Ships that travel through the wind farm area with a destination other than the transited wind farm itself
SAR	Search and Rescue
KNRM	Dutch rescue organization, working together with the Dutch coastguard
CTV	Crew Tender Vessel. Vessel used to transport personnel to and within the wind farm

EXECUTIVE SUMMARY

The Dutch government develops a policy to open three Dutch offshore windfarms (OWF) for co-use and transition of vessels smaller than 24 meters. The Dutch Ministry of Economic Affairs and Climate Policy commissioned Arcadis to give a second opinion on the risk assessment for potential hazards, that can occur in this new situation. Four objectives were defined for this assignment:

1. Assess the completeness of previous risk assessment studies, and indicate gaps found (if any);
2. Assess the risks of co-use, and transit through, OWF. Means of co-use to assess are static fishing with nets/lines/traps/pots, tidal energy and aquaculture;
3. Assess the effectiveness of proposed risk control rules in mitigation of risks, indicate the residual risks;
4. Indicate additional possible risk control rules.

In this analysis, focus is on three OWF on the Dutch west coast: Offshore Windpark Egmond aan Zee (OWEZ), Prinses Amalia Windpark (PAWP) and Luchterduinen. Each wind farm is enclosed by a safety zone, which stretches 500 meters around the wind farm.

Ad 1. Information from literature, stakeholders and from offshore windfarms in adjacent countries is used. Concerning the first question (completes of previous risk assessment), no serious gaps were found, but this first step resulted in a minor extension of the earlier identified hazards. The existing set of hazards is replaced by an extended set of 65 hazard failure modes.

Ad2. With this extended set of hazards, the risk-assessment is executed for the current situation and for the situation of an OWF that is open for transition and co-use. The risks were estimated without assumption of adaptive measures and regulations in this stage.

Ad 3. The proposed policy contains a set of regulations that are designed to reduce the risks. Main rules of these regulations from 2015 are:

1. Transit of the wind farm safety zone is allowed solely for ships up to 24 meters length;
2. Transit of the wind farm safety zones is allowed by day light only;
3. Transit of the wind farm safety zones is allowed for ships with active VHF communication equipment which is used to communicate while crossing the wind farm area;
4. Transit of the wind farm safety zones by professional fishers is allowed when their bottom disturbing fishing gear is carried in a position above the waterline, where it is visible;
5. Bottom disturbing activities, like anchoring or dragging of fishing gear, are forbidden within the wind farm safety zone;
6. Within the wind farm safety zone, third party diving activities are forbidden;
7. Professional fishing is allowed if, and only if, the fishing gear is specified as permissible by the Dutch government. This will be written in a framework in which the risks for wind farms, ecological risks, economical potential and enforcement possibilities are taken in consideration;
8. Within the wind farm safety zone, it is forbidden to perform activities that endanger or obstruct the wind farm exploitation. Any third-party activity within 50 meters from a turbine is considered to be dangerous or obstructing;

Introducing these regulations, the risk levels are expected to reduce significantly. The third question focusses on an assessment of the effectiveness of the set of regulations with a special interest in the residual risks. The result of the first three issues of the study are summarized in Table 2. This table reflects all identified hazards in the first two columns, depicting a description and identification number. It shows thereafter in three columns:

1. The current risks (with a wind farm closed by a 500 m exclusive zone);
2. The risk after opening a windfarm for co-use and transition (without additional regulations and measures);
3. The residual risks after all regulations and measures are implemented properly.

From this table the following conclusion can be derived for the transit and recreational use of the Dutch wind farms:

C.1 Opening the wind farms, combined with the proposed set of regulations will not lead to an overall increase in risks;

C.2 Based on the review and assessment, the proposed risk control measures are expected to be effective and, if properly implemented, the proposed regulations will effectively reduce the risks of the identified hazards.

The conclusions regarding the co-use of wind farm areas are as follows:

C.3 The co-use risks of tidal energy and aquaculture are under-assessed in the provided dossier and are here identified as uncontrolled. By 'uncontrolled' it is meant that there is no complete picture of involved hazards AND that many of the known hazards are not mitigated with the proposed regulations. The reason for this is, amongst other, the wide variety of possible technologies;

C.4 The co-use risks of static fishing and pot/trap fishing are uncontrolled. This means that the proposed regulations do not mitigate all hazards caused by these activities, particularly the risks to the subsea cables.

With the proposed mitigating measures in place, the expected residual risk varies from Low to Medium. A low risk is defined as a minimal impact with high, i.e. once a month, occurrence in a wind farm or a considerable impact occurring once in ten years. The Medium level ranges from minor impact with a frequent occurrence of once a month or a catastrophic impact occurring less than once in ten years.

In general, the risk level after mitigation is similar to the level in the current situation. In case of opening wind farms, an increase of vessels inside the wind farms is expected. This raises the risk of collisions between ships, compared to the current situation. Though the risk levels are similar or even lower for the hazards in the co-use groups, these groups are under assessed, as mentioned above. This means the hazards are not fully known and hence cannot be controlled fully given the current knowledge.

It is important to be aware of the differences in rule compliance of different user groups. Therefore, focus should be on an active surveillance and enforcement system. This will send a clear message to the user groups, especially in combination with information campaigns, to increase compliant behavior.

Ad 4. As a result of the review, it is strongly recommended to implement the following points:

R.1 Clear conditions should be stated by the government, when and under which circumstances the proposed policy should be revoked, reestablishing the exclusion zone around the wind farm. This should be followed by the analysis of this situation and development of policy modifications;

R.2 A possibility to impose temporal legal exclusion zones (500m) within the wind farm, placed around crane vessels (jack-up or other) should be considered by the government.

R.3 Tidal energy and aquaculture applications are advised to be based on a permitting process lead by the government. This process should contain an in-depth assessment focusing on the specified risks of the new co-use and should involve both wind farm owner and co-use entrepreneur in an early stage and facilitate a fruitful cooperation between the involved parties.

Further recommendations are provided, which could increase safety and reduce risks. The effect of those recommendations is expected to be less than those mentioned above. They would complement the entire safety system and can be seen as ‘nice to have’:

R.4 Require a publishing of detailed wind farm plan on nautical charts of the Dutch Hydrographic Service. Locations of exclusion zones, turbines, transformer stations and cable plans should be specified. This information should be made available by the wind farm owners. The wind farms should provide additional information on maintenance activities to the Coastguard, to be used in daily communication to sailors;

R.5 Require sailors to carry radar reflectors that provide a minimum recommended radar cross-section. This will allow for tracing vessels within the wind farm and in proximity of wind farm. This is particularly important in case of small recreation vessels;

R.6 Require/advise sailors to use a Personal Life Beacon (PLB) or AIS-SART device for each crew member, independent of vessel size. This will allow for effective SAR action within and in proximity of the wind farm;

R.7 Require an installation of S-VDR (Small Voyage Data Recorder) on all fishing commercial vessels with length above 12 meters, even if it is not required under IMO regulations at present. This can aid to identify a vessel which is involved in a case of e.g. cable damage due to trawling or anchoring.

Table 2. Overview of hazard groups and risk levels determined for three stages: The risk level in the current situation (Current risks); Risk level in case of unrestricted open wind farm (Open risk); Risk level when the proposed mitigating measures (2015) are realized and effective, with expected level of compliance and necessary enforcement of the proposed regulations (Residual risk).

		Id	Current risk	Open risk	Residual risk
Transition	Accidents with DoMe vessels requiring SAR action	1.1	L	L	L
		1.2	L	L	L
		1.3	L	L	L
		1.4	L	M	L
		1.5	L	M	M
		1.6	L	M	M
	Interaction of DoMe vessels with turbines	2.1	L	M	L
		2.2	L	L	L
		2.3	L	M	L
		2.4	L	L	L
		2.5	L	L	L
	Interaction of DoMe vessels with transformer stations	3.1	L	M	L
		3.2	L	M	L
		3.3	L	M	L
	Interaction of DoMe vessels with infield cables	4.1	M	H	M
		4.2	M	H	M
		4.3	M	H	M
		4.4	M	M	M
		4.5	M	M	M
	Interaction of DoMe vessels with operation and maintenance vessel	5.1	L	L	L
		5.2	M	M	L
		5.3	M	M	L
		5.4	M	M	L
		5.5	L	M	L
	Interaction with DoMe vessels with divers and ROV	6.1	M	M	M
		6.2	L	L	L
		6.3	M	M	M
		6.4	M	M	M
		6.5	M	M	M
		6.6	M	M	M
		6.7	M	M	M
		6.8	L	L	L
		6.9	L	L	L
	DoMe vessel crew entering turbine installation	7.1	L	L	L
		7.2	L	L	L
		7.3	L	L	L
		7.4	L	L	L
		7.5	L	L	L
		7.6	M	L	L
	DoMe vessel crew entering transformer station installation	8.1	L	L	L
		8.2	L	L	L
		8.3	M	M	M
		8.4	L	L	L
		8.5	L	L	L

Co-use	Static fishing static netting and lines	10.1	L	L	L
		10.2	M	M	M
		10.3	M	M	L
		10.4	M	M	M
		10.5	M	M	L
		10.6	L	L	L
	Static fishing; trap fishing	11.1	L	L	L
		11.2	M	M	M
		11.3	M	M	M
		11.4	M	M	L
		11.5	L	L	L
	Interaction with tidal energy devices	12.1	L	L	L
		12.2	M	M	M
		12.3	M	M	M
		12.4	M	M	M
	Interaction with aquaculture	13.1	L	L	L
		13.2	M	M	M
		13.3	M	M	L
		13.4	M	M	M
		13.5	M	M	L
		13.6	M	M	M

EXTENDED SUMMARY

At present (early 2018), the four operational offshore wind farms in Dutch waters are designated to be marine exclusion areas. Hence, ships may not enter these zones, except for ships related to the wind farm operators or related to the Dutch government. The Dutch government is planning to increase the number of offshore wind farms in the next decade. To reduce hinder to marine traffic, future wind farms are open for transit and co-use. Therefore, the Dutch government proposes to open three out of four operational offshore wind farms: *'Offshore Windpark Egmond aan Zee'*, *'Prinses Amalia Windpark'* and *'Luchterduinen'* for co-use and transit. The fourth wind farm, *'Gemini*', is to remain a safety area, which was decided due to its distance to shore and relative high costs to get monitoring of law enforcement systems in place.

Opening of the three wind farms is proposed to be allowed under the following conditions:

1. For ships up to 24 meters length;
2. At daytime;
3. With a functioning and active VHF and AIS installation;
4. During transit, professional fishers have to carry bottom disturbing gear above the waterline, where it is visible;
5. Seabed disturbing activities are forbidden;
6. Third party diving activities are forbidden;
7. Professional fishery is allowed with gear approved by the Dutch government;
8. Within the wind farms, a safety zone of 50 meters is established around the turbines. The 500 meters safety zones around offshore transformer stations will remain in place.

Additionally, the Dutch government will develop information campaigns to provide stakeholders with information. Also, a monitoring and evaluation program will be developed in cooperation with the stakeholders, to evaluate the proposed opening after a period of two summer seasons.

The wind farm operators and other involved stakeholders could not reach consensus on the costs and benefits of the proposed regulation. Although an extensive amount of studies was performed, the parties were not unanimous in how to interpret the risk assessment. Therefore, the Dutch Ministry of Economic Affairs and Climate Policy asked to perform an independent review of all relevant risk studies and the content of related documents, which were provided in a study dossier. This assessment includes an estimation of the residual risk and whether risks are properly mitigated, or that risks might be under- or overestimated. Focus was on the three mentioned offshore wind farms, which are to be opened for co-use and transit.

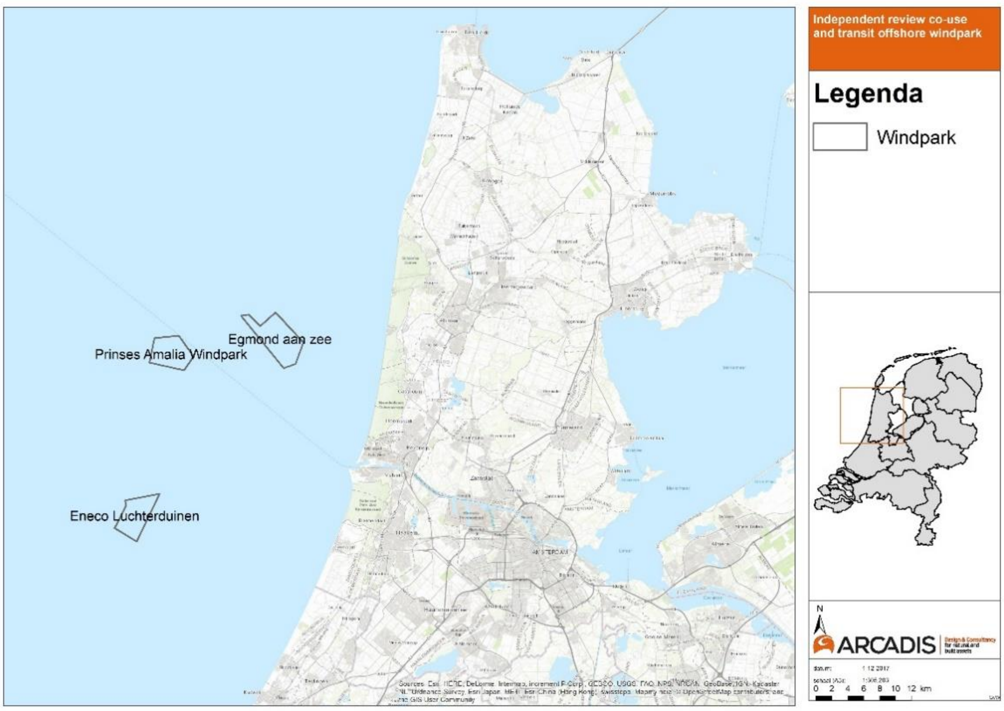

Figure 1. Locations of the three offshore wind farms in this study, relative to the Dutch west coast.

Objectives

The following four objectives were set for the review:

1. Assess the completeness of previous risk assessment studies, and indicate gaps found (if any);
2. Assess the risks of co-use, and transit through, OWF. Means of co-use to assess are static fishing with nets/lines/traps/pots, tidal energy and aquaculture;
3. Assess the effectiveness of proposed risk control rules in mitigation of risks, indicate the residual risks;
4. Indicate additional possible risk control rules.

Methodology

To create a common ground for analysis, step 1 was to create factsheet dossiers of the three wind farms (#1). This to determine factors important for the relevant hazards, caused by transit and co-use of these wind farms. These factors were:

- Distance to the shore,
- Prevailing sea currents and waves,
- Movement of the bottom,
- Layout and depth of burial of the subsea cables,
- Methods and weather limitations of the wind farm maintenance works,
- Methods to monitor wind farm access.

Secondly, an iterative research approach was adopted, including a review of research documentation, stakeholder consultation and empirical data from wind farms abroad (# 2). Thus, a review of all available risk studies of 2015 and content of related documents, which were provided as a study dossier[1].

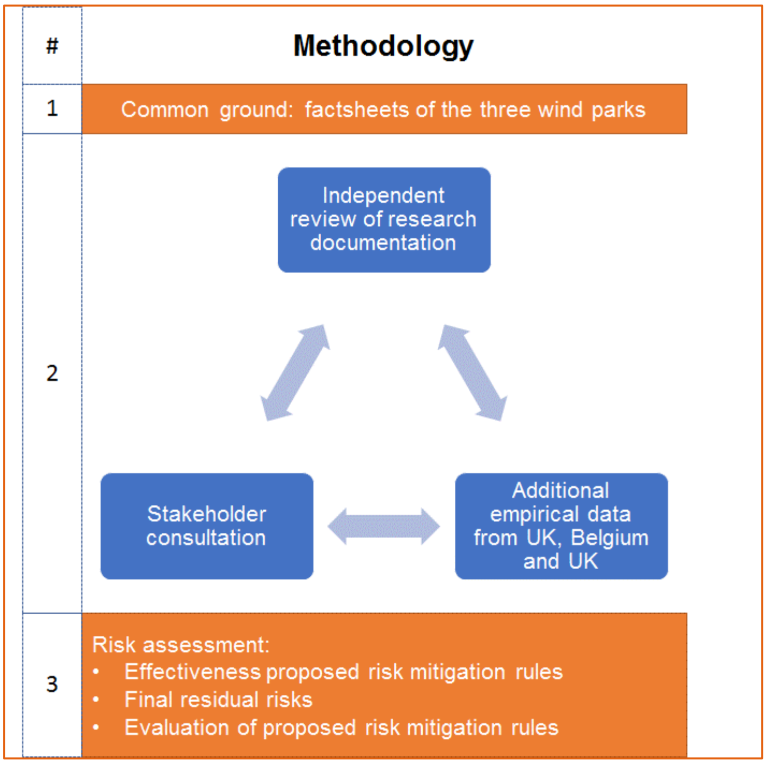

Figure 2. Methodology diagram.

Parallel to this review, meetings were organized with Noordzeewind, Eneco, Rijkswaterstaat and the Dutch Coastguard (Kustwacht), to obtain expertise and to get a better understanding of the considerations and interpretations of the existing risk assessments.

Part of the same iterative approach, information about the risks caused by transit, recreational use and commercial use of wind farms was obtained from two wind farm operators in the United Kingdom (*Gwynt y Mor Offshore Wind Farm Limited* and *E.On Climate & Renewables UK*) and governmental organizations in Belgium (*Federal Government Mobility and Transport – Shipping Department*) and Denmark (*Danish Maritime Authority*).

To assess the effectiveness of the proposed risk mitigation rules, after reviewing the documents and after the interviews, identified hazard groups were listed to describe potential failure modes and their consequences (# 3). For frequencies and consequences, data was used from Quantitative Risk Assessment by wind farm operators (2015). Further the risks at present situation and in future situation (after opening of wind farm areas) were assessed. For the future situation it was assessed how effective the proposed risk

[1] The study dossier consists of a so-called '2015 set' and 'additional set of collected studies' for this review.

mitigation rules will be; this in turn leads to the final residual risks and evaluation of the effectiveness of proposed risk mitigation rules.

Finally, and in addition to transit and recreational use, the innovative applications, like tidal energy, aquaculture, static fishing and trap/pot fishing were analyzed and associated risks were assessed.

Results and findings

Assessment of risk dossier used for policy proposal

Based on the performed review, it is stated that there is marked completeness of hazard identification and risk assessment work performed in the development of the policy proposal. In other words, the risk dossier was assumed to be complete.

The reviewed studies are very extensive and cover a wide area: collisions and collision consequences, effectiveness of SAR actions, AIS and radar detection limits, aspects of fishing in OWF, insurance aspects, legal aspects, and practices applied in other countries. Fundamentally, the technical aspects of risk assessment are sufficiently covered. No significant gaps in the performed risk assessments that would make the decision insufficiently supported were found.

The review points taken from the discussions with stakeholders and discussion of submitted position papers allowed further to identify the stakeholders' concerns and to investigate whether these concerns are covered by the proposed set of risk mitigation measures.

Concerns of wind farm operators

The proposed opening of the wind farm areas, including the related mitigating measures, still raise concerns from the perspective of the wind farm operators:

1. Who is to cover the costs of adapting the offshore facilities to the new situation, and how does this relate to the contract between operator and the government;
2. Commercial aspects of lost business, damages to the wind farm infrastructure and increased operational expenses, which were not part of earlier business plans. Currently, there is no proposal for compensation in case these hazards occur. Due to opening of the wind farm exclusion zone;
3. Loss of work time of operational & maintenance (O&M) teams and risks to OWF personnel due to responding to third party safety infringements;
4. Damages to the image of the offshore wind energy sector and possibly the wind farm owner. This might occur after partial opening of the wind farms and could be caused by accidents and following litigations. This could increase the perception that an offshore wind farm restricts freedom of sea area use.

Experiences from other countries

The data collected from the other countries indicate that in the United Kingdom and Denmark the wind farms are open for transit and both commercial and recreational use. No special requirements regarding vessel equipment or limit on the vessel size are imposed.

While wind farm operators monitor their assets themselves in general, fishermen are concerned with the use of fishing methods, like trawling, that could damage the subsea cables as well as their own equipment. In case of damage to the wind farm, the wind farm operators can request coverage of expenses to be paid by the fisherman. Therefore, fishermen tend to avoid wind farm areas in general. The fishermen and wind farm operators cooperate to limit the damages and to compensate for the loss of fishing gear and fishing income.

Regarding recreational use of wind farms, no safety concerns are mentioned. Search and Rescue (SAR) operations are performed by both rescue organizations and wind farm personnel, if needed. Also, SAR exercises are regularly performed, with participation of wind farm resources (vessels, crews).

In Belgium and Germany, wind farms are considered as maritime exclusion zones for safety reasons and to protect the wind farm equipment. This exclusion zone should prevent accidents which require SAR-actions or damages to the wind farm installations. Regular intrusions of the exclusion zones, mainly by fishermen, are registered by the Belgium Coast Guard.

Other commercial use of wind farm areas

Other commercial use of wind farm areas assessed are: static fishing with nets/lines/traps/pots, tidal energy and aquaculture. Regarding these techniques the following is noted:

1. Fishing with static nets and hook lines; The risks for transit and recreational use are controlled. However, risks for the wind farm infrastructure is not controlled. This is related to the use of the fishing gear, which should be aligned with the current, and hence may run across cables and installations. Also, unknown behavior of lost/abandoned gear and potential damages to subsea cables when the recovery action is performed by fishermen, is uncontrolled.
2. Fishing with pots and traps. The risks for transit and recreational use are controlled. However, the risks for the wind farm infrastructure is not controlled. Anchoring is necessary, and the loss of the gear is possible. As a result, gear can move onto subsea cables, causing damage, or a fisherman may damage cables during recovery attempts. Risks should be further investigated, considering new methods of marking of the gear, collecting statistics on the loss of this kind of equipment, finding technical means of recovery without damages to cables, or how to provide compensation for abandoned gear.
3. Deployment of tidal energy is an industrial endeavor. It should follow strict rules of a design and permitting process. If anything is to be undertaken in this area, it should be done with the participation of wind farm operators and with analyzing of its impact on the transiting and wind farm using vessels.
4. Growing of aquacultures is considered to be an innovative activity, in particularly in open-sea area where it is exposed to storms and currents. There is no risk analysis available that would address navigation and integrity of subsea cables. The perceived problems concern the loss of parts of the aquaculture installation and interaction with wind farm O&M vessels. Deployment of aquacultures might be considered on a joint request of wind farm operators and aquaculture entrepreneurs.

Gaps in knowledge

The review revealed four knowledge gaps that should be addressed now or in near future. However, these do not impact the conclusions and recommendations of the review. The four gaps are:

1. A lack of easily accessible, quantitative data and analysis on accidents and incidents in Dutch operational wind farms (like ones available in UK, within G+ initiative). Available data would allow for re-evaluation and specification of risks within wind farm areas and in the whole offshore wind energy industry;
2. Rescue actions are found to be too complicated in case an injured person is on the turbine/transformer station. This is caused by a lack of available equipment, training (including realistic exercises) and coordination between KNRM, Coastguard and wind farm operators. This holds both for present and future regulations. The found data indicates that accidents in offshore wind farm areas concern mostly the maintenance and operational crews, not third-party users;
3. A lack of data (statistics, controlled experiments) about drifting of static fishing gear (e.g., under what conditions the damages can occur, and what is the drifting capability), and what technical means would facilitate parties for the recovery of the lost gear without endangering of subsea electric cables. Available data and statistics in this topic area will aid in the re-evaluation and specification of risks to cables;
4. A lack of knowledge about the damage mechanism to cables (buried and uncovered) caused by modern trawling methods, like Pulse trawling or SumWing; the knowledge of these hazards would be particularly important for future development of offshore wind farms.

1 CONTEXT

This chapter provides information to understand the context in which the review is performed. It includes a situation context (section 1.1) on co-use and transit through Dutch wind farms at the North Sea. Further it describes the scope of the review (section 1.2).

1.1 Situation context

Challenges in land use planning at the North Sea

In the last decade several offshore wind farms have been built in the Dutch coastal area of the North Sea. The current legislation dictates that transit and co-use of these wind farms is not permitted, as they are set as maritime exclusion (safety) zones. This limits the accessible areas of the North Sea for all user groups of the North Sea, both professional and recreational. As the number of wind farms is expected to grow considerably in the future, the accessible sea area will decrease significantly if the legislation remains unchanged. This poses three challenges in general:

1. The limitation of accessible areas is particularly restricting for smaller vessels, such as recreational sailing and (professional) fishing groups. They prefer to avoid sea traffic lanes that are largely occupied by large merchant ships. These large merchant ships are obligated to follow only the sea traffic lanes, so in fact the inaccessibility of the wind farms poses no threat to these ships. However, as accessible areas decrease with the same amount of traffic, interaction among the various users increases, which is believed to pose a potential safety risk on the North Sea area. Therefore, it is desired to reassess the safety zones;
2. Besides hinder, the wind farms are expected to give a new dynamic to the sea ecological state. Active fishing methods in wind farm areas are relative high risk and hence not practiced in general, if not forbidden by the government. Since the risks and rules for dynamic fishing are not expected to change, sea creatures and plants will have a relative sheltered area to live and develop. This draws the attention to other static fishing methods, which might offer new options. Also, recreational fishermen expect to have good chances when fishing in wind farms, which are relative sheltered ecological systems;
3. A third reason would be that the wind farms could potentially facilitate the growth of seaweeds or serve as an energy hub when tidal energy systems would be added to the area.

Currently, the Dutch coastal waters contain four wind farms in operation. West of IJmuiden, the wind farms *'Egmond aan Zee'*, *'Prinses Amalia Windpark'* and *'Eneco Luchterduinen'* are located, while to the north of the Eemshaven wind farm *'Gemini'* is located. Those wind farms are not designed with free transit and shared use in mind. However, the Dutch government sees an important added value when wind farms would be open for third parties. In the current proposal to enhance the wind farm safety areas, the Gemini wind farm is excluded due to its distance from shore and relative high costs to allow for sufficient law enforcement.

New policy on co-use and transit by National Water Plan

In the new National Water Plan and its Policy Document on the North Sea 2016-2021, broad outlines are provided. This includes principles and direction of the national water policy for the 2016-2021 planning period, with a preview towards 2050. For wind farms it states that '*Passage through and multiple use of wind farms can contribute to efficient use of space, as well as presenting opportunities to bolster the sustainable use and biodiversity of the North Sea*' (www.noordzeeloket.nl, 2015, p. 85).

In the National Water Plan, it is planned that from 2017 onwards the three operational wind farms on the Dutch west coast will be opened during two sailing seasons for transit and co-use for ships up to 24 meters. This would be to test the feasibility of giving up the safety zone around the wind farms for these vessels. Appendix E lists the proposed regulations for the opened wind farms.

Position of the Wind farm owners: critical on risk assessment

Rijkswaterstaat was contracted by the Ministry of Infrastructure and Water Management (IenW) to prepare and facilitate the opening. Therefore, Rijkswaterstaat has assembled risk assessments and has prepared a package of mitigating measures in consultation with relevant stakeholders, including the wind farm owners (RWS - Bijl01, Dec. 2015). The wind farm owners have carried out their own risk analyses and introduced them into the process (Hoefakker B., Don, Blomen, Chivers, & Oppentocht, May 2015).

The wind farm managers are interested in effective and undisturbed management of wind farms. Damage to turbines and infrastructure and impediment to maintenance, or downtime due to other use of the wind farm, is, in any case, unacceptable to them. Maintenance and work at the wind farm must be carried out safely, without having to pay attention to other users. Any disturbance of the wind farm production brings the wind farm existence in danger as they operate on tight margins already. The planned opening for transit and co-use of their wind farms would changes the contracts they agreed on in their concession and require extra, unforeseen investments.

1.2 Scope of review – main questions

The above-mentioned process and package of measures has not led to an agreement on the impact of hazards and how to mitigate or compensate these in a sufficient manner. Arcadis was requested by the Dutch Ministry of Economic Affairs and Climate Policy to perform an independent review of the risk identification and proposed mitigating measures.

In the review, the concerned parties would have a stage to give voice to their concerns and view on the proposed regulations. Combined with these insights, the dossier would be analyzed and assessed on completeness. The goal of the project is to obtain a fact study by analyzing:

1. The studies and risk analyses conducted by the wind industry and Rijkswaterstaat for transit and joint use;
2. The effectiveness of the mitigation package as drawn up by the Dutch government to cover the risks;
3. The possible residual risk that remains and does not form part of the above.

The study focuses on three wind farms along the Dutch west coast: *Offshore Windpark Egmond aan Zee* (OWEZ), *Princess Amalia Windpark* (PAWP) and *Eneco Luchterduinen,* see Figure 3. The former is run by the firm Noordzeewind, while the latter two are run by Eneco.

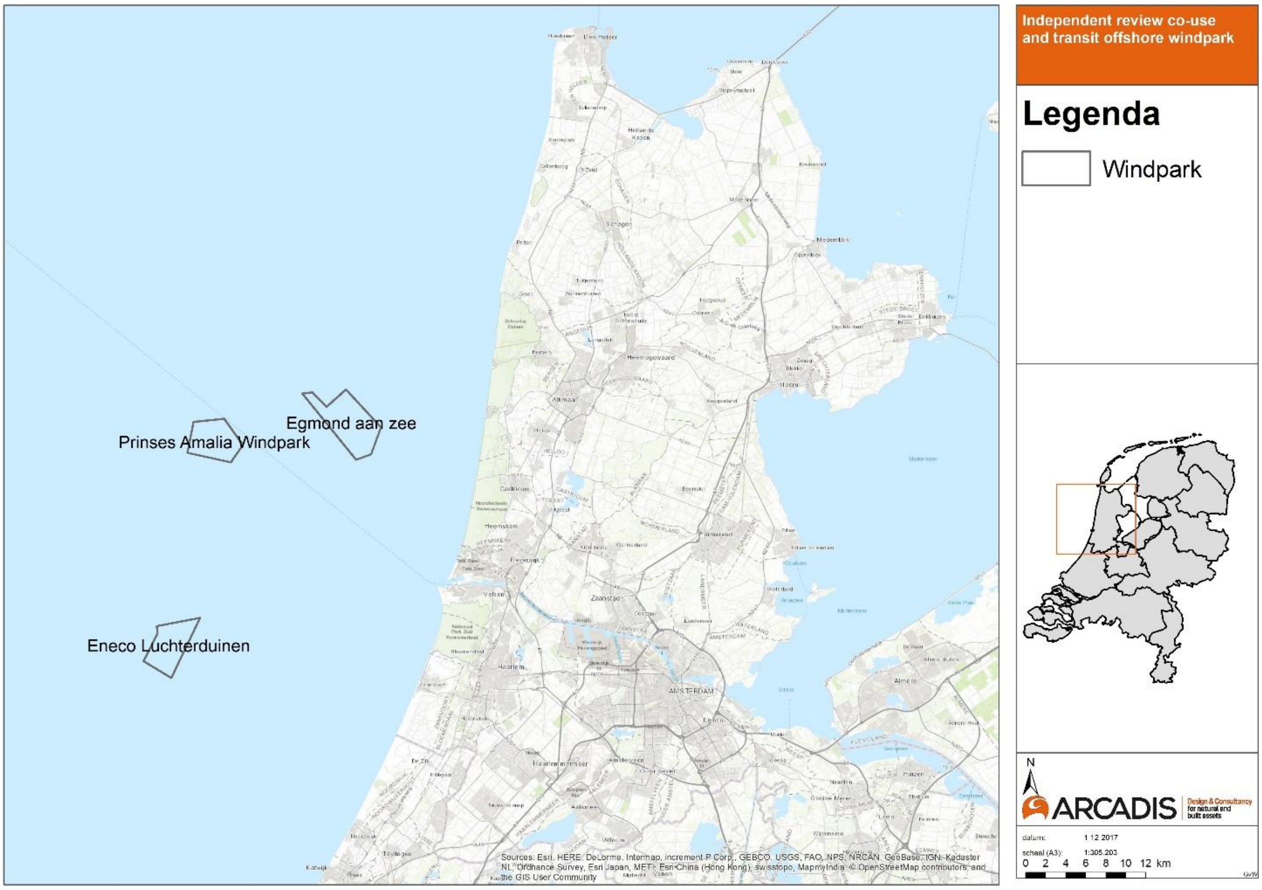

Figure 3. Locations of the three offshore wind farms in this study, relative to the Dutch west coast.

2 REVIEW METHODOLOGY

This chapter presents the methodology of the risk assessment in a three-step approach of desk-studies and (stakeholder) consultation.

To create a common ground for the analysis, step 1 was to create factsheet dossiers of the three wind farms (section 2.1). Important factors and relevant hazards of the proposed regulation were listed. Secondly, an iterative approach was followed, including a review of research documentation, stakeholder consultation and empirical data from wind farms abroad (see section 2.2). After the document review and interviews, a list of hazards was created to cover the potential failure modes. This list was used as input for the risk assessment (see section 2.3). The following sections cover these three steps and provide a more detailed explanation of the methodology. In Figure 4, the adopted methodology is shown.

2.1 Factsheets

Factsheets are developed to set a baseline of information on the current wind farms. A factsheet has been developed for each wind farm. The factsheets provide information on the wind farm alignment, positions of cables and the way in which the wind farms are protected. Next, maintenance is a key point of interest, to get insight in the frequency and deployment of work teams. In addition, the available environmental conditions are analyzed, such as wind, waves and currents together with soil morphology. In paragraph 3.3 the findings from the factsheets are discussed, the three sheets are printed in Appendix E.

2.2 Information sources

A list of documents to study is provided by I&M-EZ. These documents contain reports leading to the proposed new policy, transcripts of stakeholder sessions and other reports and studies containing information of value for this project. Parallel with the document study, meetings are organized with several stakeholders and questionnaires were send to persons representing companies involved with offshore wind farms abroad.

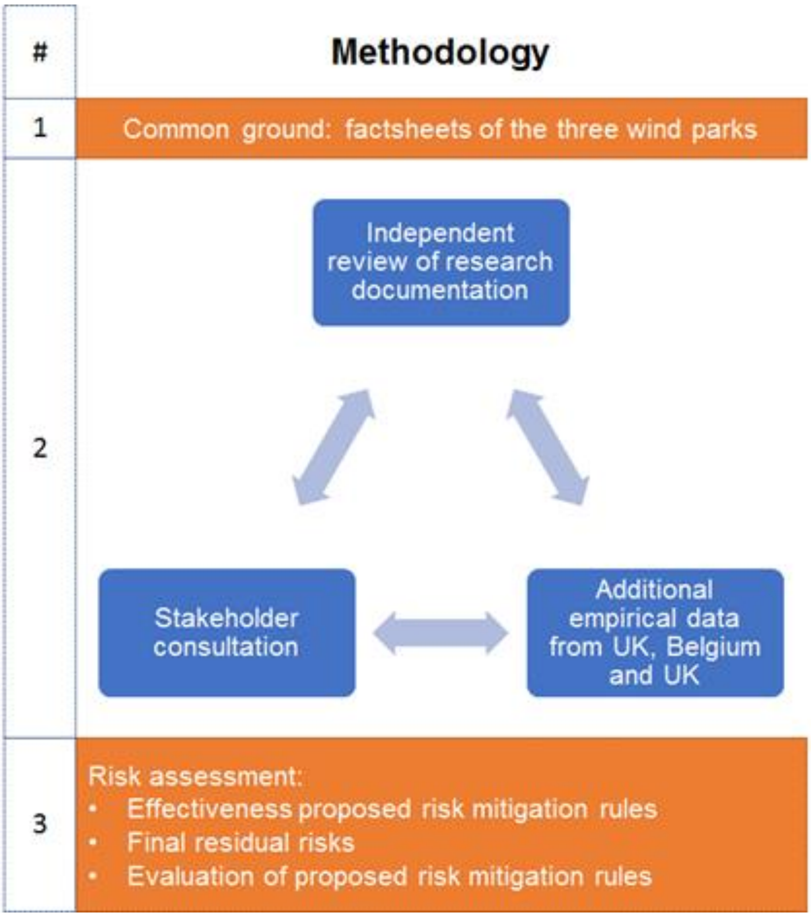

Figure 4. Methodology diagram.

Document overview

The documents, used in this study can be subdivided in three sets:

1. Documents that have been used in the process to write the proposed policy of free transit and co-use of the wind farms.
2. Documents that were provided by IenW-EZK and stakeholders to give extra background information.
3. Documents that where found by the project team.

An overview of the documents is given in Appendix B. Discussion on the findings, based on the document review is given in Paragraph 3.1.

Working sessions with stakeholders

In addition to the document study, meetings were held with representatives and relevant managers from several stakeholders. In case questions arose, additional questions were asked by e-mail. Meetings were organized with:

- Rijkswaterstaat – Mr. Joris Brouwer
- Kustwacht – Mr. Sjaco Pas
- Eneco – Ms. Marjolein Oppentocht
- Noordzeewind – Ms. Roos Knulst

Other stakeholders were not questioned in this assessment. Their opinions are sufficiently covered in the available literature and meetings were not part of the scope of this research. In case questions arose regarding remarks added by one of the other stakeholders, they could be consulted. Discussion of the findings of these sessions is printed in paragraph 3.2. A list of all stakeholders is included in Appendix D.

Information abroad wind farms

To gather more information and data on the practices, knowledge keepers on projects in the North Sea abroad (within EU) were contacted and asked to answer a questionnaire. In this questionnaire project representatives were asked about regulations, knowledge and experiences on accidents and possible unlawful intrusions. Answers were received from:

- Danish Maritime Authority;
- Belgium Federal Government Mobility and Transport – Shipping Department;
- Gwynt y Mor Offshore Wind Farm Limited, UK;
- E.On Climate & Renewables UK.

The answers and information received, based on these questionnaires are discussed in paragraph 3.4. An attempt to get contact with German authorities proved unsuccessful.

2.3 Risk assessment IMO FSA method

Parallel to the creation of factsheets, the second opinion on the risk assessment was prepared, which was conducted as an assessment in itself; according to IMO-FSA[2] method. This method is generally used for the assessment of risks in offshore wind farm industry (DTI, 2005) (DTI, 2013) (Ellis, Forsman, Huffmeister, & Johansson, 2008) (IMO, 2013). It offers a systematic five step approach, which allows to focus on various aspects of the safety of the wind farm, marine traffic and use of wind farm area. The FSA (Formal Safety Assessment) is constructed in five steps:

1. Identification of hazards. A list of all relevant accident scenarios with potential causes and outcomes, Chapter 4;
2. Assessment of risks. Evaluation of frequency and impact of hazard, to arrive at risk level, Chapter 5;
3. Risk control options. Devising regulatory regulations to control and reduce the identified risks, Chapter 5;
4. *Cost benefit analysis. Out of scope;*
5. Recommendations for decision-making, Chapter 6.

For each hazard, failure modes or accident scenarios were defined. This list allowed to assess whether the hazards described in the proposed regulation were properly covered. Combining the expected frequency of

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[2] http://www.imo.org/en/OurWork/Safety/SafetyTopics/Pages/FormalSafetyAssessment.aspx

hazardous events and the consequences of such events, the risk level was determined. The definitions used to determine this level are depicted in the risk score table, see Table 3 in Appendix F.

First, the risk level of each hazard was determined for the present situation. The format used is depicted in Table 4 with an explanation of the meaning of the different cells. Next, the changes in risk level due to opening of the wind farm area were determined. In general, the impact of hazards is not changed, though the frequency of occurring will be different. This approach is depicted in Table 5. In this table, the effect of the proposed mitigating measures and the residual risk is included as well. The aim of mitigating measures ought to reduce the risks to a level 'As Low As Reasonable Possible' (ALARP). The residual risk and possible options to mitigate risk to a lower level are the measures whether the ALARP is achieved or not.

Step 4 in the risk assessment, the cost benefit analysis, is not performed as it was not part of the scope of this assessment. While determining the risk level, the financial impact was one of the impact factors used to rate the impact of the hazards. The recommendations are derived based on the assessment of risks and the expected effect of the new risk control rules.

3 FINDINGS

In this chapter, an overview is given of the main findings from the document review, the stakeholder meetings, the factsheets and the questionnaires which were send to foreign wind farm stakeholders. This gives insight in the reasoning that formed the proposed policy and gives an indication of the important aspects related to the opening of the safety area around wind farms. Each of the four different information sources are discussed separately.

3.1 Document review

After reviewing all documents, it is noted that the main dossier "*Uitwerking besluit doorvaart en medegebruik van windparken op zee*" (MIeM-RWS, Dec. 2015) with its attachments (MIeM-RWS, Dec. 2015) give a clear overview of the topic at hand. The proposed risk mitigating measures appear to be reasonable, under the condition of active monitoring and rule enforcement.

Regarding the information available on co-use of wind farm areas, by means of static fishing, aquaculture or tidal energy installations, it is difficult to perform the assessment. In the dossier used in the development of the proposed policy, these groups are mentioned, though not covered in deep detail. Techniques and methods vary and pose technical demands on the wind farm infrastructure in some cases, which are very case sensitive and (yet) unclear. To get a complete overview of these techniques, additional research on specific techniques would be necessary. Therefore, these risks are assessed as uncontrolled. The proposed risk control measures do not act on the possible hazards related to these co-use techniques. Before any of those techniques can be used, it is required to understand, quantify and control the risks.

Concerning Search and Rescue (SAR) operation, two SAR exercises were dedicated to operations within wind farms. Based on these exercises it is concluded that SAR-operations in wind farms can be performed safely. Even though helicopter support is limited due to hinder of turbines, KNRM vessels can act effectively. Deployment of a helicopter inside the wind farm is possible, only with clear visibility (daytime) and when the pilot considers the operation to be within acceptable safety limits.

3.2 Stakeholder meetings

The main findings derived from the meetings with the operators of OWEZ (Noordzeewind), PAWP (Eneco) and Luchterduinen (Eneco), Rijkswaterstaat and the Dutch Coastguard are discussed. The former two are combined, as much of their input point to similar concerns. The latter two organizations are discussed separately.

Dutch Coastguard

Breaching of the exclusion zone happens every now and then. Main offenders seem to be fishing vessels, which try to stretch the bounds or to cut the corner of the exclusion zone around a wind farm. Safety-/exclusion zones are said to contain more fishes, which makes it attractive spots. It concerns 25-30 official intrusions of safety zones yearly. This includes zones around oil rigs and other offshore zones as well (RWS - Bijl01, Dec. 2015).

For offshore wind farms, no specific records are available. Violation of any zone can lead to a fine when a ships location and its ID are known. This starts with monitoring the safety areas by radar and AIS, if needed, ships are called by VHF to inform about a violation. Also, the coastguard performs routine flights to check on any violations of rules offshore regularly. Each flight, the three wind farms are checked as well. The last option, though an expensive and general inefficient method, is to send a ship for physical presence. Overall, the wind farms are part of a greater system that requires the coastguard's attention. It is unrealistic to claim that each violation now is recorded and acted upon, neither will this be the case in the future.

In case wind farm operators or maintenance crews notice an intruder, they can contact the coastguard and add to prosecutor files. Enforcement of the proposed mitigating zone, a 50-meter zone around turbines, will not be visible with AIS nor radar monitoring. The resolution of these systems will not be sufficient to detect an intrusion of such a zone, unless they have local receiving AIS stations or radars.

Concerning the risks under water, it is expected that the anchors of smaller vessels will have little influence on cables. The shape and weight of these anchors are such that damage on impact with cable will be negligible. When hooked, an attempt to lift the anchor will be noticed quite certainly. If no further recovering attempts are made, this limits the change of damaging the cable.

Overall, the proposed allowance for ships up to 24 meters will not introduce a significant increase of the risk. Instead, it is to expect that the largest risk to the turbines comes from the drifting of large ships. In case a large ship drifts into the wind farm, the change of damage to turbines or to underwater infrastructure, is much larger. In this case, the weight, and hence the size, of the ship will be decisive.

Wind farm operators, Noordzeewind and Eneco

The wind farm operators stress that they are concerned about their business. The operation is on a tight financial margin, as systems are relative old. They date from a period when offshore turbines where a new kind of turbines, with little experience available on the effect of offshore conditions on the installations. Any error or extra damage to e.g. an infield cable puts the existence of these wind farms at risk. Therefore, the proposed relaxation of the safety area is treated with caution.

The main difficulty is the design of the wind farm. Transit and co-use was not accounted for in the original design, as it was explicitly agreed upon in the tender not to do. This is an important point when comparing the Dutch offshore wind farm with e.g. the Danish or United Kingdom wind farms. Here, co-use and (free) transit was generally agreed upon before wind farm construction began. Outfitting the present operational Dutch wind farms will be a costly act, without benefits for the operators.

In the proposed regulation it is assumed that offenders effectively can be traced down. Then, in case of any inflicted damage, the operator can be compensated accordingly. The wind farm operators experience that the coastguard is having trouble to protect the current safety zone already, hence they have low expectations for the future regarding tracking, tracing and if needed prosecution. They worry that, even if they are compensated (fully) for their losses, the trajectory leading to the compensation will take too long. While on the other hand, they will have to respond on any damage as quick as possible, which puts pressure on their business.

Though the option to initiate or add to the Coastguard prosecution files is available, it is difficult to file a case for the wind farms. Since monitoring of the safety at sea is governed by the Dutch Coastguard, this was left out of the wind farm business case. Operators have O&M personnel physically present in the wind farms regularly and have filed cases of safety zone breaches to the coastguard, though without success. Also, it proves to be difficult for O&M personnel to document intrusions properly. Mainly because their focus is on their work in the wind farm, and possibly because it appears that many of the crew members are from the same social community as the offending crew.

Successful persecution is important for the operators reporting intrusions, because it makes the monitoring efforts meaningful. Physical enforcement of for example a surveillance vessel near and/or within the wind farm area could have added value for deterring and persecution. Though active persecution is found important, it is stressed, especially by Noordzeewind, that persecution of intruders is not desired at all. They would rather prevent any violation, which would reduce recurrence of accidents to a minimum and keep the image of the wind farm on the positive.

The wind farms are outfitted with AIS-B devices, which mainly to send out AIS signals which mark the wind farm areas. These AIS devices do have a receiving option as well, though the receiving capability is limited. Currently, a message is sent by e-mail when a vessel enters the pre-set 500m exclusion zone around the wind farms. This message only gives a single timestep location of the vessel, making it useless for any further steps. Eneco was listed to receive these e-mails but could not act accordingly with this information and abandoned this list.

When the safety zone would be removed, it is to be expected that more ships will sail through wind farm areas. Besides an increase of hinder and changes of accidents between O&M vessels and passing ships, it also increases the chance of accidents of a passing ship itself, which then might call for assistance. Assistance will be required from the nearest available ship, i.e. probably an O&M vessel. Typically, O&M crews are not trained for SAR operations apart from their own safety. While assisting in SAR operations, they are exposed to additional risks to themselves and they lose valuable time they could spend on their actual job.

In general, above comments were voiced in 2015 as well (Chris Westra Consulting BV - Bijl12, July 2015).

Concerning the idea of static fishing, deployment of tidal energy and aquacultures the following was noted. The main philosophy of the wind farms is to add to a sustainable environment by generating sustainable energy. With the current safety zone in place, the wind farms are expected to serve as an area where fishes and other sea creatures can live and bread safely. This perfectly adds to the sustainable environment, hence the idea of testing or allowing other fishing methods are faced with reservations. This in contrast to the idea of deployment of tidal energy of aquaculture systems. If there were a group that would, seriously, mean to test and develop any of those systems, they would be welcome to explore the options. However, these groups appear to be rare or actually non-existent, at least for this moment. There has been a call for aquaculture pilots in one of the wind farms, which was left without any response.

Rijkswaterstaat

Rijkswaterstaat is aware of the current trespasses of the safety zone, though it is mentioned this merely concerns ships that cut the corner or misinterpret the location of the boundary. Experiences from the UK show that the traffic will increase in the first three months off opening. After this period the farm will have almost no ‘spectators’, only sailors that are on a route and want to cross. Sailors on route generally make sure they are well prepared before they leave port, hence they will be aware of the risks when transiting wind farms.

Besides, in the current situation these sailors will sail around the wind farm, where accidents influencing the wind farms can happen as well. The proposed opening will not change much of the frequency of occurring and possible impact of these hazardous situations near wind farms.

It is noted, that even without the mentioned awareness, sailors will think twice before closing in on a turbine, or even climbing it. It is rather obvious that this involves certain risks, which put your own ship or even life at stake. Acts involving people closing in or climbing wind farm assets will be left to willful people, looking for a thrill or with other (criminal?) thoughts, or people in distress.

The main risks from Rijkswaterstaat point of view, are the large route bound ships. When they face a failure or accident and get drifted, the impact of collision or anchor dragging will be much larger compared to a fisherman with his relatively small and light ship.

3.3 Factsheets

Information on the design and operations of the three analyzed wind farms are gathered in separate factsheets. The information supports the identification of hazards and consequences within the subsequent risk assessment. In Appendix D, the entire factsheets are printed, while below a discussion on this information is printed.

Location, currents and waves

Seen from the closest shore, the minimal distance to the OWEZ wind farm is 8 km, while both PAWP and Luchterduinen are located at a minimal distance of 23 km from the coast. Though clearly visible in good weather, these are considerable distances which are not travelled by the average recreational sailor. Still, sightseeing visits are possible.

At the wind farm location, sea current and waves combined are responsible for sediment transport on the bottom. As a result, sand waves travel the seabed. Though both infield and export cables are buried to 1.5 m depth at construction, they can partly be uncovered due to the sand waves. In case a cable gets uncovered, the risk of damage increases. Damage can occur either by hooking or due to a fatigue fail mechanism in which the cable core is cracked while exposed on the bottom. Also, the sea currents are known to cause scour areas near the monopile foundations.

The potential for uncovering of in-field cables makes that anchoring, or a vessel with dragging anchor pose a threat to both infield- and export cables. Also, the use of fishing equipment with dead-weight anchors, use of long lines or static netting are a hazard for the in-field cables. Besides, the currents indicate that it will be difficult to set up static nets or the use of long lines. These are positioned in line with the sea currents which crosses infield cables and possible turbine monopiles.

Operations and maintenance and weather limits

O&M activities on the wind farm installations are performed by work teams which are brought to the site by Crew Tender Vessels (CTVs). These CTVs can carry up to three work teams, which may be deployed on different turbines within the wind farm, depending on the work required. The work teams are brought to the foot of the turbine, where they climb up the transition piece using a ladder.

Work and inspections can be done both inside and outside the turbine. Especially when work is carried out on the exterior, the crews have to take care of their tools and materials to prevent dropping objects. To reduce the time spent on the exterior, inspections are carried out using drones lately, which are controlled from a CTV. Though this reduces the risk to work crews, extra safety precautions are taken in the area where the drown is flown.

To ensure the crew a safe passage between CTV and turbine installation, work is limited by sea state. Waves must not exceed 1.5-2 meters to allow for O&M operations to be carried out. In practice, this means work is limited to the summer period, as in winter the waves generally exceed this limit. With most of the work activities taking place in summer, this coincides with the recreational sailing season. Hence, changes are that recreational ships, besides the fishermen, interfere with the work teams.

On an average work day, two CTVs will go out to the wind farm. However, the number of active vessels can increase up to seven. In that case, larger repairs and replacements will be carried out, often using a jack up barge, which includes a crane to lift large part like turbine blades or generators.

The subsea parts, i.e. electric cables and turbine foundations, are inspected as well. These inspections are performed using ROV (Remote Operated Vehicles) in general. The use of divers is prevented to reduce risks, they are called in, only if necessary.

The information on maintenance vessels, crews, qualifications and procedures can be found for example in (GPlus, 2017).

3.4 Data and information from neighboring countries

The North Sea, with her relative shallow waters, provides a good environment to deploy offshore wind farms. Hence, offshore wind farms are deployed in neighboring countries as well, raising similar concerns to the local governments as the topic at hand. Policies and experiences regarding co-use and transit of offshore wind farms differs from country to country. Therefore, a questionnaire was send out to different stakeholders to learn from their knowledge.

Responses were received from two wind farm operators in the United Kingdom (*Gwynt y Mor Offshore Wind Farm Limited* and *E.On Climate & Renewables UK*) and governmental organizations in Belgium (*Federal Government Mobility and Transport – Shipping Department*) and Denmark (*Danish Maritime Authority*). A response from German authorities was not available at the time this report was written.

Additionally, the UK Maritime & Coastguard Agency (MCA) has been issuing navigation guidelines related to offshore renewable energy installations (MGN 372 and MGN 543), which contain both information on the experiences and the policies regarding transit and co-use of wind farms.

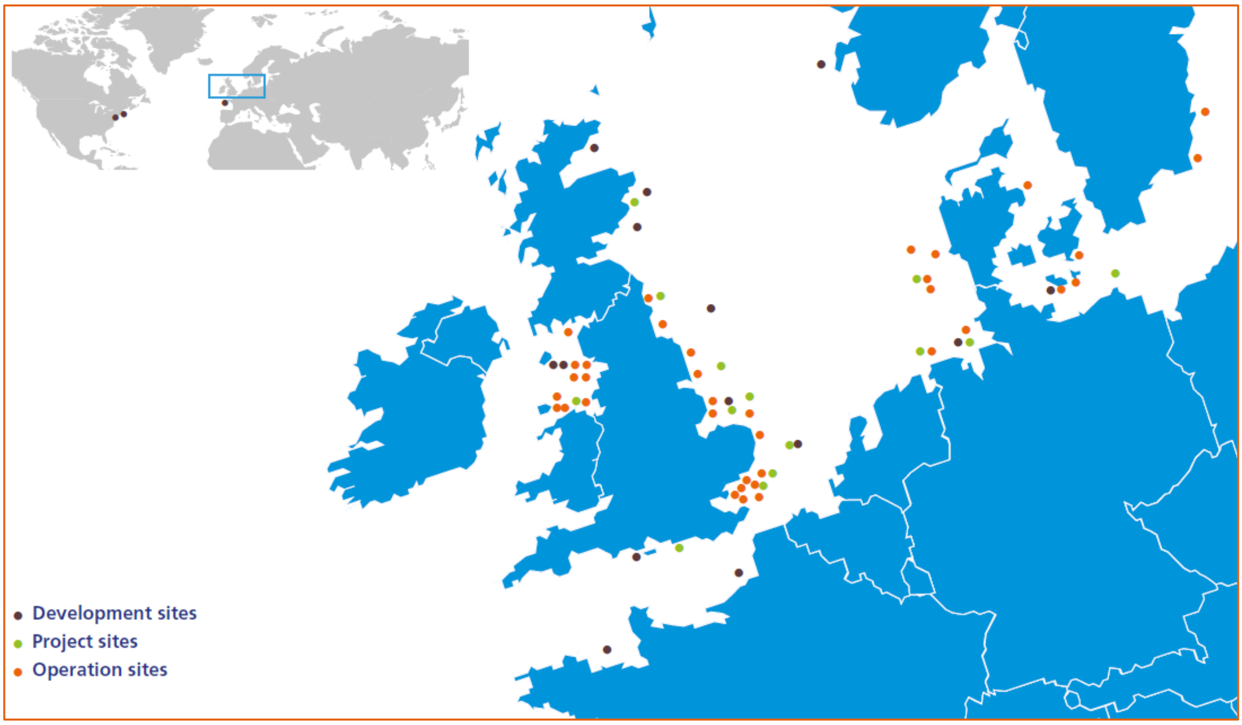

Figure 5. Location of wind farms in Europe within G+ initiative, 2016, G+ Global offshore wind health and safety organization 2016 incident data report, www.gplusoffshorewind.com, (GPlus, 2017).

Questionnaire topics

In the questionnaire, topics related to wind farm access policy were added. Also, question about allowance of third party vessels, the major concerns related to fishing or recreational activities in and around wind farms were posed. Finally, the occurrence of rule violations and accidents and the options to monitor the wind farms was questioned.

What caught the eye, is that there are no statistics available on near misses or accidents of small vessels within wind farms. This is remarkable, especially considering that wind farms in Denmark and de UK are open for transit in general, including wind farms that have been in operation over more than 10 years.

A subdivision can be made between Denmark and the UK on the one hand, and Belgium and Germany on the other hand. The former two countries generally allow for transit and co-use of the offshore wind farms, while the latter two protect the wind farms with a safety-/exclusion zone like the current Dutch policy.

Reasons and experiences closed wind farms

Main reasons to close off the wind farms are mainly a safety issue. To prevent damage to the wind farm assets and to minimize the change of accidents to happen in the area, an exclusion zone of 500 m is established around the wind farms in both Belgium and Germany.

In Belgium, the monitoring of assets is done using radar, AIS and monitoring by vessels. The latter are run by the wind farm owners. Intrusion of the safety zone happens weekly, most often by fishermen. As far as known, the intrusion has not lead to damage or lost work, however this comes with the effort of having monitoring ships on site.

Reasons and experiences open wind farms

In general, UK and Denmark wind farms are open for transit and co-use. This way they do not pose any hinder of free navigation at sea. Details on accessibility of wind farm areas are discussed at the start of wind farm planning. In the UK, most of the wind farm operators have mutual agreements with local stakeholders for good cooperation and to organize compensation of the area occupied by the wind farm. These agreements also cover a legal part in case third party users inflict any damage.

Monitoring of the wind farm assets are carried out by the operators themselves. Primarily AIS and radar are used, with some cases where CCTV is added on strategic locations. To contact other vessels, VHF is most commonly used.

The most serious threats to the wind farm infrastructure to be caused by fishing vessels are damages to cables (due to trawling and anchoring), entanglement of fishing nets, and to some extent the collision with the wind turbine. Fishing within an offshore wind farm is allowed in UK and Denmark, without limitation to the vessel size. In Denmark trawling is not allowed due to the danger to cables, in the UK, exceptions are made for single trawl fishing.

Though fishing is allowed, fishermen tend to avoid wind farms as noted by UK operators. Fear of accidents combined with a lack of knowledge of the underwater infrastructure makes they rather go to other fishing grounds.

Considering the small recreation vessels, people entering the wind turbine interior are the most serious threat. Next, the possibility of a turbine blade hitting the ships mast. These treats are followed by the possible collision of a ship with a turbine and subsequently getting crew stranded on the installation. The UK MCA strongly advises against entering turbines or transformer stations, though in some cases turbines are outfitted with first aid supplements.

None of the authorities mentioned interference of third party vessels with O&M activities, though a UK operator mentioned interference with static floating fishing gear. This specific issue was dealt with after contact between the operator and the fisherman. A UK wind farm operator comments that large maintenance (involving jack-up barges with cranes) is actively supported by MCA by issuing local temporary access limit to 500m area around these vessels.

Common remarks

To increase safety, new wind farms are planned on a safe distance from traffic lanes occupied by large vessels. Also, damaging a sub-sea cable or pipe is an international offence, hence it is strongly recommended to avoid anchoring in or nearby wind farms (MGN 372 and 543).

Also, wind farm service vessels do participate in SAR actions within and outside of wind farms, in coordination with the SAR center (in BE they only participate in exercises). A large UK wind farm operator indicates that within wind farms SAR action is extended to all vessels, outside wind farms it is under coordination of SAR center.

3.5 Remarks based on dossier study and meetings

In the present and the future system of risk mitigation, i.e. risk control measures, some components are to be considered.

Concerning the present and proposed future regulations, a clear responsibility to take care of the legal enforcement is given to state authorities, i.e. the Dutch Coastguard. Hence, monitoring of the assets, detection of offences and the provision of evidence for prosecution steps are the coastguard's responsibility. Wind farm operators are part of this system as well; they have access to the monitoring coastguards monitoring systems in their area and can add files of evidence to the prosecution dossier. Also, operators can file a claim on their own, which can be supported by the coastguard or other agencies. Nevertheless, the provided regulations direct this responsibility to state institutions at first.

Systems used for monitoring sea traffic and enforcement of regulations are maintained by the Dutch coastguard in cooperation with Rijkswaterstaat. Monitoring is done using radar, AIS, vessel- and airplane patrols. Together with VHF communication, these systems are used to provide information for sailors, effectively coordinate SAR operations in case of an accident, or to provide evidence in case an offence is suspected. The areas of OWEZ, PAWP and Luchterduinen are tested and have good coverage for ships with a size larger than 10-12 meters long. To be able to efficiently receive signals of smaller ships, either the systems need to be extended or upgraded.

4 INDENTIFICATION OF HAZARDS

This chapter presents an overview of the hazards that were identified in the risk assessment dossier. A distinction has been made in the identified hazards from the documentation up to the former risk assessment from 2015 (section 4.1) and the additional hazards that have been identified in more recent documents and developments (section 4.2). Though the focus in this report is on OWEZ, PAWP and Luchterduinen, the hazards that have been identified apply to wind farms in general.

4.1 Hazard groups

Based on the study dossier, a list of hazards was derived. Main purpose of this list is to get an overview of the things that can go wrong. This list is the main input for the risk analysis itself and was crosschecked with the windfarm operators and Rijkswaterstaat. Though no risk study was performed by the government in the trajectory leading to the proposed policy from 2015, a great deal of the hazards was covered in the policy dossier. For the sake convenience, only the 13 hazard groups are printed here. The total list of hazards is printed in Appendix F.

In the table below, thirteen groups of hazards are printed which were identified after reviewing the project documentation.

Table 3. List of the 13 hazard groups.

Transit and co-use vessels
1. Accidents with DoMe vessels, requiring SAR action;
2. Interaction of DoMe vessel with turbines;
3. Interaction of DoMe vessel with transformer stations;
4. Interaction of DoMe vessel with in-field cables;
5. Interaction of DoMe vessel with O&M vessels;
6. Interaction of DoMe vessel with divers and ROVs (survey vessels);
7. DoMe vessel crew entering turbine installation;
8. DoMe vessel crew entering transformer station installation;
9. Non-permitted ship uses the wind farm.
Co-use methods
10. Static fishing, static netting and lines;
11. Static fishing – Trap fishing;
12. Interaction with/caused by deployment of tidal energy device;
13. Interaction with/caused by deployment of aquacultures.

4.2 Additional hazards after 2015 proposal

During the stakeholder sessions, from the questionnaires and while reviewing additional documents, several extra hazards were identified. These new set of hazards substitutes the hazards that were part of the 2015 decision dossier. In Table 3, an overview of these added hazards is given. In the overview of hazards in Appendix F, these additional hazards are marked.

The reason for this distinction is to clarify what issues were already part of the scope in the risk assessment of 2015 and what were the additional issues. They arose as a result of new regulations, new insights and new developments in the wind farm sector.

Table 4 New identified hazards.

Hazard group	New identified Hazards
2. Interaction of DoMe vessel with turbines:	c. Collision of a vessel with a turbine J-cables; d. Collision of a vessel with turbine blade; e. Ice thrown from turbine blade on DoMe vessel.
3. Interaction of DoMe vessel with transformer stations:	c. Collision of a vessel with J-tube export cables.
4. Interaction of DoMe vessel with in-field cables:	f. Sinking ship landing on infield cable; g. Other tools/parts of ship dropped on infield cable.
5. Interaction of DoMe vessel with O&M vessels:	e. Falling objects from O&M vessel (crane).
6. Interaction of DoMe vessel with divers and ROVs (survey vessels):	g. (Unmarked) fishing gear (ropes, nets) gets in recreational diver's way; h. Drifting collision with a recreational diver vessel; i. Powered collision with a recreational diver vessel.
7. DoMe vessel crew entering turbine installation:	f. Injury to windfarm personnel when taking people off the installation.
8. Interaction with/caused by deployment of tidal energy device:	a. Obstacle in water, i.e. marking buoys; j. Interference with O&M vessel performing maintenance activities; k. Interference with ROV or survey activities as result of trap location; l. Interference of tidal energy infrastructure with wind farm infrastructure.

5 RISK ASSESSMENT

This chapter analyses the risks and hazards that are idenitified and discussed in chapter 3 according the the probability of occurrence, the consequences and the effectiveness of the current and the proposed regulations in the risk mitigation. Once the risk assessment is finalized in the first paragraph, the risks and hazards are interpreted in a broader context and translated to the impact and control measures that will follow, see section 5.2.

5.1 Risk impact analysis

In this section, each hazard group as defined in chapter 4.1 will be commented upon per risk table. For each hazard group, an overview of the including hazards will be given, with a description of the impact and frequency of occurance in the present situation. This will be followed by the changes occuring in case the safety zone is opened. The effect of mitigating measures will be discussed, concluding with the residual risk. In short per hazard group:

a. Overview of hazards;
b. Impact and frequency in present situation;
c. Changes in future situation with opened safety zone;
d. Effect of mitigating measures;
e. Residual risk.

In Table 4, an overview is given of the risk score table, used to determine the risk level based on impact and frequency of hazards happening. An explanation of the risk tables is given in Table 5 and Table 6. The actual risk tables, Table 7 - Table 32, all tables are printed in Appendix H.

General comments

If the exclusion zone around wind farms is (partly) removed, this will change the way vessels are spread around the area and its proximity. Currently, vessels are directed around the wind farm, which leads to a relative higher density of ships on the bounds of the exclusion zone. When ships are alowed to sail through the wind farm, the density of vessels inside the wind farm will increase, while the density on the former boundaries will decrease. Though the chance of accidents in the wind farm will increase (MARIN, 2003), this chance will decrease just outside the former bounds. That is, if the assumption of the correlation between area vessel density and probability of accidents holds[3]. It is speculative whether the accident rate will change accordingly, or that the larger spreading of vessels might decrease the accident rate. For now, there is no data available (as far as the authors know) that enables to make evidence-based predictions. The quantitative studies to estimate collision risk mainly use models based on route-bound vessels, which is not necessary applicable when estimating small vessel collision risks (MARIN, 2013).

Monitoring of assets by e.g. AIS, visual and radio contact, is considered to be important for preventing situations that might have more grave consequences. For example, radio communication prevents further intrusion into the wind farm area (MGN 543 (M+F), 2016) (MGN 371 (M+F), 2015) (Chris Westra Consulting BV - Bijl12, July 2015).

In case of a collision, it is to be noted that powered collisions are most likely the more hazardous kind, compared to drifting collisions. In a powered collision, a higher amount of energy is contained in the moving ship. At impact the energy level is an important factor in the resulting damage.

5.1.1 Accidents with DoMe vessels, requiring SAR action

This group applies to third party vessels (DoMe-vessels) which are in distress within the wind farm. In Table 7 and Table 8 an overview of the risks is printed.

Hazards

1. Man overboard;
2. Injury / serious sickness onboard;
3. Fire and injury onboard, disabled vessel;

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[3] The models of collisions and accidents, like SAMSON (used in (MARIN, 2013)) assume constant failure frequency rate (event/year). However, the assumption is not valid – accident frequency depends on navigation area, vessel age and maintenance, crew training and onboard procedures. These aspects can alter.

4. Disabled and drifting vessel;
5. Disabled and sinking vessel;
6. Collision between two vessels, disabled, injuries, sinking/drifting.

Impact and frequency in present situation

In the current situation, third party ships are directed around the wind farms. However, these ships can enter the area still, either accidently (lack of knowledge or while drifted) or on purpose. Based on the information found in the study dossier, frequency was set to be 1 in 10 years (B). Based on the dossier, meetings and expertise, the frequency is lifted for hazard 1.2 to 1 in 3 years (C); injury or seasickness do occur quite regular, though are usually not reported.

Impacts of the hazards range from mediate to important, according to the study dossier. In case of hazard 1.5 and 1.6, these impacts are considered to be severe (4), one level higher. Apart from possible human injuries, the financial impact can rise above € 10M.

Changes in future situation with opened safety zone

In case the exclusion zone is opened, the frequency of hazards will increase in all instances. That is, looking at the wind farm area solely without considering the near vicinity.

Effect of mitigating measures

It is expected that use of VHF and AIS will have effect on each hazard. In case of distress, these systems help to determine location and improve communication with vessels out on the water. For hazard 1.1 – 1.3 the frequency is not altered since VHF and AIS will not have a preventive but rather an effect when the hazard has occurred.

The frequencies of hazard 1.4 – 1.6 are influenced by use of AIS and VHF. Collision courses can be detected and communicated. Also, extra awareness can be created using information campaigns preventing sailors to use e.g. anchors in case of distress. By limiting vessel sizes, impact is limited as well.

Residual risk

The residual risk is comparable to the risk in the current situation. Hazard 1.1 – 1.4 are low, while the 1.5 and 1.6 hazards are medium. The main reason is the impact level, which is difficult to reduce since the impact of having fatalities and/or a sunken ship are considerable.

5.1.2 Interaction of DoMe vessel with turbines

This group applies to third party vessels which somehow interact with a wind turbine. Table 9 and Table 10 in Appendix H are dedicated to the risk tables belonging to this hazard group.

Hazards

1. Collision of a vessel with a turbine pile;
2. Collision of a vessel with a turbine landing;
3. Collision of a vessel with a turbine J-cables;
4. Collision of a vessel with turbine blade [note: scenario added in 2017];
5. Ice thrown from turbine blade on DoMe vessel [note: scenario added in 2017].

Impact and Frequency in present situation

Except for hazard 5, each of the hazards is estimated to occur 1 in 10 years (B). Even with exclusion zone, these situations can occur, either due to an accident or due to persons whom enter the wind farm on purpose. Hazard 5 is estimated to have a probability of less than 1 in 10 years. Though icing is an existing issue, the chance of icing situations in which a third-party vessel is nearby and actually hit by a piece of ice is very small.

The impact of these hazards is set at Important (3), except for the second hazard, which is assumed to be Mediate (2). At impact, a vessel can cause damage to the turbine (part) which can hinder production. Together with the loss of production, extra maintenance will be required to repair the damage. Costs can rise to some million euros. Also, impact or when hit by thrown off ice, personal injury can have a major health effect.

Hazard 2 is the one hazard with a lower impact level. The financial damage is assumed to be lower since no critical parts are exposed on the landing. Damage can occur with lower impact energy, which limit the possible injury of the vessel's crew.

Changes in future situation with opened safety zone

Hazard 1-3 are assumed to have an increased probability, up to 1 in 3 years (3) due to the allowance to enter the wind farm area which increases traffic around the turbines. Hazard 4 and 5 are not altered in probability; the number of vessels with a mast high enough to be hit by turbine blades are limited (hazard 4), and the chance that ice is thrown off with impact on a third-party vessel does not influence the probability enough to increase the level.

Effect of mitigating measures

The planned new regulations will be particularly effective for low energy collisions that would result from conscious incursion into 50m exclusion zone around a turbine. Similarly, limiting the navigation within the wind farm area to the daytime will be effective in controlling the collision risk due to bad spatial orientation in the wind farm at night. The required communication onboard would mitigate the consequences like flooding or sinking small vessels in case of a collision, or when handling a man-overboard situation.

Requring of AIS onboard gives a better overview of navigation situation on the wind farm area. Information like behaviour guide lines can be an aid as well (KNWV-NPvW - Bijl16, Mei 2015) (RWS - Bijl09, May 2015) (The Royal Yachting Association and the Cruising Association, 2004).

The data from UK on the height of yacht masts (The Royal Yachting Association and the Cruising Association, 2004) indicate that only 4% of yachts have masts higher than 22m. This and the 50m exclusion zome make the collision with turbine blades very unlikely (Chris Westra Consulting BV - Bijl12, July 2015).

Residual risk

The residual of each hazard is low level. Collisions, if occurring are drifting accidents or conscious violations. The latter case is un-controlled in any situation and therefor can happen in present situation as well.

To further reduce the residual risk of icing, there is a possibility to issue warnings in case of icing on turbine blades. This can either be derived based on meteorological data (Ilinca, 2011) or by measurement of turbine production as reported by (Etemaddar, Hansen, & Moan, 2014)). The availability of radios and VHF onboard to issue warnings, and information campaigns will further reduce the risk due to this hazard.

5.1.3 Interaction of DoMe vessel with transformer station

In this hazard group, collisions of third-party vessels with the transformer station (if on site) are described. Table 11 and Table 12 in Appendix H present the risk tables which are part of this hazard group.

Hazards

1. Collision of a vessel with a station base (foundation);
2. Collision of a vessel with a station landing;
3. Collision of a vessel with J-tube export cables [note: scenario added in 2017].

Impact and Frequency in present situation

At present there is a chance that small vessels navigating in the buffer zone around wind farms would collide with transformer station; such a probability is lower than collision with turbines, since the transformer station is located within the wind farm area and it is a single installation. No such events were mentioned during stakeholder meetings, nor were they reported in foreign surveys (GPlus, 2017). The propability is assumed to be an occurance of 1 in 10 years (B).

Impact could either have a major health effect and/or cause financial damage resulting the impact level to be set at Important (3).

Changes in future situation with opened safety zone

The (partial) opening of the 3 wind farms for small vessels will somehow increase the probability of collision with the transformer station, due to increase of the density of small vessel traffic on the wind farm area. However, one may expect that the dominant collision types will be low energy ones, caused by drifting vessels and vessels planning intrusion

Effect of mitigating measures

The exclusion zone will reduce the chance of conscious approaching the transformer station. The requirement of operating AIS and VHF radio communication can help to inform crews when unauthorized approaches are detected and it will help in case of rescue action. Information campaigns will create awareness of the risks and will reduce the number of concious violations.

Residual risk

The residual risks are low level, comparable to the current situation. Either vessels can drift into the transformer station or a conscious decision is made hit or attempt to enter the transformer resulting in a collision.

5.1.4 Interaction of DoMe vessel with in-field cables

In this group, interaction of third-party vessels with sub-sea wind farm infrastructure is discussed, i.e. the in-field cables which connect the turbines to each other and the transformer station (if applicable). In Appendix H the two related risk tables are printed, referring to Table 14 and Table 15.

Hazards

1. Anchor dropped on the cable;
2. Anchor dragged over the cable and hooks on the cable;
3. Fishing gear hooked on the cable/connector and dragging;
4. Sinking ship landing on infield cable [note: scenario added in 2017];
5. Other tools/parts of ship dropped on infield cable [note: scenario added in 2017].

Impact and Frequency in present situation

The impact of the described hazards when occuring are assumed to be Severe. The main consequence is damage to a cable, which leeds to a loss of production. The main issues is replacement of the damaged cable. Costs are dependent on spare part policy, but in general are costly both in terms of finance and time. In case of cable damage, loss of production is very dependent on location and on season of the damage. In general, turbines are interconnected in strings before a connection is made to the transformer or export cable. A single crack can disconnect a string of several tubrines.

To initiate a replacement campaign, costs, including loss of production can rise above € 10 M, hence the impact level is assumed to be severe (4).

In the current situation, probability of these hazards are low. A case of anchor dragging over an export cable was noted in a stakeholder meeting, as are cases of similar hazards caused by trawling gear hitting a cable (DNV, 2010) (DBERR, 2008). Seen these reports, the probability of hazard 1-3 are assumed to be 1 in 10 years (B). Hazard 4 and 5 are assumed to occur less than 1 in 10 years (A). The main reason is the current restriction area, which generally keeps out third-party vessels. This seems to be effective in these cases as no report of occurances of these hazards in wind farms are known to the authors.

Changes in future situation with opened safety zone

The proposed relaxation of the safety zone will increase the probability of each hazard. Allowing third-party vessels in the wind farm area will increase the probability of hazard 1-3 to a 1 a year level (D), while hazard 4 and 5 increases to a 1 in 10 years probability.

Effect of mitigating measures

Tracking by AIS and radar, combined with the obligation of using VHF minimizes conscious anchor dropping or use of trawls in wind farms. The AIS allows for precise determination of location within the wind farm, toghether with information campaigns, this should help to avoid anchors or fishing gear to be dropped or dragged over cables. Estabilsment of exclusion zones around wind turbine or transformer will not influence the risk related to these hazards as cables run across these areas, outside the exclusion zones.

Information campaigns reduce the chance of incidents like dropping of a dead-weight anchor on the cable (North Hoyle Offshore Wind Farm (KIS-ORCA), 2016). Also, allowing only small vessel size into the wind farms will limit the size of objects onboard (e.g., no containers), so only small objects can be dropped.

Residual risk

The residual risk is on the same level, Medium, as the current situation, though slightly altered. The probability of the first three hazards will be higher than at the present level. Without the set of regulations, the Risk will be High. Due to the mitigating measures the probability is estimated to be C and thereby the risk comes to the same level as in the present situation.

Combined with the consequences of the hazards, the risk is set to medium level. In case the impact level would be reduced, a low risk level would be achievable. However, to reduce impact, extra protection of cables would be necessary. The cost-benefit of this exercise is out of scope of this analysis.

Small additions to the system, like regular and accurate mapping of cables via survey and making the location data (charts) available for navigators would further limit the chances of anchoring over cables even in emergency situation.

In addition, one might consider the risk of larger vessels anchored ouside but near wind farm areas. Expecially in bad weather, anchor dragging can occur. In case such a vessel is directed towards the wind farm or export cable, impact would be certainly severe. But this risk is not influenced by the opening of the wind farms. Though probability of such event is low, awerness is important. In case a ship hooks a cable, the one and only response would be to release the anchor and report.

5.1.5 Interaction of DoMe vessel with O&M vessels

The interaction of third-party ships, sailing through a wind farm, with O&M vessels which are working on the wind farm, is discussed in this hazard group. Table 15 and Table 16 show the risk tables which belong to this group, see Appendix H.

Hazards

1. Un-marked fishing gear (ropes, nets) gets into the propellers of O&M vessels;
2. Intrusion into an exclusion zone, creating danger and averting the attention of the crew from the work;
3. Drifting collision with O&M vessel;
4. Powered collision with O&M vessel;
5. Falling objects from O&M vessel (crane) [note: [note: scenario added in 2017].

Impact and Frequency in present situation

Eneco and Noordzeewind shared reports describing intrusion of the safety area by third party small vessels, hazard 2. Due to these intrusions, the maintenance crew were distracted and in some cases the CTV vessel had to move over in order to secure the perimeter. Impact of this kind of hazards are Minimal (level 1), though the disruption of maintenance work can be relatively costly. The same goes for the first hazards, where impact is limited to lost time of maintenance.

Hazard 3 and 4 were defined a level 4 impact in the 2015 dossier, assuming major costs and the loss of 1 to 3 lives. Based on meetings and expertise, this level is assumed to be slightly lower, level 3, which is comparable to the impact of hazard 5

The probability of the first two hazards is set to a level B, 1 a year, as a result of the operator reports. For hazard 3 and 4, this level is set to a 1 in 10 years, similar to comparable hazards in previous risk tables. Hazard 5 is assumed to have a possibility B aswell, though objects or tools are dropped quite regularly, the combination with a (third-party) vessel being present right under this object, is unlikely and no reports of such occurances are known to the authors.

Changes in future situation with opened safety zone

The probability of interaction between small vessels and O&M vessels in wind farm areas will increase, because of increase of the density of small vessels on the wind farm areas. It is not expected that the opening will affect the number of instances where O&M vessels catch a piece of fishing gear or rope. Such pieces of debris float with tide and waves.

Effect of mitigating measures

Monitoring system, in particular AIS, allows to track small vessels which provides information on incoming ships that might cause hinder. The requirement of maintaining VHF radio communication makes possible to warn vessels which come to close. The communication campaign will increase awareness of hazards and will reduce the conscious violations of the exclusion zones where the O&M vessels operate. Toghether, the proposed rules reduce the probability of hazards to occur, except for floating fishing gear, as pointed out in the above.

Residual risk

With the proposed mitigating measures, the residual risk returns to a low risk level for each hazard, similar to the present situation. In particular, it is expected that the awareness resulting from information campaigns will help to reduce the probability of hazard two, intrusion into an exclusion zone. Currently, little is known as little information is known. Clear and regular communication would be helpful.

At present the marine crew of an O&M vessel is expected to maintain a watch for events occurring in its neighborhood (RWS - Bijl11, Dec. 2015); therefore introducing small vessel presence on the wind farm area will not change the situation of the maritime crew (similar workload is expected).

Introduction of a 500 m exclusion zone around crane barges could help to reduce the risks caused by falling objects further down. This can help to reduce loss of work due to third-party vessels coming to close. This same rule is used in the UK (MGN 543 (M+F), 2016).

5.1.6 Interaction of DoMe vessel with divers and ROVs

ROVs are deployed to assess the under-water infrastructure of wind farms. Assistance from divers is very rare, and only allowed in case the ROV is not able to perform a certain task. This hazard group describes the hazards involved. Table 17 and Table 18, printed in Appendix H show the risk tables that belong to this group.

Hazards

1. Un-marked fishing gear (ropes, nets) gets into diver's way;
2. Un-marked fishing gear (ropes, nets) gets into ROV's way;
3. Drifting collision with a diver vessel;
4. Powered collision with a diver vessel;
5. Drifting collision with a ROV mother vessel;
6. Powered collision with a ROV mother vessel;
7. (Unmarked) fishing gear (ropes, nets) gets in recreational diver's way [note: scenario added in 2017];
8. Drifting collision with a recreational diver vessel [note: scenario added in 2017];
9. Powered collision with a recreational diver vessel [note: scenario added in 2017].

Impact and Frequency in present situation

The probability of each of the hazards was assumed to be level B in the dossier, as far as it was considered. Based on additional reports and meetings this is shifted to level A. Usually actions involving ROVs or divers are well prepared and monitored, which makes that the described hazards rarely occur (level A).

However, when hazards like those described here do occur, impact is Important (3) or Severe (4). Especially when divers are involved, lives are at stake. This is the case for hazard 1, 3, 4 and 7. In case of hazard 5 and 6, the financial damage can include both ROV and damage to the mother vessel, which is assumed to be several millions and worst case higher then € 10 M, which results in a level 4 as well.

Changes in future situation with opened safety zone

The future situation will increase the density of small vessels on the wind farm area, hence the probability of collisions. For conscious actions this not necessarily is the case, since the working vessels display notices and signs requesting others to keep wide berth from the working area.

An exception of the increase in probability is made for hazard 1. Reasoning for this point is the same as for hazard 5.1.

Effect of mitigating measures

Use of AIS and VHF will allow for monitoring and making contact with vessels nearby. This decreases the frequency of incidents. Relatively small vessels have lower potential for damages to diver vessels, which makes the 24 meter size limit effective. Prehibiting fishing by trawling, an imposing fishing gear to be kept above the waterline reduces the chances of loosing gear, or submerged collisions between gear and ROV or worst case, a diver.

Residual risk

With the mitigation regulations in place, the residual risk is assumed to be similar to the present level. Even though interactions may occur more often, the probability will not rise significantly. The impact stays severe in some cases. This is due to the value of the equipment and the lives at stake. The latter is only the case when divers are active, which is a rare case.

In addition, it is noted that recreational diving is prohibited, according to proposed new regulations. This will keep probability of related events at very low level and equal to the present situation.

5.1.7 DoMe vessel crew entering turbine installation

In this hazard group, hazards are described involving third-party persons entering wind farm assets. The corresponding risk tables are printed in Appendix H, Table 19 and Table 20.

Hazards

1. Injury while moving over the turbine installation;
2. Man overboard while moving over the turbine installation;
3. Damaging the turbine installation;
4. Injury in closed (electrical) part of the turbine;
5. Injury while transferring to/from vessel to turbine ladder
6. Injury to windfarm personnel when taking people off the installation [note: scenario added in 2017].

Impact and Frequency in present situation

In the present situation, the probability of hazard events is 1 in 10 years (B). Little is known about these hazards; some events were reported by hear-say. Since no way of monitoring is available to know the actual rate, this frequency seems to be subjective.

The impact of the listed hazards however, can be of Important level (3). Untrained people entering wind turbines are exposed to serious injuries when moving on to, or over a turbine installation. Initially, the sixth hazard was rated a Severe impact (4), however this set equal to the impact level of the other hazards. Wind farm personnel is trained to move on and over the installations and knowhow to deal with the hazard.

Changes in future situation with opened safety zone

At opening of the wind farm, the increased density of traffic inside the wind farm could result in an increase of the frequency of people entering wind turbines, though this effect is assumed to be marginal. In general, people taking the risk to close in to these structures are aware of the risk they take, and they act willful or driven by a distress situation. A safety zone will not keep those people out.

Effect of mitigating measures

The enforcement and communication of the existance of a safety zone might reduce the frequency of occuring slightly, however this will be marignal. AIS and VHF could be used to monitor and contact vessels in distress or behaving strangely, though this not necessary affect the impact or frequency level. As noticed above, people climbing wind farm assets have a reason or bad intentions, which is not changed with these regulations.

Residual risk

The residual risk level is similar to the present risk level. The area around turbines continue to function as a buffer/exclusion zone and considering the number of reports, which are very limited, the probability of un-authorized people entering a turbine is low.

Means to reduce the impact level can be deployed, i.e. the safety of the installations could be improved. This could be achieved by installing fences to limit access and prevent people from falling or even entering the assets. Another option could be to install CCTV for monitoring together with lights/speakers activated on entrance of the turbine.

Additionally, it would be worth to consider outfitting turbines to function as a safe haven in case of distress. In addition, SAR teams of for example the KNRM could be trained to safely enter turbines during SAR-operations. This would reduce the stress which might be put on wind farm O&M crews which otherwise have to act.

5.1.8 DoMe vessel crew entering transformer station installation

The hazards involved when un-authorized people enter a transformer station are listed in this group. Table 21 and Table 22 in Appendix H show the corresponding risk tables.

Hazards

1. Injury while entering/leaving transformer station;
2. Injury while moving over the transformer facility;
3. Man over board while moving over the transformer facility;
4. Damaging the transformer installation;
5. Injury in closed (electrical) part of the transformer station.

Impact and Frequency in present situation

As far as concerned in the 2015 dossier, impact and frequency of listed hazards are comparable to the hazards from previous group, group 7. An exception is made for hazard 3, since the damage that potentially can be done on a transformer stations is larger than that in a turbine, e.g. by damaging critical parts in a transformer station could disconnect the entire wind farm from the electricity network with considerable loss of production. This Impact would transcend a loss of € 10 M.

Changes in future situation, effects of mitigating measures and residual risk

The changes due to the opening of the wind farm exclusion zone will be comparable, if not the same as the effects discussed in the previous group, hazard group 7. The same goes for the effect of mitigating measures and the residual risk

5.1.9 Non-permitted ship uses the wind farm area

This section describes the hazards in case a non-permitted ship, larger than 24 meters in length, enters the wind farm area. For this hazard group, no separate risk tables are constructed.

Hazards

1. Interaction with turbines;
2. Interaction with transformers;
3. Interaction within-field cables;
4. Interaction with O&M vessels;
5. Interaction with divers and ROVs.

Impact and Frequency in present situation

The above hazards are described in more detail in the above hazard groups, though applied on ships smaller than the 24-meter length limit. The frequency is assumed to be of same level. Like described in the above, only few reports contain records of incidents and intrusions. It is expected that the size limit mainly alters the impact level.

Vessels larger than 24 meters are heavier, which is a decisive aspect when it comes to potential damage. The higher weight results in a higher energy being contained in a sailing vessel. Also, these vessels are provided with more power. The increased weight will affect cases of drifting collisions, while the increased power will affect powered collisions. Also, the larger ships usually are outfitted with heavier anchors and other equipment as well, which has a higher impact on infield cables compared to the lighter versions.

Changes in future situation with opened safety zone

There is no basis to assume that the rate of incursions by larger than 24 meter length vessels will increase after partial opening of wind farms and introduction of new regulations. Therefore, it the risk level is expected to remain the same level.

Effect of mitigating measures

The proposed mitigating measures will have little or no effect on the proposed opening of the restriction area. On the one hand the selective opening might create confusion amongst captains, though information campaigns should take care of this confusion. Also, the new situations require the coastguard to increase their monitoring efforts around the wind farms, this should result in an improved enforcement of regulations and hence a reduction of offenders.

Residual risk

As impact and frequency do not alter significanlty, so won't the risk level. One might speculate that risk level slightly decreases as a result of an increased awareness, extra monitoring and reduction of vessel density in the area just outside the exclusion zone.

5.1.10 Static fishing – Static netting and lines

This section discusses the hazards involving static fishing using static nets and lines. Since this group describes hazards of activities which are currently not employed, only an interpretation of the risk level is given for the case this kind of techniques were to be used in an offshore windfarm. This is displayed in the first risk table, which is slightly altered from the risk tables as displayed so far. In the second table, the effect of the proposed mitigating measures is assessed. The risk tables are printed in Table 23 and Table 24, Appendix H.

Hazards

1. Obstacle in water, i.e. marking buoys with lines attached and possible small distance of nets to water surface;
2. Use of anchor to secure nets on bottom;
3. Interference with O&M vessel performing scheduled activities;
4. Interference with ROV or survey activities as result of trap location;
5. Fishermen forms obstacle during fishing;
6. Loss or drifting of gear into turbine or cables, use of grapnels to recover the gear damages cables.

Impact and Frequency

The nets and lines used for this type of fishing are secured to the seabed using deadweight anchors. On the surface, they are marked with buoys, which serve as a warning for other sailors and form connection points for the fishermen to retrieve the gear together with the catch.

Due to the static set-up, this type of fishing can form an obstacle in the water for passing vessels, requiring ships to redirect their route. The same goes for the fishing vessel when setting or retrieving the gear. The use of anchors creates a danger when subsea cables are near, especially when they might be uncovered. Direct impact of the anchor, or hooking might damage the cable. In case gear gets loose and gets a drift, it might get stuck on turbine foundation or uncovered cables. When fishermen try to recover potential lost gear with for example grapnels, this imposes an additional hazard.

Impact of above hazards vary from Mediate (2) to Important (3). It involves mainly loss of work time or damage to equipment which will be limited to € 10 M most likely. The frequency of these hazards ranges from a low 1 in 10 years (B) to an expected 1 a year (D). When these methods are practiced in a wind farm it is likely that there will be some interaction between fishing gear and O&M vessels on a yearly basis. On the other hand, is the loss of gear rather rare and the probability of this gear to get stuck on wind farm assets is low, 1 in 10 years.

Effect of mitigating measures

The proposed mitigating measures have little influence on the listed hazards. Except for drifted gear, providing information on the wind farm will be helpful, though not enough to reduce the frequency level. For hazard 3 and 5 it is expected that a reduction of the probability is achieved by the demand for active VHF and AIS, and the designated smaller exclusion zones around turbines and transformer station. These measures create a distance between the wind farm assets above sea level and allow for contact to inform on scheduled activities or deployed gear. In case of accidents or violations, AIS can be helpful to track involved vessels which will have a preventive effect on violations.

Residual risk

With the proposed regulation in place, the residual risk differs from Low to Medium. Since the proposed regulations are not written to mitigate the risk of static fishing, they are not really affecting the risk level. Additional measures could be taken to reduce the risk level. An important option would be to create a system in which wind farm crew and fishermen share information on location of gear and planned operations. This system should coordinate the different activities within the wind farm.

5.1.11 Static fishing – Trap fishing

This hazard group describes the hazards involved in static fishing using traps. Since this group describes hazards of activities which are currently not employed, only an interpretation of the risk level is given for the case this kind of techniques were to be used in an offshore windfarm. This is displayed in the first risk table. In the second table, the effect of the proposed mitigating measures is assessed. Reference is made to Appendix H, Table 25 and Table 27.

Hazards

1. Obstacle in water, i.e. marking buoys with lines attached;
2. Use of anchor to secure traps on bottom;
3. Interference with ROV or survey activities as result of trap location;
4. Fishermen forms obstacle during fishing;
5. Loss or drifting of gear into cables, recovery with grapnels into cables.

Impact and Frequency

Trap fishery is performed using different kind and size pots, which are placed on the seabed with some bait. Once placed, the traps are left for a couple of hours to let the catch enter. To keep the traps stationary, they are secured to the bottom with deadweight anchors. Buoys, attached to the traps mark the location on the surface. The hazards involved in this kind of fishing are comparable to fishing with static nets and lines, discussed in the previous section. Impact and frequency levels of hazards in this group differ slightly from the levels in the static nets and lines group, however the risk level is comparable. The same goes for the effect of the mitigating measures and the residual risk, hence the reader is referred to this previous section, section 5.1.10

5.1.12 Interaction with/caused by deployment of tidal energy device

The hazards in this group give insight in the risk of interaction with/caused by deployment of tidal energy. Since this group describes hazards of activities which are currently not employed, only an interpretation of the risk level is given for the case this kind of techniques were to be used in an offshore windfarm. This is displayed in the first risk table. In the second table, the effect of the proposed mitigating measures is assessed. See Table 28 and Table 29 in Appendix H

Hazards

1. Obstacle in water, i.e. marking buoys;
2. Interference with O&M vessel performing scheduled activities;
3. Interference with ROV or survey activities as result of trap location;
4. Interference of tidal energy infrastructure with wind farm infrastructure.

Impact and Frequency

Deployment of tidal energy devices will require joint efforts of both the wind farm operator and tidal energy entrepreneur. Currently, there is little experience with tidal energy devices, which limits the available research into the hazards of such devices. The main hazards are listed here, which indicate the potential effect on wind farm operations. The impact of these hazards ranges from Minimal (2) to Severe (4). This is mainly caused by the effect of the tidal energy systems influencing the wind farm’s O&M activities and the change that the wind farm infrastructure is damaged by the tidal energy system. In the former case, impact is relatively low, while the loss of business and costs of repairs can have a large impact.

Determination of the frequency of those hazards is rather subjective. It is assumed that the listed hazards occur rather frequent; mainly 1 in 3 years (C), and in case of the second hazard 1 in a year (D). It is stressed that, the decision for deployment of tidal energy systems would be a joint decision of both the wind farm owner and the tidal energy entrepreneur.

Effect of mitigating measures

With the current state of knowledge, it is assumed that none of the proposed mitigating measures influences the risk level of presence of tidal energy systems in a wind farm. The one rule that provides help, is the provision of information on the wind farm, and in this case the presence of tidal energy systems.

Residual risk

For some vessels and activities tidal energy devices will create hazards; however, no details can be reasonably given not knowing what kind of installation one deals with. In current state of technology, these activities are still an industrial endeavor. Rules and agreements on the design and permitting process should be developed, including detailed risk analysis. This should contain analyses of its impact on the transiting vessels, other vessels using the wind farm vessels and on the wind farm operations and infrastructure needs.

5.1.13 Interaction with/caused by deployment of aquacultures

This section discusses the hazards involved when deploying an installation to grow aquacultures. Since this group describes hazards of activities which are currently not employed, only an interpretation of the risk level is given if this kind of techniques were to be used in an offshore windfarm. This is displayed in the first risk table. In the second table, the effect of the proposed mitigating measures is assessed. The risk tables are printed in Table 30 and Table 31, Appendix H.

Hazards

1. Obstacle in water, i.e. marking buoys with lines attached and possible small distance of ropes to water surface;
2. Use of anchor to secure lines on bottom;
3. Interference with O&M vessel performing scheduled activities;
4. Interference with ROV or survey activities with aquaculture gear;
5. Aquafarmer forms obstacle during fishing;
6. Loss or drifting of gear into turbine or cables.

Impact and Frequency

Deployment of aquaculture installation at sea is actively investigated in Dutch and Belgian (amongst other) coastal waters (Buck, Nevejan, Mathieu, Chambers, & Chopin, 2017)(Verhaeghe, Delbare, & Polet, 2011)(Kamermans, P. & Smaal, A.C., 2014)(Hauke L. Kite-Powell, Di Jin, & Hoagland P., 2003). Most of these tests were performed in shallow and on rather sheltered areas, where impact of waves is limited. The differences with the offshore conditions of the wind farm areas are not researched jet. Therefor the set of hazards defined in this group are very broad and generalized.

Impact could differ from a Mediate (2) to an Important (3) level. The level is mainly governed by the financial impact when any of these hazards occurs. This is either due to a loss of time for O&M teams, the loss of production due to damages or the costs of replacing damaged wind farm gear.

The frequency of occurrence is assumed to differ between a 1 in 3 years (C) and 1 a year (D) level. Since the techniques are relative new in this kind of offshore environment, the frequency of these hazards is expected to be relatively high. The strength of aqua farmers gear is put to the test, and protocols to allow for joint use of the windfarm area are to be developed. These processes will be iterative with a high level of trial and error.

Effect of mitigating measures

It is expected that the proposed mitigating measures sort little effect on the risk level. Information is important to prevent the aquaculture (entrepreneur) to form an obstacle or to prevent the aquaculture entrepreneur from dropping anchors on wind farm subsea cables. Use of AIS and VHF can help in the communication and monitoring of active ships within the wind farm, which should help reducing the frequency of hazard 5.

Residual risk

The residual risk ranges from low to medium. It is stressed dough, that the current knowledge available is too little to carry out a reliable risk assessment. For example, parts of the aquaculture installation can be lost due to waves. In this situation it creates uncontrolled hazard and risk to the wind farm cables, since the gear can be drifted/moved by the action of currents and waves into unknown location.

Like mentioned in previous section, rules and agreements on the design and permitting process should be developed, including detailed risk analysis. This should contain analyses of its impact on the transiting vessels, other vessels using the wind farm vessels and on the wind farm operations and infrastructure needs.

5.2 Interpretation and discussion of control measure impact

In the following the effectiveness of proposed regulations and recommendations in controlling (mitigation) of risks is discussed. The regulations from 2015 and the recommendations from the present analysis are discussed separately.

In general, the proposed regulations and recommendations have the potential to mitigate the risks involved with transit and co-use of the three offshore wind farms.

The proposed regulations are part of the whole nautical safety system, consisting of a legal framework, information sources, a framework of interactions between wind farm operators and third parties' stakeholders, training and consciousness of the third party actors, the technical equipment available onboard third party vessels, and technical and operational capabilities of both the State Agencies and wind farm operators.

The effectiveness of the proposed measures depend strongly on the level of enforcement and prosecution, which was recognized both in 2015 and stressed in the present study again.

5.2.1 Regulations proposed in 2015

In summary, several strong points are distilled from the regulations proposed in 2015, listed in Appendix E6.2Appendix E:

Limiting the allowed vessel to 24-meter length constrains the maximum kinetic energy that may be transferred in case of a collision. This limits the consequences, i.e., prevents from large structural or physical damages. Also, the anchors of these small vessels are typically small, which limits (to some extent) the chance of hooking to subsea cables and the subsequent potential damage.

By limiting access to daytime only, gives some advantages. First, it allows for easier detection of obstacles in the wind farm area; Second, SAR operations are more effective; Last, easier detection of trespassers when eyes are on the perimeter.

Requiring transiting fishing vessels to sail with fishing gear stowed position allows for easier detection of violations. This request gives a clear definition of what is allowed and what not, which will discourage attempts to violate the regulations.

The obligation to have and use AIS and VHF systems on board when entering a wind farm. This will reduce the impact of accidents. Vessels can easily contact the coastguard or other possible nearby vessels and request for help. AIS will help to quickly locate the vessel, which makes SAR operations more effective. Also, the monitoring of vessel behavior in and around wind farms is improved. Odd behavior can be noticed, and action can be taken accordingly. Hence, detection of violations is improved which has a preventive effect, though this requires (extra) effort from the coastguard since it is their responsibility to monitor the wind farm assets.

With the introduction of 50 m (turbines) and 500 m (transformer station) exclusion zones, a clear message can be spread to inform people of the hazards and limits present in those areas. Though the resolution of AIS and radar systems will be to coarse to detect vessels in the 50 m zone with certainty, strange behavior, e.g. wandering around, can be noticed. It is noted (again) this will require (extra) action from the coastguard, not only noticing these instances, but also effectively responding to them.

Attention should be payed to make information campaigns effectively. Especially in the transition period, before the safety/restriction zone is opened, extra efforts will be required. An information campaign and permanent information about the navigation situation within wind farms will help to limit entries of the wind farm. Informed sailors who do enter, will have a better understanding of the hazards involved, making a more calculated decision. The information might also show thrill seekers there is not much to gain violating the rulse in a wind farm which might turn them off. It should be noticed that a certain group of this latter group will be attracted to these structures, nomatter the rules and hazards.

5.2.2 Additions proposed in 2017

In addition to the 2015 dossier, several additions were proposed which are summarized in bullets below.

- Publication of a detailed wind farm plan in the sea charts, combined with communication on planned operations in the wind farm will aid the transit planning and highlight the hazards involved.

- A more pro-active supervision by the coastguard should occur in the period after the opening of the offshore wind farms. This will send a clear message to users and (potential) trespassers and reduces the number of violations in the future.
- Requirement of carrying radar reflectors that provide a minimum recommended radar cross-section. This will allow for better radar tracing within and around the wind farm. The combination of radar and AIS tracking has a higher potential of detection and identification, and the radar is resilient to the loss of AIS signal. This proposed requirement is particularly important in case of small fiberglass vessels, that are practically undetectable by radar.
- The requirement or advise to use of a Personal Life Beacon (PLB) or AIS-SART device by each crew member of a vessel. This allows for more effective SAR action within and in proximity of the wind farm. Especially taking in consideration that the operation of a helicopter inside the wind farm is limited.
- The requirement of installation of S-VDR (Small Voyage Data Recorder) on all commercial fishing vessels with length above 12 meters, even if it is not required under IMO regulations at present). Such device will help to identify vessels involved in e.g. a cable damage due to bottom disturbing activities (Danalec Marine, 2017) (JRC, 2009) (Sperry Marine, 2007).

5.2.3 Regulation compliance and enforcement

With the proposed regulations are expected to be effectively reducing the risk level of most hazards. Still, stakeholders will respond different to these regulations. As mentioned in *RWS - Bijl01. (Dec. 2015)*, it is to be expected that professional fishery, and in a smaller extend recreational fishery, tend to break the rules more often than other user groups. A solid enforcement system, with high fine rate with high changes of detection are supposed to be effective to reduce violations of professional fishers. The high change of detection, combined with information campaigns are expected to be a good guide for recreational fishers.

Recreational and professional sailors are expected to follow the rules more often. To avoid rule breaking behavior, consistent surveillance is expected to reduce the number of violations, which should be strengthened with information campaigns.

The importance of good surveillance and enforcement is stressed. In current situation, the safety zone sends a clear message to third party vessels to stay out. Also, the current 500-meter perimeter around the wind farms improves the monitoring abilities. With the proposed opening of wind farms, allowed distances to turbines will decrease, making monitoring more difficult. Also, the change of rules, and difference in rules for different size ships, might result in confusion. Clear communication, active surveillance and if needed enforcement are supposed to send a clear message and will be necessary to prove the proposed regulation to be effective.

5.2.4 Opposing opinions of involved stakeholders

This section describes differences in the position of the offshore wind farm managers and participants from governmental agency (RWS). In the documentation first surfaced in 2015 (Hoefakker B., Don, Blomen, Chivers, & Oppentocht, May 2015) – by OWFs, and the response of RWS (RWS - Bijl15, Dec 2015)). During this analysis, several meetings were organized were both the wind farm representatives and the involved people from Rijkswaterstaat (RWS) were present. During these meetings it was voiced that the position of the OWF representatives had not changed at all, while the position of people from RWS is reflected in proposed new regulations.

Without further comments, the main concerns and differences are described below.

Position of the offshore wind farm managers

- The planning of the offshore wind farms was performed with another set of boundary conditions and regulations, i.e. the wind farm area was to remain an exclusion zone. The proposed regulations changing this agreement in a way that is detrimental to the business and safety of the wind farms. Therefore, in the framework of partial opening of offshore wind farm, some compensation schemas have to be provided for the prevention of and for the recovery from undesired events. “Who will pay?” is an often comment on potential failure modes. As a result, the wind farms presently in operations might be well excluded from the new regulations (as is the case for the Gemini wind farms), and the latter should concern only the future offshore wind farms;
- Any impact on the production and profitability of the offshore wind farms, including changes in operational procedures, is unacceptable;

- Any costs related to accidents and their prevention (repairs, indemnities, lost business, extra investments - CAPEX, extra operational outlays - OPEX) are unacceptable, since they influence negatively the (already fragile) bottom line;
- Based on the experiences so far, there is no trust that the enforcement of new regulations will happen and that it will be deterring the undesired behavior of people allowed into wind farm areas;
- There is no belief – based on the experience up to today - that the monitoring and identification of trespassers, to be performed by coastguard, will be effective;
- A Precautionary Principle is adopted for the mitigation of risks. This means that the costs of consequences of an accident are treated as given, independently of the chance of occurrence of the specific accident (failure mode), i.e., the potential accident is treated as occurring with certainty during the remaining lifetime of the wind farm installation. The QRA Matrix Table (Hoefakker B., Don, Blomen, Chivers, & Oppentocht, May 2015) indicates that the ALARP approach (As Low As Reasonably Practicable) is used for risk analysis. However, in the presented position it is not being considered;
- At present, the need for more active persecution and - if possible – warning, identification and documenting of offenders by remote (radar, AIS, other electronic surveillance means) and on-the-scene available assets (boats, ships, airplanes) was put forward a number of times as condition for a long-term effectiveness of proposed regulations and recommendations.

Position of managers from the governmental agency, Rijkswaterstaat (RWS)

- The proposed set of new regulations goes far in the direction of requests expressed by off shore wind farms in their 2015 position paper (Hoefakker B., Don, Blomen, Chivers, & Oppentocht, May 2015);
- The proposed regulations will work. They will be properly announced, there will be monitoring and there will be carefully crafted enforcement by coastguard and RWS;
- The RWS managers consider the decision on the opening of the wind farms important and have a position that this decision should occur in the nearest future (2018). This position arises from the planned development of Dutch offshore wind farms. In the period 2015-2017 there were discussions, meetings and studies, which achieved a general acceptance regarding the proposed new regulations of almost all stakeholders, except the wind farms. As a result, there is a risk that the decision will be delayed beyond 2018, so no experiences on the effectiveness of the proposed new regulations will be available when the large development of offshore wind farms will begin;
- It is pointed out that the offshore wind farms do not adopt ALARP (As Low As Reasonably Practicable) position when the risk mitigation measures are concerned. Some events before or after mitigation have a very small chance of occurrence, so the resulting risks are acceptable. However, the wind farms consider the undesired events to be occurring with certainty during the installation lifetime. This is a strong difference between the wind farms and the governmental agency managers in the perception of risks and in the acceptance of the residual risk levels. This further reflects on the difference in the perception of the effectiveness of the proposed risk mitigation measures;
- It is pointed out that at present the offshore wind farm managers accept the ALARP policy when operating and maintaining their wind farms, but on the other hand, the ALARP policy is rejected by them when the opening of OWFs is being considered.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The conclusions related to transit and recreational use of the three Dutch offshore wind farms are:

C.1 Opening the wind farms, combined with the proposed set of regulations will not lead to an overall increase in risks;

C.2 Based on the review and assessment, the proposed risk control measures are expected to be effective and, if properly implemented, the proposed regulations will effectively reduce the risks of the identified hazards.

The conclusions regarding the co-use of wind farm areas are as follows:

C.3 The co-use risks of tidal energy and aquaculture are under-assessed in the provided dossier and are here identified as uncontrolled. By 'uncontrolled' it is meant that there is no complete picture of involved hazards AND that many of the known hazards are not mitigated with the proposed regulations. The reason for this is, amongst other, the wide variety of possible technologies;

C.4 The co-use risks of static fishing and pot/trap fishing are uncontrolled. This means that the proposed regulations do not mitigate all hazards caused by these activities, particularly the risks to the subsea cables.

Residual risk

With the proposed mitigating measures in place, the expected residual risk varies from Low to Medium. A low risk is defined as a minimal impact with high, i.e. once a month, occurrence in a wind farm of a considerable impact occurring once in ten years. The Medium level ranges from minor impact with a frequent occurrence of once a month or a catastrophic impact occurring less than once in ten years. In general, the risk level after mitigation is of the same level as the present situation. However, in case of opening the wind farm, an increase of vessels inside the wind farms is expected. This raises the risk of collisions between ships, compared to the current situation.

On the other hand, it is expected that the risk level of several groups will reduce due to the proposed mitigating measures. The proposed monitoring and communication requirements will improve safety in and around the wind farms. It is stressed though, this will require considerable extra effort from the Dutch coastguard which is the responsible institute.

Though the risk levels are similar or even lower for the hazards in the co-use groups, these groups are under assessed, as mentioned above. This means the hazards are not fully known and hence cannot be controlled fully given the current knowledge.

It is important to be aware of the differences in rule compliance of different used groups. Therefore, focus should be on an active surveillance and enforcement system. This will send a clear message to the user groups, especially in combination with information campaigns, to increase compliant behavior.

6.2 Recommendations

As a result of the review, it is strongly recommended to implement the following points:

R.1 Clear conditions should be stated by the government, when and under which circumstances the proposed policy should be revoked, reestablishing the exclusion zone around the wind farm. This should be followed by the analysis of this situation and development of policy modifications;

R.2 A possibility to impose temporal legal exclusion zones (500m) within the wind farm, placed around crane vessels (jack-up or other) should be considered by the government.

R.3 Tidal energy and aquaculture applications are advised to be based on a permitting process lead by the government. This process should involve both wind farm owner and co-use entrepreneur and facilitate a fruitful cooperation between the involved parties.

Further recommendations are provided, which could increase safety and reduce risks. The effect of those recommendations is expected to be less than those mentioned above. They would complement the entire safety system and can be seen as ‘nice to have’:

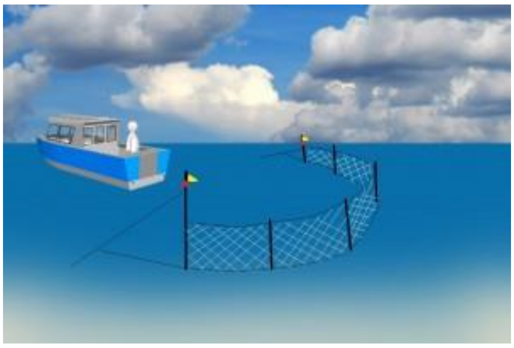
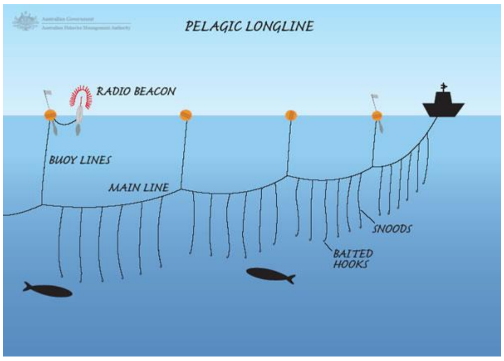
R.4 Require a publishing of detailed wind farm plan on nautical charts of the Dutch Hydrographic Service. Locations of exclusion zones, turbines, transformer stations and cable plans should be specified. This information should be made available by the wind farm owners. The wind farms should provide additional information on maintenance activities to the Coastguard, to be used in daily communication to sailors;

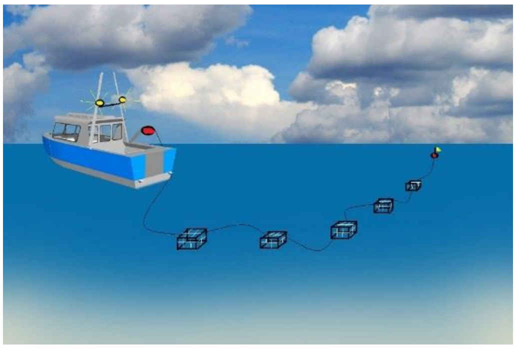
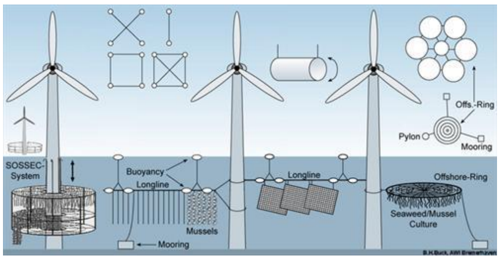
R.5 Require sailors to carry radar reflectors that provide a minimum recommended radar cross-section. This will allow for tracing vessels within the wind farm and in proximity of wind farm. This is particularly important in case of small recreation vessels;

R.6 Require/advise sailors to use a Personal Life Beacon (PLB) or AIS-SART device for each crew member, independent of vessel size. This will allow for effective SAR action within and in proximity of the wind farm;

R.7 Require an installation of S-VDR (Small Voyage Data Recorder) on all fishing commercial vessels with length above 12 meters, even if it is not required under IMO regulations at present. This can aid to identify a vessel which is involved in a case of e.g. cable damage due to trawling or anchoring.

APPENDIX A – LIST OF DEFINITIONS

Activity	Description	Comments
Tree cod fishing	Tree cod fishing is a fishing method by which a fisherman draws two towed nets across the seabed. The catch consists mainly of flatfish.	 Source: www.wikipedia.nl, 2 nov 2017
Boomkorvisserij	Boomkorvisserij is een visserijmethode waarbij door een viskotter twee sleepnetten over de zeebodem worden getrokken. De vangst bestaat vooral uit platvis.	
Upright gear fishing	An upright fish gear consists of a float-shaped upper-paw and a heavy-handed paw with a single or multi-walled network between them. The standing fish gear is anchored at least on either side in any way on the seabed. An upright position is perpendicular to the ground and is not propelled by flow or any tensile force.	 Source: www.goedevissers.nl, 2 nov 2017
Staand want visserij	Een staand want is een vistuig bestaande uit een van drijvers voorziene bovenpees en een verzwaarde onderpees met daartussen een één- of meerwandig netwerk. Het staand want wordt tenminste aan beide zijden op enigerlei wijze op de zeebodem verankerd. Een staand want staat loodrecht op de bodem en wordt niet door stroming of enigerlei trekkracht voortbewogen.	
Long-line fishing	Long-line fishing is a fishing technique used by professional fishermen in sea fishing. Long-term cables are used, the so-called main line. This main line has sidelines with brackets and bait.	 Source: www.wikipedia.nl, 2 nov 2017
Lange lijn vissen	Langelijnvisserij is een visserijtechniek die gebruikt wordt door beroepsvissers in de zeevisserij. Hierbij worden lange dunne kabels gebruikt, de zogenaamde hoofdlijn. Aan deze hoofdlijn zitten zijlijnen met haakjes en aasvis.	

Activity	Description	Comments
Hive fishing	Hives with bait are plunged to the bottom. After a few hours, these traps are taken out of the water, one by one. This method allows you to catch both fish and crustaceans.	
Manden of korven visserij	Korven of manden met aas worden uitgezet op de bodem. Deze vallen worden na een aantal uren, één voor één boven water gehaald. Met deze methode kan men zowel vis als schaaldieren vangen.	Source: http://www.visenseizoen.nl/korf-lijnvisserij/, 2 nov 2017
Wind farm maintenance	Work on/inspection of turbines, underwater construction, scour protection, cables and connections.	
Windpark onderhoud	Werk aan / inspectie van turbines, onderwaterfundament, scheurbescherming, kabels en aansluitingen.	Source: www.deltares.nl, 2 nov 2017
Transit	Navigating through a wind farm on sea.	
Doorvaart	Het doorvaren van een windpark op zee.	
Sea weed cultivation	Seaweed farming is the practice of cultivating and harvesting seaweed. In deeper water floating cultivation lines are being used, that are anchored to the bottom.	
Zeewierteelt	Zeewierbouw is de praktijk van het kweken en oogsten van zeewier. In dieper water worden drijvende teeltlijnen gebruikt die aan de bodem zijn verankerd.	Source: www.wikipedia.org, 2 nov 2017

Activity	Description	Comments
Mussel seed capture facilities	Floating structures of nets and ropes, where mussel larvae adhere, where after they grow into mussels of one to two centimeters (mussel seed). Mussel growers harvest the mussel seed and sow it on the mussel cultivation areas.	 Source: www.groenkennisnet.nl, 2 nov 2017
Mosselzaadinvang-installaties	Drijvende constructies van netten en touwen, waar mossellarven zich aan hechten, die vervolgens uitgroeien tot mosseltjes van één tot twee centimeter (mosselzaad). Mosselkwekers oogsten het mosselzaad en zaaien het uit op de mosselkweekpercelen.	
Tidal energy	Tidal energy is energy that is gained by using the difference in water height between ebb and flood.	 Source: www.wikipedia.nl, 2 nov 2017
Getijdenenergie	Getijdenenergie is energie die wordt gewonnen door gebruik te maken van het verschil in waterhoogte tussen eb en vloed.	

APPENDIX B – LIST OF DOCUMENTS

Documents part of decision making process 2015

1. (MIeM-RWS, Dec. 2015) Uitwerking besluit doorvaart en medegebruik van windparken op zee, in het kader van Nationaal Waterplan 2016 – 2021 - RWS, december 2015;
2. Bijlagen bij uitwerking besluit doorvaart en medegebruik van windparken op zee - RWS, december 2015;
   a. (RWS - Bijl01, Dec. 2015) Toezicht en Handhaving;
   b. (RWS - Bijl02, Dec. 2015) Search and Rescue in windparken bij toelaten van schepen van derden;
   c. (Kustwacht - Bijl03, June 2015) Evaluatie SARES 3 juni 2015;
   d. (Kustwacht - Bijl04, Sept. 2015) SAR helitest Luchterduinen;
   e. (RWS - Bijl05, Dec. 2015) Kosten aanleg en onderhoud sensoren radar, AIS & VHF;
   f. (RWS - Bijl06, Dec. 2015) Juridisch kader voor doorvaart en medegebruik in windparken;
   g. (RWS - Bijl07, Dec. 2015) Visserij/aquacultuur in relatie tot het medegebruik/doorvaart windmolenparken;
   h. (Röckmann & et al, 2015) VisRisc - risicoschatting medegebruik visserij in windparken;
   i. (RWS - Bijl09, May 2015) Risicosessie doorvaart en medegebruik windparken, 27 mei 2015;
   j. (RWS - Bijl10, Dec. 2015) Risico's, betekenis en mogelijke maatregelen;
   k. (RWS - Bijl11, Dec. 2015) Beheer en Onderhoud binnen windparken;
   l. (Chris Westra Consulting BV - Bijl12, July 2015) Navigating wind farms, an inventory of experiences;
   m. (Marsh Nederland - Bijl13, Sept. 2015) Memo Marsh, Verzekeringsaspecten voor windparken;
   n. (Hoefakker B., Don, Blomen, Chivers, & Oppentocht, May 2015) Position paper + risico's en kosteninschatting van exploitanten bestaande parken (drie delen);
   o. (RWS - Bijl15, Dec 2015) Reactie Rijk op Position paper en risicoschatting door de windsector;
   p. (KNWV-NPvW - Bijl16, Mei 2015) Aanbeveling voor kleine schepen en die in of in de nabijheid van winturbineparken varen; Koninklijk Nederlands Watersport Verbond Nederlands Platform voor Waterrecreatie, Vereniging voor Beroepschartervaart;
   q. (RWS - Bijl17, Dec. 2015) Test detectie en communicatie in winparken ten behoeve van toezicht en handhaving;
3. (Kustwacht - 2016) Plan van Aanpak implementatie doorvaart en medegebruik – dd 20-05-2016;
4. (Rijkswaterstaat, 2016) Evaluatie en Monitoringsplan extern – 8 november 2016;
5. (Rijkswaterstaat, 2017) Concept beleidsregels (concept beleidsregels versie 1404 SO.pdf) – dd 12-04-2017;
6. (Kustwacht - 2017, Juni 2017) Rapport AIS-metingen op 7 juni 2016 ter bepaling van de dekking van AIS (klasse A en B) van windmolenparken OWEZ, Amalia en Luchterduinen;
7. (Rijkswaterstaat, 2017) Concept folder Doorvaart door windparken – februari 2017;
8. (Rijkswaterstaat, 2017) Concept gedragscode Doorvaart door windparken – februari 2017.

Correspondence between government and wind sector

9. (Hoefakker B. , et al., Common Position Paper & QRA regarding Open Offshore Wind Park Access in response to 'Verslag risicosessie doorvaart en medegebruik windparken, 27 mei 2017', 'Stakeholder advice DM', 'Ontwerp beleidsnota Noordzee 2016-2021' en 'Eindversie kennisdoc [...]', 2015) Position paper windsector as input for meeting in October 2015: Common Position Paper & QRA regarding Open Offshore Wind farm Access in response to 'Verslag risicosessie doorvaart en medegebruik windparken, 27 mei 2015', 'Stakeholder advice DM', Ontwerp beleidsnota Noordzee 2016 – 2021' and 'Eindversie kennisdocument Varen en vissen in windparken'. Inclusief bijlage: QRA Matrix van WPE's – oktober 2015:
   a. BIJLAGE: (Hoefakker B. , et al., 2015).
10. (Ministry of Infrastructure and Environment, 2015) Brief van voorzitter IDON (D. Slangen) aan exploitanten bestaande windmolenparken Prinses Amalia Windpark, Offshore Windpark Egmond aan Zee, Luchterduinen en Gemini Windparken en NWEA over doorvaart en medegebruik – 9 december 2015. Inclusief bijlage: reactie vanuit Rijk op QRA (kwantitatieve risicoanalyse) – 3 december 2015:
    a. Bijlage: (Rijkswaterstaat, 2015).
11. (NWEA, 2016) Brief van NWEA aan D. Slangen met verwijzing naar NWEA Position Paper van oktober 2015 over doorvaart en medegebruik – 20 mei 2016.

Documents related to meetings

12. (Rijkswaterstaat, 2015) Verslag risicosessie stakeholders doorvaart en medegebruik 27 mei 2015;
13. (Rijkswaterstaat, 2015) Verslag stakeholdersessie met windsector – 19 oktober 2015;
14. (Brouwers, 2015) Powerpoint Joris Brouwers: Wind energy at sea; Passage & shared use Interpretation and refining on damage risks by vessels – oktober 2015;
15. (Rijkswaterstaat, 2016) Plenaire presentatie stakeholdersbijeenkomst – 11 juli 2016;
16. (Rijkswaterstaat, 2016) Verslag stakeholdersbijeenkomst – 11 juli 2016;
17. (Krapels, 2017) Powerpoint Jeroen Krapels: Meldingsprocedure schending voorwaarden voor doorvaart – april 2017.

Documents related to wind farm permits

Offshore Windpark Egmond aan Zee

18. (Grontmij, 2017) MER - Scheepvaart en veiligheid (Grontmij);
19. (MARIN, 2003) Onderzoek MARIN: IMER Near Shore Windpark: Effecten op de veiligheid van de scheepvaart voor vijf inrichtingsvarianten – 7 maart 2003;
20. (Infraconsult + Engineering, 2006) Onderzoek Infra Consult + Engineering - Ship Impact – Maart 2005;
21. (NoordzeeWind, 2006) Onderzoek Noordzeewind mbt toepassing van energie absorberend materiaal op de buitenste turbines - 18 september 2006;
22. (MARIN, 2006) Onderzoek MARIN: NSW - MEP Maritime and marine risk assessment of calamitous (oil) spills – juli 2006.

Prinses Amalia windpark

23. (MARIN, 2013) Onderzoek MARIN: Scheepvaartbewegingen Prinses Amalia windpark, analyse voor 2009, 2010, 2011 (eindrapport) – 19 september 2013;
24. (E-Connection, 2003) Brief van E-Connection Q7-WP BV aan Directie Noordzee (nu RWS Zee en Delta) – Monitorings- en evaluatieprogramma Offshore windpark Q7-WP, Wbr-vergunning AMU/743 5 november 2003.

Eneco Luchterduinen

25. (MARIN, 2008) Marin - Veiligheidsstudie - Windpark Q10;
26. (Grontmij, 2008) MER Offshore windpark Q10.

Additional documents

27. (NoordzeeWind, 2008) OWEZ_R_141_20080215-General-Report.pdf;
28. (NoordzeeWind, 2006) Scheepvaart_OWEZ_R_280_20060720.pdf;
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APPENDIX D – STAKEHOLDERS

1. Rijkswaterstaat (Zee en Delta);
2. Dutch coastguard;
3. Eneco – Managing the Prinses Amalia Windpark (PAWP) and Luchterduinen;
4. Noordzeewind – Managing Offshore Windpark Egmond aan Zee (OWEZ);
5. KNRM/Heli rescue;
6. Visserbond;
7. Recreational sailors;
8. Dutch Ministry of Infrastructure and the Environment;
9. Nederlandse Charterbootvereniging;
10. Vereniging voor Beroepschartervaart (BBZ);
11. Watersportverbond;
12. Sportvisserij Nederland;
13. Visned;
14. Vissen voor de Wind.

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APPENDIX E – LIST OF PROPOSED MITIGATING MEASURES IN 2015 DOSSIER

List of proposed mitigating measures 2015 dossier, as described in *Uitwerking besluit doorvaart en medegebruik van windparken op zee, in het kader van Nationaal Waterplan 2016 – 2021* (Rijkswaterstaat, 2015).

a. Conditions that will be part of the policy as described in the ‘waterwet’:
    a. Transit of the wind farm safety zone is allowed solely for ships up to 24 meters length;
    b. Transit of the wind farm safety zones is allowed by day light only;
    c. Transit of the wind farm safety zones is allowed for ships with active VHF communication equipment which is used to communicate while crossing the wind farm area;
    d. Transit of the wind farm safety zones by professional fishers is allowed when their bottom disturbing fishing gear is carried in a position above the waterline, where it is visible;
    e. Bottom disturbing activities, like anchoring, dragging of fishing gear, are forbidden within the wind farm safety zone;
    f. Within the wind farm safety zone, third party diving activities are forbidden;
    g. Professional fishing is allowed if, and only if, the fishing gear is specified as permissible by the Dutch government. This will be written in a framework in which the risks for wind farms, ecological risks, economical potential and enforcement possibilities are taken in consideration;
    h. Within the wind farm safety zone, it is forbidden to perform activities that endanger or obstruct the wind farm exploitation. Any third-party activity within 50 meters from a turbine is considered to be dangerous or obstructing;

c. The 500 m safety zones around offshore transformation zones, or offshore high voltage stations will not be changed;
d. The Dutch government will develop and implement an information strategy to inform and instruct all stakeholders of the policy changes regarding the wind farm safety zones. A code of conduct will be developed containing examples of preferred behavior which is not caught in obligatory rules. Amongst other, attention will be paid to the risks of entering a wind farm with bad visibility or storm and the advantages of Personal Location Beacons and AIS-SART.
   Activities to provide information, as well as the development of the code of conduct will be organized in cooperation with the stakeholders;
e. The Dutch government will develop a plan to monitor and evaluate the proposed relaxation of the safety zone. The behavior of third party persons will be monitored and evaluated over a period of two summer seasons, in which above proposed rules are applied. In this monitoring and evaluation program, surveillance and enforcement activities performed by the State will be included. Also, attention will be paid to the options and costs of monitoring systems and equipment, both evaluating and looking forward. Part of this system will be an exchange of information between wind farm owners and the Dutch coastguard;
f. Newbuild wind farms will be opened when the entire area is developed. This starts with the Borssele wind farm area. Necessary measures and conditions will be determined based on the above-mentioned evaluation;
g. The Dutch government will take care of the installation of the necessary sensors and systems to effectively monitor the affected wind farm areas;
h. The Dutch government will make an agreement on visible numbering of the individual wind turbines.

APPENDIX F – FACTSHEETS

Wind farm Fact Sheet - OWEZ

1) Companies involved		Comments
Developers	Bouwcombinatie Egmond (BCE) - Ballast Nedam - Vestas	http://egmondonline.nl/activiteiten/bezoek/offshore-windpark-egmond-aan-zee/
Operators	NoordzeeWind B.V. - Nuon (Vattenval AB) - Shell Wind Energy Ltd.	http://www.noordzeewind.nl/

2) Wind farm construction data		Comments
General info		
Name	Offshore Windpark Egmond aan Zee (OWEZ)	
A.k.a	-	
Country	The Netherlands	
Region	Noord-Holland	
Status	Operational	
Location		See **Figure 6** and **Figure 7**
Sea name	North Sea	

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Centre latitude	54.606°
Center longitude	4.419°
Area	24 km^2
Minimal distance to shore	10 km
Distance from shore to wind farm center	13.7 km
Bathymetry, morphology and soil type	
Depth range	15-18 m
Depth range stated by developer (relative to chart datum)	16-21 m
Wind farm bottom morphology description	See Figure 8
Environmental conditions	Info found in http://www.noordzeewind.nl/wp-content/uploads/2012/02/OWEZ_R_122_Wave_20050701_20081231-20100107.pdf, pages:
Tidal range	p.20
Current direction and speed roses	p.27
Monthly wave height/direction roses	Wave height over year: p.20 Wave distribution and roses: p.24
Relation Hs – Tp, wave spectrum type	p.32
Monthly wind direction/speed roses	p.17-19; See Figure 9 and Figure 10 this document
Wind spectrum type, parameters	p.17-19
Monthly temperatures statistics	Water temp over year: p.20
Misalignment wave and wind	p.25-26
Turbines, transformers, converters	

Total boilerplate power of the wind farm	108 MW	
Turbine model (name, link to figures, drawings, photos, etc.)	Vestas V90 wind turbine	
Turbines		Info found in: http://www.noordzeewind.nl/wp-content/uploads/2012/02/OWEZ_R_141_20080215-General-Report.pdf, pages:
Number of turbines	36	
Turbine boilerplate power	3 MW	
Total turbine height (from MSL)	115 m	
Turbine hub axis height (from MSL)	70 m	
Turbine rotor diameter	90 m	
Foundation (short description, picture)	**Monopile** 45 m monopile: 30 m in sea bottom, 15 m in water. **Scour protection** Dimension 25m x 1,8 m Mass = 1500 ton per monopile.	p.12-14 p.17-18
Turbine dry mass (whole construction excluding underground part)	Monopile mass = 230 tons Anode ring and J-tubes = 10 tons Transition piece = 147 tons Tower = 94 ton Nacelle and blades = 114 ton Total for one turbine = 595 ton	
Turbine structure diameter and cross-section area at MSL	4.6 m	

Remote stop of turbine and redundancy stop systems	No	
Nominal rotor speed	16.1 RPM	
Rotor speed interval	9.0 – 19.0 RPM	
Brake method	Pitch blades	
Transformers	N/A	No offshore transformer used. Infield-cables are bundled in three export cables which run to a transformer station on the coast.
Cabling in-field and export		
Grid		
Converter/collector platforms	1	
Offshore transformer/converter	None	
Cables shore landing point	Velsen-Noord	
Grid connection point	Velsen-Noord	
Export cables		
Number of export cables	3	
Average length per cable	15 km	
Nominal voltage per cable	34 kV	
Maximal voltage per cable	36 kV	
Cable section area	500 mm^2	
Burial depth	1.5 m	
Additional cover protection	Concrete matrasses and artificial seaweed	Export cables cross three data cables. At cross points, extra cross-point matrasses are provided

Minimum bend radius	N/A	A minimum allowed bend radius implies a certain breaking point of a cable. In fact, damage will occur before breaking when the copper screen of the cable gets damaged.
Chart (nautical) of cable layout from wind farm to shore	See Figure 7	
In-field (array) cables		
Array cable length	9 km	
Nominal voltage	1 kV	
Cable section area	3x300 mm^2 or 3x120 mm^2	
Burial depth	Nominal 1-1.5 meter	This is the nominal depth at time of construction. Due to movement of the seabed, exposure < 1m has been observed, in particular near the turbines.
Additional cover (protection, armoring)	Yes	Cables are laid under surface concrete mattresses near the turbine. J-tubes are used near the surface of the foundation up to the transition piece
Minimum bend radius	Unknown	A minimum allowed bend radius implies a certain breaking point of a cable. In fact, damage will occur before breaking when the copper screen of the cable gets damaged.
Chart (nautical) of in-field cable layout within the wind farm	See **Figure 7**	

3) Wind farm operational data	**Showing methods of wind farm use and maintenance**
Ports used for construction (potentially also for decommissioning) and for maintenance/operations	

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Construction	IJmuiden
Operations and maintenance	IJmuiden
Decommissioning	IJmuiden
Placement within navigation routes, economic zone, proximity of other wind farms, proximity of other renewable energy / non-renewable energy sites and transport routes	
Placement of nearby fishing ports	Den Helder, IJmuiden, Scheveningen
SAR centers, governmental monitoring centers	See Figure 11
Maintenance requirements	
List of survey/inspection activities	• Statutory inspections • Cable inspections
List of maintenance activities	• Servicing turbines • Blade repairs • Component replacement • Coating activities • Meteorological mast maintenance (Research parties)
Frequency of maintenance and surveys/inspections	Operations and Maintenance is done during fair weather periods with low wave heights (<1.5 m significant wave height). Usually from April – Sept high activity levels at site; average circa 8-12 teams for 36 turbines plus meteorological mast (37 offshore structures). Whereas the number of activities are reduced due to strong winds/high waves from Oct – March; usually circa 3-5 teams on site. There is no maximum number of teams (yet), though it is unlikely to have more than 15 teams
Time and manning for each type of work (boat crew, work crew)	Depends on the activity and the weather; at OWEZ CTV is usually in on site between 08.30 am until 4.30 pm, 5 days a week (Monday/Friday). Rope access teams can stay at site until sunset, major works such as cable layers or jack up vessels will work 24/7.

	Exceptional days request contractors and staff to work for circa 10hrs on site (excluding travel to/from).	
Methods of meeting the maintenance requirements		**N/A**
Estimation of maintenance schedules		**N/A**
Maintenance work (boats, work ships)		
Technical means of performing maintenance work	N/A	
Environmental limitations to maintenance works	Not specified	
Development of SAR-procedures and exercises for maintenance, inspection or survey crews	Not by operator. Third party performing the maintenance/inspection/survey might have their own policy.	
Existence of monitoring systems for controlling of the access to the wind farm area and wind farm installations	No	
Existence of monitoring system for controlling intrusion of wind farm area	No	Though safety zone violations observed by the CTV captain (vessels entering 500m zone) are recorded as HSE observations. Such events are shared with the Coastguard is informed. Near misses (vessels attempting to enter safety zone) are not reported to the coastguard but resolved with warnings by the captain of the Crew Transfer Vessel (CTV). With the safety zone clearly in place trespassing was dealt with informally: vessels were requested to leave and no attempt for fines were made.
Insurance of the wind farm	N/A	

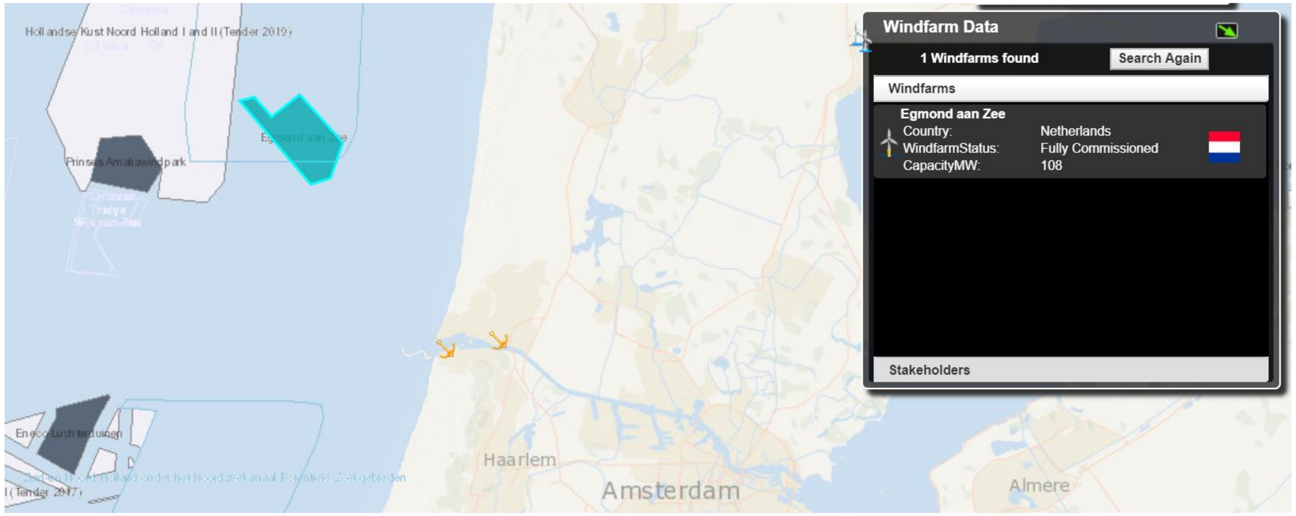

Figure 6. Location wind farm Egmond aan Zee, relative to coast.

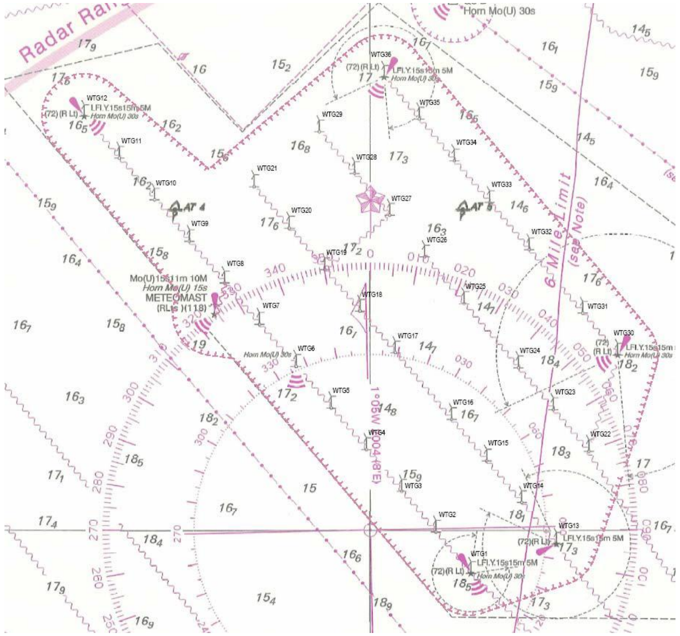

Figure 7. Layout Offshore Wind farm Egmond aan Zee.

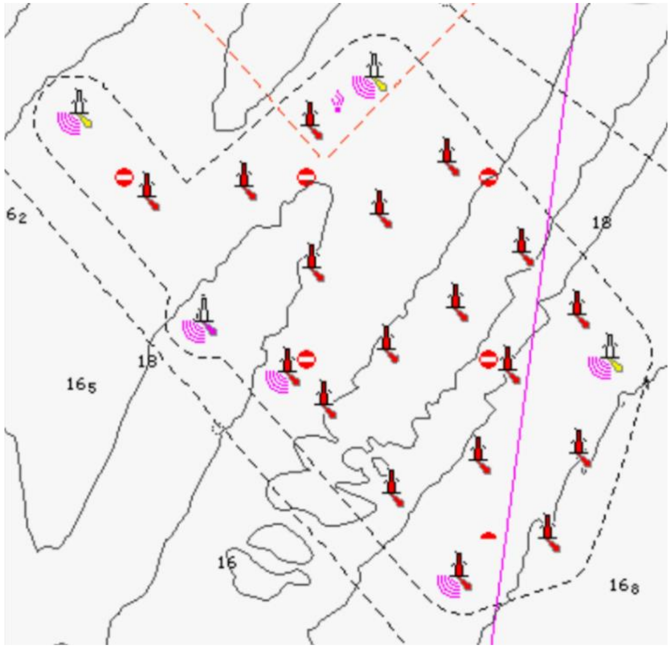

Figure 8. Bottom morphology in wind farm area, November 2017, Navionics charts.

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant wind direction													
Wind probability >= 4 Beaufort (%)	86	88	80	69	74	65	66	72	75	82	86	87	**77**
Average Wind speed (kts)	23	20	18	16	17	15	15	16	17	19	21	23	**18**
Average air temp. (°C)	7	5	6	9	12	14	17	18	17	14	11	8	**11**

Figure 9. Wind statistics Hoorn/Q1 Platform, based on observations between 05/2005 - 10/2017. Source www.windfinder.com/windstatistics-a_q1-platform, date: 28-11-2017.

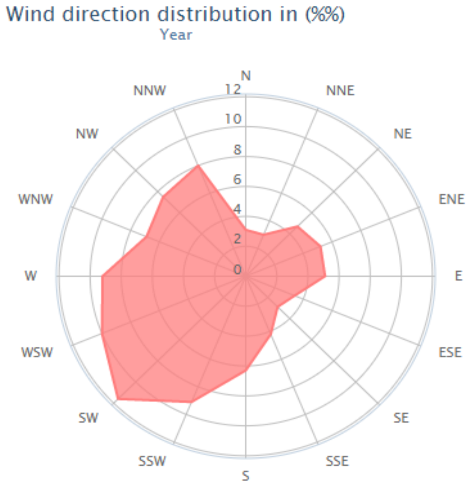

Figure 10. Wind rose Hoorn/Q1 Platform, based on observations between 05/2005 - 10/2017. Source www.windfinder.com/windstatistics-a_q1-platform, date: 28-11-2017.

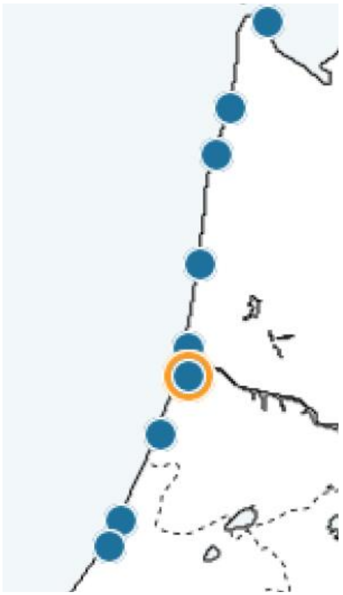

Figure 11. Locations KNRM-stations. From top to bottom: Den Helder, Callantsoog, Petten, Egmond aan Zee, Wijk aan Zee, IJmuiden (circled), Zandvoort, Noordwijk aan Zee and Katwijk aan Zee.

Wind farm Fact Sheet – PAWP

1) Organisations involved		Comments
Developers	Van Oord Vestas	
Operators	Offshore wind farm Q7 Eneco Wind B.V. (Owner)	

2) Wind farm construction data		Comments
General info		
Name	Prinses Amalia Windpark (PAWP)	
A.k.a	Q7	
Country	Netherlands	
Region	Noord-Holland	
Status	Active	
Location		See Figure 12
Sea name	North Sea	
Centre latitude	52.588º	
Center longitude	4.223º	

Area	17 km^2
Minimal distance to shore	23 km
Distance from shore to wind farm center	26.5 km
Bathymetry, morphology and soil type	
Depth range	19-24 m
Depth range stated by developer (relative to chart datum)	19-24 m
Wind farm bottom morphology description	See Figure 14
Environmental conditions	
Tidal range	-65 cm NAP – 137 cm NAP
Current direction and speed roses	-
Monthly wave height/direction roses	-
Relation Hs – Tp, wave spectrum type	-
Monthly wind direction/speed roses	See **Figure 17** and **Figure 18**
Wind spectrum type, parameters	-
Monthly temperatures statistics	-
Misalignment wave and wind	-
Turbines, transformers, converters	
Total nameplate power of wind farm	120 MW
Turbine model (name, link to figures, drawings, photos, etc.)	Vestas V80-2.0 MW
Turbines	

Number of turbines	60
Turbine nameplate power	2 MW
Total turbine height (from MSL)	99 m
Turbine hub axis height (from MSL)	59 m
Turbine rotor diameter	80 m
Foundation (short description, picture)	Grounded monopile
Turbine dry mass (whole construction excluding underground part)	-
Turbine structure diameter and cross-section area at MSL	-
Remote stop of turbine and redundancy stop systems	Yes, remote stop to idling position. To lock the rotor, action is needed on the turbine itself
Transformers	
Name	Prinses Amalia windpark Substation
Status	Operational
Location (Lat – Long)	52.59 – 4.24
Type	Monopile
Topside	
Weight	650 ton

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Dimensions	25 x 15 x 15 m	Hight: 19m above mean sea level
Helideck	No	Winch to and from transformer is possible with clear vision
Service port/berth (dimension of service vessel accepted)	IJmuiden	
Crew spaces (overnight y/n?)	No	
Station		
Number of transformers	1	
Transformer power	140 MVA	
Transformer voltage ratio	24/150 kV	Switchgear: 150kV and 22 kV GIS
Other equipment	N/A	
Cabling in-field and export		
Grid		
Converter/collector platforms	None	
Offshore transformer/converter	Prinses Amaliawindpark Substation	
Cables shore landing point	IJmuiden (Wijk aan Zee)	
Grid connection point	Velsen-Noord	
Export cables		
Number of export cables	1	
Average length per cable	28	
Nominal voltage per cable	150 kV	3 phase export cable in sea (3 cores)
Maximal voltage per cable	170 kV	

Cable diameter	208 mm
Burial depth	1.5 – 3 meters
Additional cover protection	Protection with matrasses to cover cable crossings
Minimum bend radius	-
Chart (nautical) of cable layout from wind farm to shore	See Figure 16
In-field (array) cables	*3 phase inter-tube cable at sea*
Array cable length	45 km
Nominal voltage	24 kV
Cable diameter	208 mm
Burial depth	Nominal 1 meter. Though depth and location vary due to bottom movement
Additional cover (protection, armoring)	Protection with matrasses to cover cable crossings
Chart (nautical) of in-field cable layout within the wind farm	See **Figure 15**

3) Wind farm operational data	**Showing methods of wind farm use and maintenance**
Ports used for construction (potentially also for decommissioning) and for maintenance/operations	

Construction	IJmuiden	
Operations and maintenance	IJmuiden	
Decommissioning	IJmuiden	
Placement within navigation routes, economic zone, proximity of other wind farms, proximity of other renewable energy / non-renewable energy sites and transport routes		
Placement of nearby fishing ports	Den Helder, IJmuiden, Scheveningen	
SAR centers, governmental monitoring centers	See *Figure 19*	
Maintenance requirements		
List of survey/inspection activities	• Periodic inspection, mainly in nacelle • Inspection of blades • Inspection transformer station • Inspection of foundation and cables	Inspections and maintenance carried out by people entering turbine/nacelle, by rope access climbing, using jack-up crane vessel or a drone.
List of maintenance activities	• Periodic servicing, mainly nacelle • Maintenance and repair of blades • Replacement large parts • Resolving errors • Maintenance offshore transformer • Maintenance foundation and cables	Inspections and maintenance carried out by people entering turbine/nacelle, by rope access climbing, using jack-up crane vessel or a drone.
Frequency of maintenance and surveys/inspections	Approximately 100 days/year to perform maintenance and inspection work	Working is limited by environmental conditions, i.e. wave height, temperature and windspeed.
Time and manning for each type of work (boat crew, work crew)	On average day: 2 crew tender ships with a total of 3-6 teams in the wind farm. During large campaigns, up to 7 crew tenders carry round a total of 14-20 teams. Average time spent during maintenance: 10 hours at location, 2 hours traveling to and from location. Maximum working time: 12 hours. Can only be exceeded in case of emergency.	
Methods of meeting the maintenance requirements		

Underwater inspection activities with ROVs – description	Underwater inspections performed using a survey ship, equipped with a multibeam, side scan sonar and other. Inspection of monopile at/above waterline is performed by rope access teams.
Underwater inspection activities with divers - description	Deployment of divers is reduced to a bare minimum because of the safety risks. In case of diving activities are necessary, diving is done with umbilical equipment according to Dutch ‘Arbocatalogus Werken onder Overdruk’.
Array cable repair work – description	In case of failure, the failed section will be replaced (length roughly 600 m). New cable will be trenched while old cable will be removed. Lead time: 2-6 months. Within this period, the entire string of turbines will be shut off. Turbines will need to be conserved.
Export cable repair work (within the wind farm) – description	In case of failure, the section of failure needs to be determined. A new piece of cable will be inserted. Lead time 3-8 months. Within this period, the entire wind farm cannot operate. Turbines will need to be conserved.
Turbine inspection and maintenance – description (including role of work boats)	• Yearly, +/- 100 days of ‘normal’ maintenance performed with one crew tender. Most of work is performed in the turbine nacelle. • Maintenance of turbine blades performed by rope access teams and/or jack-up crane vessel. Varying number of teams: 1-4 crew tenders or one jack-up. • Replacement of large parts (gear box or generators) performed 2 times per year using jack-up vessel. • Coating campaigns, repairing parts of steel work and inspection of bolts.: Once every 2-year performed by one crew tender with 2-3 teams.
Transformer inspection and maintenance – description (including role of work boats)	Yearly inspection and maintenance of all components, performed by approximately 30 different contractors over approximately 50 days. • High voltage 33 kV and 150 kV equipment • Low voltage 240V and 400V equipment • Auxiliary equipment: emergency power generator, cranes, HVAC, firefighting, UPS, etc.

Methods of positioning of work boats during performing the work within the wind farm	• Crew tenders: Push with rubber fender onto boat landing. Only allowed when significant wave height < 1,5 meter with approved fender (Eneco demand). Crew tenders are obliged to have radar, electronical sea chart and to be certified according to the MCA workboats code. • Other maintenance ships must oblige to certain demands when positioning close to turbines: Minimum DP2 vessels with three independent systems to determine position (with certified IMCA standards) • Minimum distance for (ecological) research close to turbine foundation is 100 meters, or 500 meters distance from transformer station.	
Estimation of maintenance schedules		
Days per year	100 days per year	
Average number of maintenance boats at a maintenance day	2 Crew tender vessels	
Maximum number of maintenance boats at a maintenance day	7 crew tender vessels, one jack-up crane vessel	
Average time a maintenance boat spends within wind farm area	10 hours	
Maximum time a maintenance boat spends within wind farm area	10 hours	
Maintenance work (boats, work ships)		
Technical means of performing maintenance work	• Crew tenders: Windcat XX (Various codes, Windcat Workboats), West Hinder (Acta Marine), Wenduine (Acta Marine), Waddenzee (Acta Marine) • Jack ups: WIND (Ziton), Pioneer (Ziton), Bold Tern (Fred Olssen), MPI Resolution (MPI) • Cable-lay vessel: CS Recorder (Global Marine) • Ecological research: Ivero (Gardline), must keep 100 m clearance from turbine • Survey: Storm (Deep), must keep 100 m clearance from turbine	All ships need to have had an IMCA-CMID inspection, less than 1 year ago.
Environmental limitations to maintenance works	Unknown	

Existence of SAR procedures and exercises for maintenance, inspection, survey work crews	No
Existence of monitoring systems for controlling of the access to the wind farm area and wind farm installations	No
Existence of monitoring systems for controlling of the intrusion of shipping into wind farm area	No 24/7 monitoring. Since 2015, an AIS system is installed with poor coverage. Trespasses are not registered. Violations of safety are only by crew tender operators.
Insurance of the wind farm	N/A

Figure 12. Location windfarm Prinses Amalia windpark, relative to coast

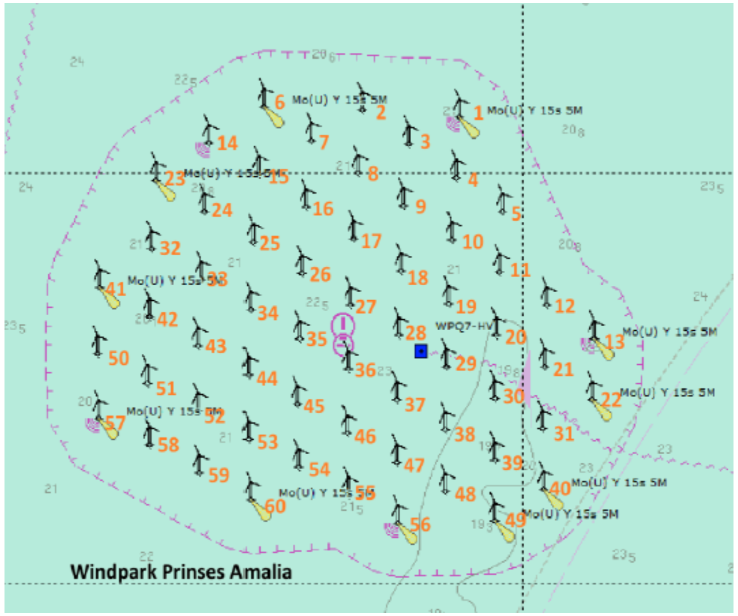

Figure 13. Layout Prinses Amalia windpark with turbine numbering.

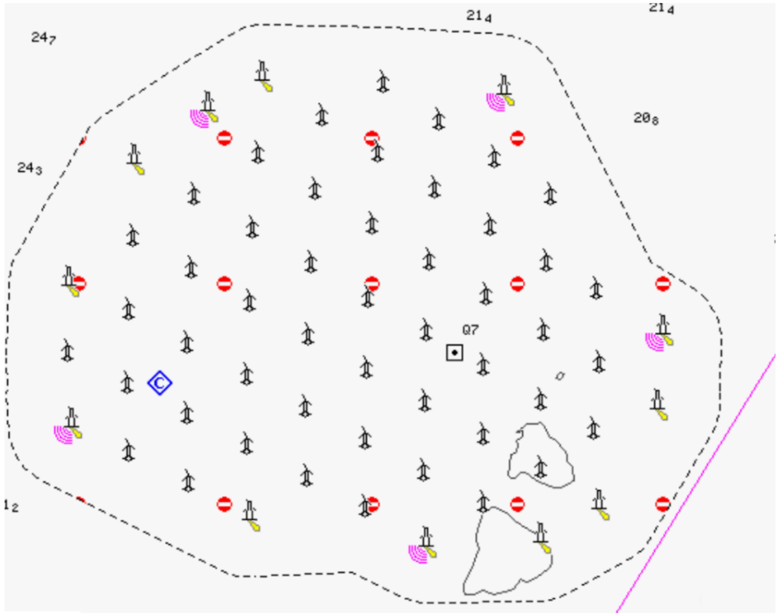

Figure 14. Nautical chart of Prinsess Amaliawindpark including bottom depth relative to Lowest Astronomical Tide (LAT)

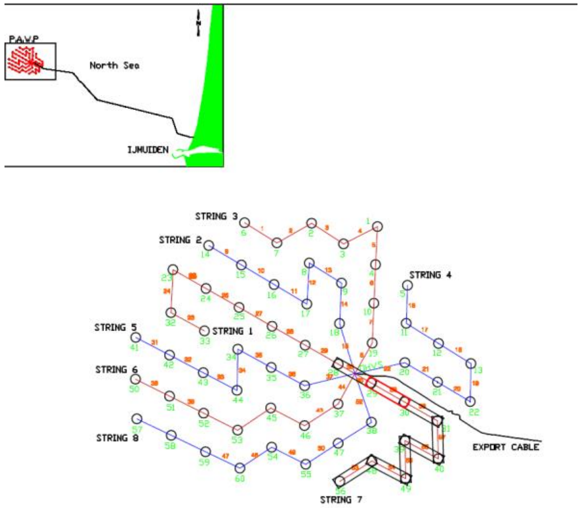

Figure 15. Windfarm infield cable layout. Source: Eneco b.v.

Figure 16. Path of export cables Prinses Amaliawindpark (left) and Offshore Windpark Egmond aan Zee (right).

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant wind direction													
Wind probability >= 4 Beaufort (%)	86	88	80	69	74	65	66	72	75	82	86	87	77
Average Wind speed (kts)	23	20	18	16	17	15	15	16	17	19	21	23	18
Average air temp. (°C)	7	5	6	9	12	14	17	18	17	14	11	8	11

Figure 17. Wind statistics Hoorn/Q1 Platform, based on observations between 05/2005 - 10/2017. Source www.windfinder.com/windstatistics-a_q1-platform, date: 28-11-2017

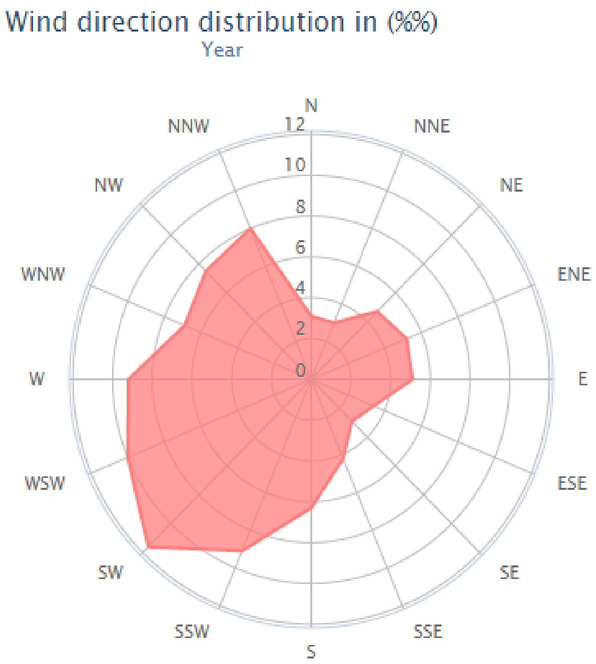

Figure 18. Wind rose Hoorn/Q1 Platform, based on observations between 05/2005 - 10/2017. Source www.windfinder.com/windstatistics-a_q1-platform, date: 28-11-2017.

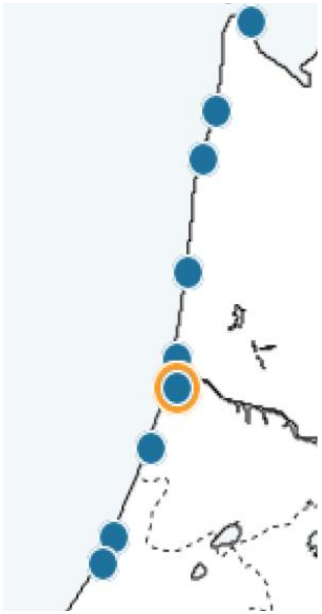

Figure 19. Locations KNRM-stations. From top to bottom: Den Helder, Callantsoog, Petten, Egmond aan Zee, Wijk aan Zee, IJmuiden (circled), Zandvoort, Noordwijk aan Zee and Katwijk aan Zee.

Wind farm Fact Sheet - Luchterduinen

1) Organisations involved		Comments
Developers	Eneco Wind B.V. Van Oord NV (main contractor) Vestas (Turbine manufacturer)	
Operators	Eneco Wind B.V. Eneco (50% owner) Mitsubishi (50% owner)	

2) Wind farm construction data		Comments
General info		
Name	Eneco Luchterduinen	
A.k.a	70, Q10	
Country	Netherlands	
Region	Noord-Holland	
Status	Operational	
Location		**See Figure 20 and Figure 21**
Sea name	North Sea	
Centre latitude	52.405º	
Center longitude	4.163º	

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Area	16 km^2	
Minimal distance to shore	23 km	
Distance from shore to wind farm center	24.2 km	
Bathymetry, morphology and soil type		
Depth range	18-22 m	
Depth range stated by developer (relative to chart datum)	18-24 m	
Wind farm bottom morphology description	See Figure 23	
Environmental conditions		
Tidal range	-65 cm NAP – 137 cm NAP	
Current direction and speed roses	N/A	
Monthly wave height/direction roses	N/A	
Relation Hs – Tp, wave spectrum type	N/A	
Monthly wind direction/speed roses	See Figure 17 and Figure 18	
Wind spectrum type, parameters	N/A	
Monthly temperatures statistics	N/A	
Misalignment wave and wind	N/A	
Turbines, transformers, converters		
Total nameplate power of wind farm	129 MW	
Turbine model (name, link to figures, drawings, photos, etc.)	Vestas V112-3.0 MW Offshore	http://www.noordzeewind.nl/wp-content/uploads/2012/02/OWEZ_R_141_20080215-General-Report.pdf

Turbines		
Number of turbines	43	
Turbine nameplate power	3 MW	
Total turbine height (from MSL)	137 m	
Turbine hub axis height (from MSL)	81 m	
Turbine rotor diameter	112 m	
Foundation (short description, picture)	Grounded monopile	
Turbine dry mass (whole construction excluding underground part)	Tower = 525 ton	Turbine has no transition piece. Only monopile foundation and tower.
Turbine structure diameter and cross-section area at MSL	4.5 m	
Remote stop of turbine and redundancy stop systems	Remote stop possible	
Transformers		
Name	Eneco Luchterduinen Substation	
Status	Operational	
Location (Lat/Lon)	52.40/4.17	
Type	Monopile	
Topside		
Weight	900 ton	

ARCADIS

Dimensions	25x15x15 m	Hight: 19m above mean sea level
Helideck	No	Winch to and from transformer is possible with clear vision
Service port/berth (dimension of service vessel accepted)	IJmuiden, Vlissingen	
Crew spaces (overnight y/n?)	No	
Station		
Number of transformers	2	
Transformer power	80 MVA	
Transformer voltage ratio	33/150 kV	
Other equipment	Switchgear: 155 kV and 33 kV GIS	
Cabling in-field and export		
Grid		
Converter/collector platforms	None	
Offshore transformer/converter	Eneco Luchterduinen Substation	
Cables shore landing point	Noordwijk aan Zee	
Grid connection point	380 kV transformer at Sassenheim	
Export cables		
Number of export cables	1	
Average length per cable	25 km	
Nominal voltage per cable	150 kV	
Cable diameter	208 mm	

Burial depth	1.5 – 3 meters	
Additional cover protection	Matrasses cover cable crossings	
Minimum bend radius	*Indication* 5.3 meter in static tank for storage/coiling	
Chart (nautical) of cable layout from wind farm to shore	See Figure 22	
In-field (array) cables		
Array cable length	32 km	43 array cables (one each turbine)
Nominal voltage	33 kV	
Cable diameter	129 mm	
Burial depth	Nominal 1 meter. Though depth and location vary due to bottom movement	
Additional cover (protection, armoring)	Protection with matrasses to cover cable crossings	
Chart (nautical) of in-field cable layout within the wind farm	See Figure 21	

Wind farm operational data		**Showing methods of wind farm use and maintenance**
Ports used for construction (potentially also for decommissioning) and for maintenance/operations		
Construction	IJmuiden	
Operations and maintenance	IJmuiden	

Decommissioning	IJmuiden	
Placement within navigation routes, economic zone, proximity of other wind farms, proximity of other renewable energy / non-renewable energy sites and transport routes		
Placement of nearby fishing ports	Den Helder, IJmuiden, Scheveningen	
SAR centers, governmental monitoring centers	See Figure 26	
Maintenance requirements		
List of survey/inspection activities	• Periodic inspection, mainly in nacelle • Inspection of blades • Inspection transformer station • Inspection of foundation and cables	Inspections and maintenance carried out by people entering turbine/nacelle, by rope access climbing, using jack-up crane vessel or a drone.
List of maintenance activities	• Periodic servicing, mainly nacelle • Maintenance and repair of blades • Replacement large parts • Resolving errors • Maintenance offshore transformer • Maintenance foundation and cables	Inspections and maintenance carried out by people entering turbine/nacelle, by rope access climbing, using jack-up crane vessel or a drone.
Frequency of maintenance and surveys/inspections	Approximately 100 days/year to perform maintenance and inspection work	Working is limited by environmental conditions, i.e. wave height, temperature and windspeed.
Time and manning for each type of work (boat crew, work crew)	On average day: 2 crew tender ships with a total of 3-6 teams in the wind farm. During large campaigns, up to 7 crew tenders carry round a total of 14-20 teams. Average time spent during maintenance: 10 hours at location, 2 hours traveling to and from location. Maximum working time: 12 hours. Can only be exceeded in case of emergency.	
Methods of meeting the maintenance requirements		
Underwater inspection activities with ROVs – description	Underwater inspections performed using a survey ship, equipped with a multibeam, side scan sonar and other. Inspection of monopile at/above waterline is performed by rope access teams.	

Underwater inspection activities with divers - description	Deployment of divers is reduced to a bare minimum because of the safety risks. In case of diving activities are necessary, diving is done with umbilical equipment according to Dutch 'Arbocatalogus Werken onder Overdruk'.
Array cable repair work – description	In case of failure, the failed section will be replaced (length roughly 600 m). New cable will be trenched while old cable will be removed. Lead time: 2-6 months. Within this period, the entire string of turbines will be shut off. Turbines will need to be conserved.
Export cable repair work (within the wind farm) – description	In case of failure, the section of failure needs to be determined. A new piece of cable will be inserted. Lead time 3-8 months. Within this period, the entire wind farm cannot operate. Turbines will need to be conserved.
Turbine inspection and maintenance – description (including role of work boats)	• Yearly, +/- 100 days of 'normal' maintenance performed with one crew tender. Most of work is performed in the turbine nacelle. • Maintenance of turbine blades performed by rope access teams and/or jack-up crane vessel. Varying number of teams: 1-4 crew tenders or one jack-up. • Replacement of large parts (gear box or generators) performed 2 times per year using jack-up vessel. • Coating campaigns, repairing parts of steel work and inspection of bolts.: Once every 2-year performed by one crew tender with 2-3 teams.
Transformer inspection and maintenance – description (including role of work boats)	Yearly inspection and maintenance of all components, performed by approximately 30 different contractors over approximately 50 days. • High voltage 33 kV and 150 kV equipment • Low voltage 240V and 400V equipment • Auxiliary equipment: emergency power generator, cranes, HVAC, firefighting, UPS, etc.
Methods of positioning of work boats during performing the work within the wind farm	• Crew tenders: Push with rubber fender onto boat landing. Only allowed when significant wave height < 1,5 meter with approved fender (Eneco demand). Crew tenders are obliged to have radar, electronical sea chart and to be certified according to the MCA workboats code.

	• Other maintenance ships must oblige to certain demands when positioning close to turbines: Minimum DP2 vessels with three independent systems to determine position (with certified IMCA standards) • Minimum distance for (ecological) research close to turbine foundation is 100 meters, or 500 meters distance from transformer station.	
Estimation of maintenance schedules		
Days per year	100 days per year	
Average number of maintenance boats at a maintenance day	2 Crew tender vessels	
Maximum number of maintenance boats at a maintenance day	7 crew tender vessels, one jack-up crane vessel	
Average time a maintenance boat spends within wind farm area	10 hours	
Maximum time a maintenance boat spends within wind farm area	10 hours	
Maintenance work (boats, work ships)		
Technical means of performing maintenance work	• Crew tenders: Windcat XX (Varius codes, Windcat Workboats), West Hinder (Acta Marine), Wenduine (Acta Marine), Waddenzee (Acta Marine) • Jack ups: WIND (Ziton), Pioneer (Ziton), Bold Tern (Fred Olssen), MPI Resolution (MPI) • Cable-lay vessel: CS Recorder (Global Marine) • Ecological research: Ivero (Gardline), must keep 100 m clearance from turbine • Survey: Storm (Deep), must keep 100 m clearance from turbine	All ships need to have had an IMCA-CMID inspection, less than 1 year ago.
Environmental limitations to maintenance work	Unknown	
Existence of SAR procedures and exercises for maintenance/ inspection/ survey work crews	No	

Existence of monitoring systems for controlling of the access to the wind farm area and wind farm installations	No
Existence of monitoring systems for controlling of the intrusion of shipping into wind farm area	No 24/7 monitoring. Since 2015, an AIS system is installed with poor coverage. Trespasses are not registered. Violations of safety are only by crew tender operators.
Insurance of the wind farm	**N/A**

Figure 20. Location windfarm Luchterduinen, relative to coast

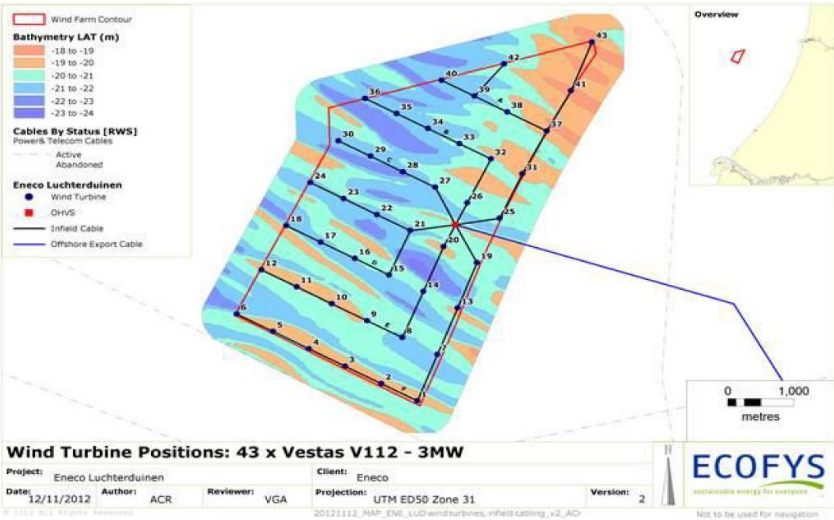

Figure 21. Layout Luchterduinen incl. infield cables and export line.


Figure 22. Path of export cable Luchterduinen.

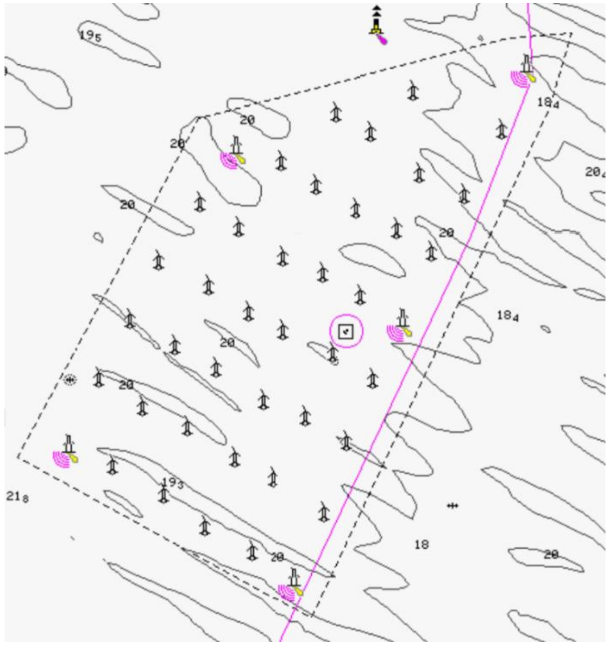

Figure 23. Nautical chart of Luchterduinen, including bottom depth relative to Lowest Astronomical Tide (LAT).

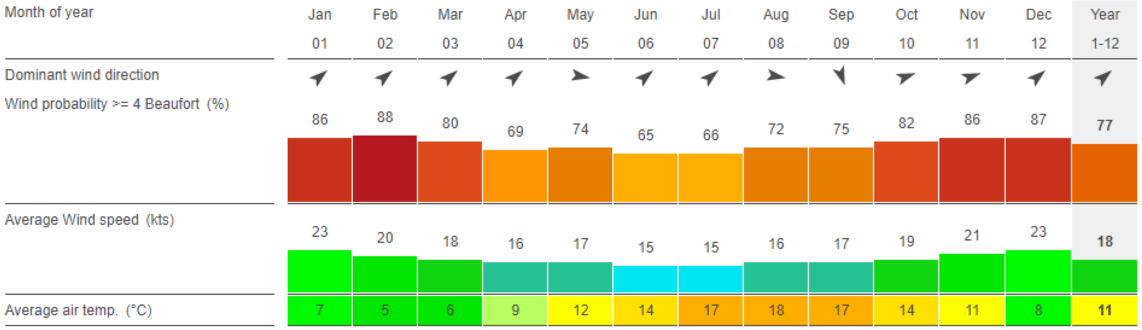

Figure 24. Wind statistics Hoorn/Q1 Platform, based on observations between 05/2005 - 10/2017. Source www.windfinder.com/windstatistics-a_q1-platform, date: 28-11-2017.

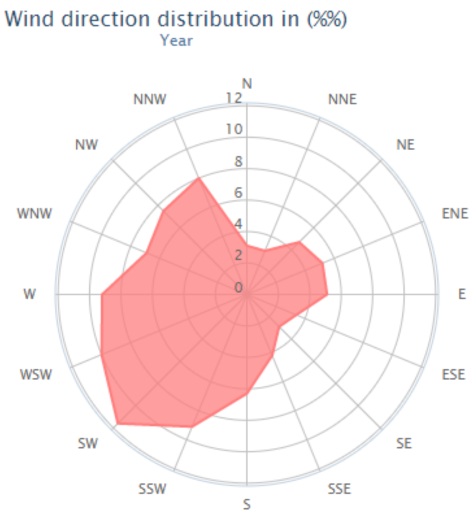

Figure 25. Wind rose Hoorn/Q1 Platform, based on observations between 05/2005 - 10/2017. Source www.windfinder.com/windstatistics-a_q1-platform, date: 28-11-2017.

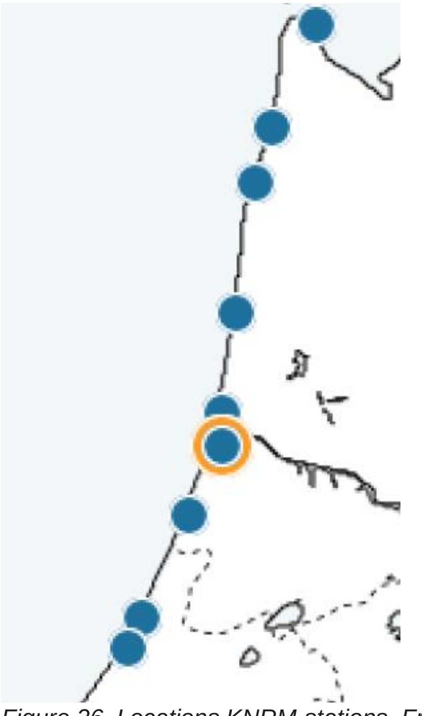

Figure 26. Locations KNRM-stations. From top to bottom: Den Helder, Callantsoog, Petten, Egmond aan Zee, Wijk aan Zee, IJmuiden (circled), Zandvoort, Noordwijk aan Zee and Katwijk aan Zee.

APPENDIX G – HAZARD GROUPS

Within the hazard groups, more detailed (sub) hazards – failure modes or accident scenarios - are identified.

Hazard group	Hazard sub group
1. Accidents with DoMe vessels requiring SAR action	a. Man overboard. b. Injury / serious sickness onboard. c. Fire and injury onboard, disabled vessel. d. Disabled and drifting vessel. e. Disabled and sinking vessel. f. Collision between two vessels, disabled, injuries, sinking/drifting.
2. Interaction of DoMe vessel with turbines	a. Collision of a vessel with a turbine monopile. b. Collision of a vessel with a turbine landing. c. Collision of a vessel with a turbine J-cables [note: scenario added in 2017]. d. Collision of a vessel with turbine blade [note: scenario added in 2017]. e. Ice thrown from turbine blade on DoMe vessel [note: scenario added in 2017].
3. Interaction of DoMe vessel with transformer stations	a. Collision of a vessel with a station base (foundation). b. Collision of a vessel with a station landing. c. Collision of a vessel with J-tube export cables [note: scenario added in 2017].
4. Interaction of DoMe vessel with in-field cables	a. Anchor dropped on the cable. b. Anchor dragged over the cable and hooks on the cable. c. Fishing gear hooked on the cable/connector and dragging. d. Sinking ship landing on infield cable [note: scenario added in 2017]. e. Other tools/parts of ship dropped on infield cable [note: scenario added in 2017].
5. Interaction of DoMe vessel with O&M vessels	a. Un-marked fishing gear (ropes, nets) gets into the propellers of O&M vessels. b. Intrusion into an exclusion zone, creating danger and averting the attention of the crew from the work, also danger for themselves (dropped objects). c. Drifting collision with O&M vessel.

	d. Powered collision with O&M vessel. e. Falling objects from O&M vessel (crane) [note: scenario added in 2017].
6. Interaction of DoMe vessel with divers and ROVs	a. Un-marked fishing gear (ropes, nets) gets into diver's way. b. Un-marked fishing gear (ropes, nets) gets into ROV's way. c. Drifting collision with a diver vessel. d. Powered collision with a diver vessel. e. Drifting collision with a ROV mother vessel. f. Powered collision with a ROV mother vessel. g. (Unmarked) fishing gear (ropes, nets) gets in recreational diver's way [note: scenario added in 2017]. h. Drifting collision with a recreational diver vessel [note: scenario added in 2017]. i. Powered collision with a recreational diver vessel [note: scenario added in 2017].
7. DoMe vessel crew entering turbine installation	a. Injury while entering/leaving turbine installation (landing). b. Injury while moving over the turbine installation (platform). c. Man overboard while moving over the turbine installation (platform/ladder). d. Damaging the turbine installation. e. Injury in closed (electrical) part of the turbine. f. Injury to windfarm personnel when taking people off the installation [note: scenario added in 2017].
8. DoMe vessel crew entering transformer station installation	a. Injury while entering/leaving transformer station. b. Injury while moving over the transformer facility. c. Man overboard while moving over the transformer facility. d. Damaging the transformer installation. e. Injury in closed (electrical) part of the transformer station.
9. Non-permitted (larger than 24m length) ship uses the wind farm area	a. Interaction with turbines. b. Interaction with transformers. c. Interaction within-field cables. d. Interaction with O&M vessels. e. Interaction with divers and ROVs.
10. Static fishing – Static netting and lines	a. Obstacle in water, i.e. marking buoys with lines attached and possible small distance of nets to water surface. b. Use of anchor to secure nets on bottom. c. Interference with O&M vessel performing maintenance activities. d. Interference with ROV or survey activities as result of trap location. e. Fishermen forms obstacle during fishing. f. Loss or drifting of gear into turbine or cables, use of grapnels to recover the gear damages cables.

11. Static fishing – Trap fishing	a. Obstacle in water, i.e. marking buoys with lines attached. b. Use of anchor to secure traps on bottom. c. Interference with ROV or survey activities as result of trap location. d. Fishermen forms obstacle during fishing. e. Loss or drifting of gear into cables, recovery with grapnels damaging cables.
12. Interaction with/caused by deployment of tidal energy device [note: scenario added in 2017]	a. Obstacle in water, i.e. marking buoys. f. Interference with O&M vessel performing maintenance activities. g. Interference with ROV or survey activities as result of trap location. h. Interference of tidal energy infrastructure with wind farm infrastructure.
13. Interaction with/caused by deployment of aquacultures	a. Obstacle in water, i.e. marking buoys, elements of the device creating unseen obstacles. b. Use of anchor to secure lines on bottom. c. Interference with O&M vessel performing maintenance activities. d. Interference with ROV or survey activities with aquaculture gear. e. Aquafarmer forms obstacle during activities. f. Loss or drifting of gear into cables.

APPENDIX H – RISK TABLES EXPLANATION

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Table 5. Risk score table. Construction of risk level using frequency and impact of a hazard.

Risk Score table - Determine risk level based on impact / severity and frequency / probability of occurrence.

Risk level	Required action
L - Low	Check that no other risks can be eliminated; Proceed with recording of residual risk
M - Medium	Reduce risks as far as reasonable practical (ALARP), noting applicable proportionality factors; Consider alternative design or construction method; If alternatives are not available, specify precautions to be adopted; Record residual risks
H - High	Seek alternative solution; If alternatives are not available, specify precautions to be adopted and advice / elevate to senior management; Record residual risks

				<-- Low --- **Impact (I)** --- High -->					
				None	Minimal	Mediate	Important	Severe	Catastrophe
Consequence on people health / safety / security				No health effect / injury	Slight health effect / injury	Minor health effect / injury	Major health effect / injury	PTD / or 1 to 3 fatalities	Multiple fatalities
Loss of revenue / financial damage (€)				< 10 k	< 100 k	< 1 M	< 10 M	< 100 M	> 100 M
Effect on Environment (HSE & CEM)				None	Slight	Minor	Localized	Major	Massive
Impact on reputation				None	Slight	Limited	Considerable	National	International
Description	One-time incident	Return of incidents		0	1	2	3	4	5
Never heard of in industry	< 1%	< 1 in 10 years	A	L	L	L	L	M	M
Has occurred in industry	< 10%	1 in 10 years	B	L	L	L	L	M	H
Has occurred in company	< 25%	1 in 3 years	C	L	L	L	M	M	H
Happens several times per year in company	< 50%	1 a year	D	L	L	M	M	H	H
Happens several times per year on location	> 50%	1 a month	E	L	M	M	H	H	H

<-- High - **Frequency (F)** - Low -->

Table 6. Explanation of risk table covering the present situation and assessment of gaps.

Hazard group ## - Group description

		Present situation, i.e. operational wind farm				**Arcadis assessment of gaps**			
		1	2	3	4	5	6	7	8
Id	Hazard failure mode	F	Consequence	I	Risk	Addressed in studies?	F	I	Current risk
p-#.1 p-#.2 p-#.3 p-#.4 p-#.5 p-#.6	Detailed failure modes defined per hazard group. See Chapter 4.	Failure frequency of occurrence. See Table 3	Explanation of consequence when failure occurs	Impact of failure when it occurs	Resulting risk, according to Table 3	Is the failure addressed in studies, used in development of proposed policy?	Reassessment of failure frequency	Reassessment of failure impact	Wat is the risk level, with the gap-changes
Id	**Sources and comments**								
p-1.1 p-1.2 p-1.3 p-1.4 p-1.5 p-1.6	Description of the sources and comments on findings. Note, for hazard group 10-13, this table is slightly altered. For these tables, the assessment of gaps is omitted, these hazards where not part of the 2015 dossier, and where added later.								

Table 7. Explanation of risk table for future situation when opening the wind farm safety zone, including the effect of proposed mitigating measures.

<table>
<tr><td></td><td colspan="13">Hazard group ## - Group description</td></tr>
<tr><td></td><td>Present</td><td colspan="2">Open WF</td><td colspan="8">Reduction of risk by proposed control measures?</td><td colspan="2">Proposed situation</td></tr>
<tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>Id</td><td>Current risk</td><td>F</td><td>Risk</td><td>Info. campaign</td><td>Active VHF onboard</td><td>Active AIS onboard</td><td>No anchoring</td><td>No trawling</td><td>50m zone turbine</td><td>500m zone trans.</td><td>Max. 24 m vessels</td><td>F</td><td>Residual Risk</td></tr>
<tr><td>f-1.1</td><td rowspan="6">Risk level as defined after the gap analysis</td><td colspan="2" rowspan="6">Change of frequency and risk level when wind farm safety area is released</td><td colspan="8" rowspan="6">The proposed mitigating measures are split in eight groups. For each measure its effect on reducing the risk of a failure is checked. YES, if the measure reduces the risk level, NO if not. N/A is measure is not related to hazard</td><td colspan="2" rowspan="6">Frequency and risk level when proposed policy is active</td></tr>
<tr><td>f-1.2</td></tr>
<tr><td>f-1.3</td></tr>
<tr><td>f-1.4</td></tr>
<tr><td>f-1.5</td></tr>
<tr><td>f-1.6</td></tr>
<tr><td></td><td colspan="13">Sources and comments</td></tr>
<tr><td>p-1.1</td><td colspan="13" rowspan="6">Description of the sources and comments on findings.</td></tr>
<tr><td>p-1.2</td></tr>
<tr><td>p-1.3</td></tr>
<tr><td>p-1.4</td></tr>
<tr><td>p-1.5</td></tr>
<tr><td>p-1.6</td></tr>
</table>

APPENDIX I – RISK TABLES PER HAZARD GROUP

Table 8 Hazard group 1. Accidents with DoMe vessels requiring SAR action.

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Hazard failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-1.1	Man overboard	B	No timely rescue; crew injured	2	L	YES	B	2	L
p-1.2	Injury / serious sickness onboard	B	Serious injury treatment delayed	2	L	YES	C	2	L
p-1.3	Fire and injury onboard, disabled vessel	B	Serious injury treatment delayed	2	L	YES	B	2	L
p-1.4	Disabled and drifting vessel	B	Collision: drifting: anchor hooks subsea cable	3	L	YES	B	3	L
p-1.5	Disabled and sinking vessel	B	Vessel and environmental damage; death	3	L	YES	B	4	M
p-1.6	Collision between two vessels, disabled, injuries, sinking/drifting	B	Vessel and environmental damage; death	3	L	YES	B	4	M

Id	**Sources and comments**
p-1.1-6	Occurrences based on 'Bijlages bij uitwerking besluit doorvaart en medegebruik ' #14 of dossier and others
p-1.1-6	There is no support in the data, impact and frequency based on expert judgement
p-1.5-6	Concerns most probably interaction with O&M vessels. RWS expects lower frequency, though level A is considered to be too low
p-1.1-6	Use of helicopters for SAR-operations is restricted to good visibility. SAR-operations within wind farm carried out by boats mainly

Table 9 Hazard group 1. Accidents with DoMe vessels requiring SAR action

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	Current risk	F	Risk	Info.	Active VHF onboard	Active AIS onboard	No anchoring	No trawling	50m zone turbine	500m zone transform.	Max. 24m vessel	F	Residual Risk
f-1.1	L	C	L	NO	YES	YES	N/A	N/A	N/A	N/A	N/A	C	L
f-1.2	L	C	L	NO	YES	YES	N/A	N/A	N/A	N/A	N/A	C	L
f-1.3	L	C	L	NO	YES	YES	N/A	N/A	N/A	N/A	N/A	C	L
f-1.4	L	C	M	YES	YES	YES	N/A	N/A	N/A	N/A	YES	B	L
f-1.5	M	C	M	YES	YES	YES	N/A	N/A	N/A	N/A	YES	B	M
f-1.6	M	C	M	YES	YES	YES	N/A	N/A	N/A	N/A	YES	B	M

Id	Sources and comments
f-1.1-6	AIS and VHF radio allow for easier SAR action, so the change of serious accident/injury is reduced
f-1.4	Ships up to 24 meters use relative small anchor; less change of hooking a cable and lower consequences in case of a collision
f-1.6	Smaller vessels are damaged less severe in case of a ship-ship collision, hence lower change of sinking
f-1.5-6	Comment RWS: frequency lower, frequency of drifting should likely be larger than sinking

Table 10 Hazard group 2. Interaction of DoMe vessel with turbines

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Hazard failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-2.1	Collision of a vessel with a monopile	B	Serious damage to turbine/vessel	3	L	YES	B	3	L
p-2.2	Collision of a vessel with a transition piece	B	Damage to turbine landing / vessel; no access to turbine	2	L	Not fully	B	2	L
p-2.3	Collision of a vessel with a turbine J-tubes	B	Damage to cable/lost production of turbines, shock/loss production	3	L	Not fully	B	3	L
p-2.4	Collision of a vessel with turbine blades	B	Damage to yacht, turbine/loss production, people injured	3	L	NO	B	3	L
p-2.5	Ice thrown from turbine blade on DoMe vessel	A	People injured/killed, damage to vessel	3	L	NO	A	3	L

Id	**Sources and comments**
p-2.1	This can happen at present for vessels entering from outside of the wind farm. Serious damage only for larger vessels
p-2.1	Studies seem to overestimate damages to monopiles in case of small vessels, because small vessels are treated as rigid bodies
p-2.2-3	Not reported with respect to third party vessels
p-2.3	This failure was not analyzed in presented documents, brought up during stakeholder meeting
p-2.4	RYA (UK) data indicate that only 4% of yachts have air draught exceeding 22m, this limits the probability
p-2.5	It should be possible to predict icing on wind turbine blades as icing affects the efficiency of a wing, so shall the turbine productivity be influenced. Together with knowledge of weather conditions the suspect can be raised which allows for warning.

Table 11 Hazard group 2. Interaction of DoMe vessel with turbines

	Present	Open WF		Risk reduction capability of specific control measures								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbine**	**500m zone transform.**	**Max. 24m vessel**	**F**	**Residual Risk**
f-2.1	L	C	M	YES	YES	YES	N/A	N/A	YES	N/A	YES	B	L
f-2.2	L	C	L	YES	YES	YES	N/A	N/A	YES	N/A	YES	B	L
f-2.3	L	C	M	YES	YES	YES	N/A	N/A	YES	N/A	YES	B	L
f-2.4	L	B	L	YES	YES	YES	N/A	N/A	YES	N/A	YES	B	L
f-2.5	L	A	L	YES	YES	YES	N/A	N/A	YES	N/A	YES	A	L

Id	**Sources and comments**
f-2.1	Serious damage to turbine is possible, only with a large vessel at speed. Serious damage to small vessel is possible. Sources: Marin and INFRA studies
f-2.2-3	Would practically mean a small vessel attempting to land or colliding
f-2.2-3	Barriers due to monitoring (AIS, radar) plus VHF radio potentially reduce the change to approach a turbine
f-2.4	Information about air space underneath turbine reduces risk. Yachts with 20m+ masts have professional crew whom manage risks better than average sailor. Sources: MGN 372, MGN 543, Report on accident statistics UK and DK, 'Bijlage bij besluit doorvaart en medegebruik ' #12.
f-2.1-5	Frequency for open wind farm determined based on available data from Marin, received from wind farm operators, incident reports Coastguard and (partly) QRA matrix

Table 12. Hazard group #3. Interaction of DoMe vessel with transformer stations.

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-3.1	Collision of a vessel with a station base (foundation)	B	Serious damage to station/vessel	3	L	NO	B	2	L
p-3.2	Collision of a vessel with a station landing	B	Damage to landing, production loss / damage to vessel	3	L	NO	B	3	L
p-3.3	Collision of a vessel with J-tube export cables	B	Damage to export cables/major loss of production	3	L	NO	B	3	L

Id	**Sources and comments**
p-3.1	It can happen at present for vessels entering from outside of the wind farm too. Serious damage only for larger vessels. No reports on such events with third party vessels. Studies overestimate damages to the monopile, in case of small vessels, because vessels are treated as a rigid body.
p-3.2	Not reported with third party vessels.
p-3.1-3	Up till now, no reporting on this kind of events at all.

Table 13. Hazard group #3. Interaction of DoMe vessel with transformer stations.

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-3.1	L	C	M	YES	YES	YES	N/A	N/A	N/A	YES	YES	B	L
f-3.2	L	C	M	YES	YES	YES	N/A	N/A	N/A	YES	YES	B	L
f-3.3	L	C	M	YES	YES	YES	N/A	N/A	N/A	YES	YES	B	L

Id	**Sources and comments**
f-3.1	Serious damage to the monopile, only by large vessel (length larger than 35 meters) at speed. For small vessels, rather the small vessel will be damaged, instead of the turbine monopile. I.e. the size of the vessels limits the damage. See table of hazard group #2.
f-3.1-3	Information potentially reduces the number of incidents, AIS and VHF allow for tracking and to make contact and hence warning. This will limit the chance of an accident happening. The exclusion zone of 500-meter acts as an extra deterrence.

Table 14. Hazard group #4. Interaction of DoMe vessel with infield cables.

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-4.1	Anchor dropped on infield cable	B	Array cable damage/loss production	4	M	Partly	B	4	M
p-4.2	Anchor dragged over the cable and hooks / grapnels on the cable	B	Array cable damage/loss production	4	M	Partly	B	4	M
p-4.3	Fishing gear hooked on the cable/connector and dragging	B	Array cable damage/loss production	4	M	Partly	B	4	M
p-4.4	Sinking ship landing infield cable	B	Array cable damage/loss production	4	M	No	A	4	M
p-4.5	Other tools/parts of ship dropped on infield cable	B	Array cable damage/loss production	4	M	No	A	4	M

Id	**Sources and comments**
p-4.1-3	Highest perceived risk to cables; combination of both Impact and Frequency.
p-4.4	Size, shape and weight decisive when it comes to impact.
p-4.5	To have serious impact, the object should be rather heavy to crush or crack the core of the cable. It could be e.g. a heavy dead-weight anchor.
p-4.1-5	Up till now, one interaction with cable is reported (OWEZ). This suggests the enforced exclusion zone is effective.

Table 15. Hazard group #4. Interaction of DoMe vessel with infield cables.

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-4.1	M	D	H	YES	YES	YES	YES	YES	N/A	N/A	YES	C	M
f-4.2	M	D	H	YES	YES	YES	YES	YES	N/A	N/A	YES	C	M
f-4.3	M	D	H	YES	YES	YES	YES	YES	N/A	N/A	YES	C	M
f-4.4	M	B	M	YES	YES	YES	YES	YES	N/A	N/A	YES	B	M
f-4.5	M	B	M	YES	YES	YES	YES	YES	N/A	N/A	YES	B	M

Id	**Sources and comments**
f-4.1-2	Information about cable layout will reduce the frequency of an anchor being dropped on or dragged over a cable.
f-4.1-2	Available AIS and VHF will allow for position determination and will avoid anchors being dropped on or dragged over a cable.
f-4.3	Information plus AIS monitoring will reduce the chance of trawling within a wind farm.
f-4.1-5	Small vessels up to 24 meters have relative small anchors, this reduces the change of an anchor hooking a cable, if the cable is buried.
f-4.1-5	Information about prohibited activities, combined with AIS and VHF which allow for tracking and detection, will limit the number of anchoring or trawling incidents, or any other bottom disturbing activity.
f-4.5	Information campaigns will reduce the change of incidents with dropping objects. The limit to vessel size will limit the size of objects that might be dropped.

Table 16. Hazard group #5. Interaction of DoMe vessel with operation and maintenance vessel.

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-5.1	Un-marked fishing gear gets into the propellers of O&M vessel	D	Disruption of maintenance	1	L	NO	D	1	L
p-5.2	Intrusion into an exclusion zone, creating danger and averting crew attention from work, creating an unsafe work situation	D	Disruption of maintenance	1	M	Partly	D	1	L
p-5.3	Drifting collision with O&M vessel	B	Vessel damage/injuries/death	4	M	Partly	B	3	L
p-5.4	Powered collision with O&M vessel	B	Vessel damage/injuries/death	4	M	Partly	B	3	L
p-5.5	Falling objects from O&M vessel (crane)	B	Injury/death	3	L	NO	B	3	L

Id	**Sources and comments**
p-5.1-5	Impact depends on type of operations and maintenance vessel. E.g. a jack up vessel can have a larger impact compared to a crew tender. Additional mitigating measures proposed in next table.
p-5.2	Incidents are reported (OWEZ), but do not seem to be a problem in other parts of industry. Negative response when asked to foreign third parties.
p-5.3-4	No such incident has been reported in the industry. The impact and frequency might be overestimated.
p-5.5	This hazard requires a vessel or person to be close to a crane ship or turbine with a team working on the outside of the turbine. Frequency of dropping objects is relative high, while the frequency of a ship close to this high risk (lifting) work is relative low. Combination of both object falling AND ship coming to close to operations is most likely lower.

Table 17. Hazard group #5. Interaction of DoMe vessel with operation and maintenance vessel.

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-5.1	L	D	L	YES	YES	YES	N/A	N/A	N/A	N/A	N/A	D	L
f-5.2	M	E	M	YES	YES	YES	N/A	N/A	N/A	N/A	N/A	C	L
f-5.3	M	D	M	YES	YES	YES	N/A	N/A	N/A	N/A	YES	B	L
f-5.4	M	D	M	YES	YES	YES	N/A	N/A	N/A	N/A	YES	B	L
f-5.5	L	C	M	YES	YES	YES	N/A	N/A	N/A	N/A	N/A	B	L

Id	**Sources and comments**
f-5.1-5	Information campaigns provide knowledge about safe behavior in wind farm and potentially reduces the frequency of accidents.
f-5.1-5	VHF and AIS allow for tracking, detection and warning of possible intrusions and hence reduce the frequency of accidents.
f-5.1-5	The limit to vessel size limits the impact of a collision.
f-5.1-5	Potential additional mitigating measure; Create an exclusion zone around jack-up vessels. This allows for early warning and can reduce frequency of accidents.

Table 18. Hazard group #6. Interaction of DoMe vessel with divers and ROV.y

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-6.1	Un-marked fishing gear (ropes, nets) gets into diver's way	B	Injury/death	4	M	Partly	A	4	M
p-6.2	Un-marked fishing gear (ropes, nets) gets into ROV's way	B	Loss of time/damage	3	L	Partly	A	3	L
p-6.3	Drifting collision with a diver vessel/Diver	B	Damage vessel, Injury/death	4	M	Partly	A	4	M
p-6.4	Powered collision with a diver vessel/Diver	B	Damage vessel, Injury/death	4	M	Partly	A	4	M
p-6.5	Drifting collision with a ROV mother vessel	B	Damage vessel, Injury/death	4	M	Partly	A	4	M
p-6.6	Powered collision with a ROV mother vessel	B	Damage vessel, Injury/death	4	M	Partly	A	4	M
p-6.7	(Unmarked) fishing gear (ropes, nets) gets in recreational diver's way	B	Injury/death	4	M	Partly	A	4	M
p-6.8	Drifting collision with a recreational diver vessel	B	Damaged vessel	3	L	Partly	A	3	L
p-6.9	Powered collision with a recreational diver vessel	B	Damaged vessel	3	L	Partly	A	3	L
Id	**Sources and comments**								
p-6.1-9	Practically no reports on this kind of incidents. Frequency at present is probably low, level A								
p-6.1-6	Vessels in these hazards are marked using navigation aids and can be observed, hence change of coming to close is relative low.								

Table 19. Hazard group #6. Interaction of DoMe vessel with divers and ROV.

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-6.1	M	B	M	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	M
f-6.2	L	B	L	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	L
f-6.3	M	B	M	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	M
f-6.4	M	B	M	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	M
f-6.5	M	B	M	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	M
f-6.6	M	B	M	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	M
f-6.7	M	B	M	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	M
f-6.8	L	B	L	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	L
f-6.9	L	B	L	YES	YES	YES	N/A	YES	N/A	N/A	YES	A	L

Id	**Sources and comments**
f-6.1-9	Information will decrease the frequency of intrusions
f-6.1-9	Active use of AIS and VHF allows for monitoring and making contact. This will decrease the frequency of incidents
f-6.1-9	Small vessels have a lower potential for damages
f-6.1-9	By prohibiting active trawling in the wind farm, the chance of a diver or ROV being in danger by these vessels is reduced
f-6.7-9	No reports from industry showing problems with recreational divers, risks taken are similar to open sea
f-6.7-9	Recreational diving is prohibited in proposed rules, which will reduce the number activities drastically. Probably will never happen
f-6.8-9	Recreational diving is usually performed with air tanks. Hence, divers are less bounded to support vessel which reduces the impact on the diver when support vessel gets damaged.

Table 20. Hazard group #7. DoMe vessel crew entering turbine installation.

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-7.1	Injury while moving over the turbine transition piece	B	Injury/death	3	L	Partly	B	3	L
p-7.2	Man over board while moving over the turbine transition piece	B	Injury/Death	3	L	Partly	B	3	L
p-7.3	Damaging the turbine installation	B	Damage, Injury/death	3	L	Partly	B	3	L
p-7.4	Injury in closed (electrical) part of the turbine. I.e. injury in part of turbine closed by a door	B	Damage, Injury/death	3	L	Partly	B	3	L
p-7.5	Injury while transferring to/from vessel to turbine ladder	B	Injury/death	3	L	Partly	B	3	L
p-7.6	Injury to wind farm personnel while transferring persons off the turbine installation	B	Injury/death	4	M	No	B	3	L

Id	**Sources and comments**
p-7.1-4	Practically no reports in industry on this kind of entries. Only by ENECO.
p-7.1-4	At present, entry of the turbine (transition piece and turbine interior) is prevented by prohibition/safety zone only.
p-7.1-6	MCA MGN 534 indicates that turbines may/should be used as safe haven for people in distress.
p-7.5	No data indicating such event has happened
p-7.1-6	Hazards are addressed partly by prohibition of entrance to facility, even without monitoring and communication.

Table 21. Hazard group #7. DoMe vessel crew entering turbine installation.

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-7.1	L	B	L	YES	NO	NO	N/A	N/A	YES	N/A	N/A	B	L
f-7.2	L	B	L	YES	NO	NO	N/A	N/A	YES	N/A	N/A	B	L
f-7.3	L	B	L	YES	NO	NO	N/A	N/A	YES	N/A	N/A	B	L
f-7.4	L	B	L	YES	NO	NO	N/A	N/A	YES	N/A	N/A	B	L
f-7.5	L	B	L	YES	NO	NO	N/A	N/A	YES	N/A	N/A	B	L
f-7.6	M	B	L	YES	NO	NO	N/A	N/A	YES	N/A	N/A	B	L

Id	**Sources and comments**
f-7.1-6	Information campaign will make people aware and hence keep the frequency of intrusions low.
f-7.1-6	Prescribing use of AIS and VHF allow for tracking and communication before the intrusion takes place. Afterward, this can help in prosecution too.
f-7.1-6	Establishment of a 50m zone around turbine both warns and allows for warning and persecution. This will reduce the frequency of intrusions.

Table 22. Hazard group #8. DoMe vessel crew entering transformer station installation.

		Present situation				Arcadis assessment of gaps			
		1	2	3	4	5	6	7	8
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**	**Addressed in studies?**	**F**	**I**	**Risk**
p-8.1	Injury while moving over the transformer facility	B	Injury/death	3	L	Partly	A	3	L
p-8.2	Man over board while moving over the transformer facility	B	Injury/Death	3	L	Partly	A	3	L
p-8.3	Damaging the transformer installation	B	Damage, Injury/death	4	M	Partly	A	4	M
p-8.4	Injury in closed (electrical) part of the transformer station	B	Damage, Injury/death	3	L	Partly	A	3	L
p-8.5	Injury while entering/leaving transformer station	B	Injury/death	3	L	Partly	A	3	L

Id	**Sources and comments**
p-8.1-5	No such events reported by third party organizations or by stakeholders. Frequency most likely overestimated.
p-8.1-5	Hazards are addressed partly by prohibition of entrance to facility, even without monitoring and communication.

Table 23. Hazard group #8. DoMe vessel crew entering transformer station installation.

	Present	Open WF		Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**Current risk**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-8.1	L	B	L	YES	NO	NO	N/A	N/A	N/A	YES	N/A	B	L
f-8.2	L	B	L	YES	NO	NO	N/A	N/A	N/A	YES	N/A	B	L
f-8.3	M	B	M	YES	NO	NO	N/A	N/A	N/A	YES	N/A	B	M
f-8.4	L	B	L	YES	NO	NO	N/A	N/A	N/A	YES	N/A	B	L
f-8.5	L	B	L	YES	NO	NO	N/A	N/A	N/A	YES	N/A	B	L

Id	**Sources and comments**
f-8.1-5	Information can prevent attempts to enter transformer facility.
f-8.1-5	Prescribing use of AIS and VHF allow for tracking and communication before the intrusion takes place. Afterward, this can help in prosecution too.
f-8.1-5	The 500m exclusion zone allows for monitoring and warning before entry of transformer station. Also ground for prosecution.
f-8.1-5	Since there are no reports on intrusions of the transformer stations at all, the frequency level in case of open wind farm without application of any rules might be lower. I.e. column 2 would have a frequency level B.

Table 24. Hazard group #10. Static fishing, static netting and lines.

		General risk			
		1	2	3	4
Id	**Failure mode**	**F**	**Consequence**	**I**	**Risk**
p-10.1	Obstacle in water, i.e. marking buoys with lines attached and possible small distance of nets to water surface	C	Damage to vessel, loss of time	2	L
p-10.2	Use of anchor to secure nets on bottom	C	Damage to cables	3	M
p-10.3	Interference with O&M vessel performing activities	D	Loss of time	2	M
p-10.4	Interference with ROV or survey activities as result of gear location	C	Loss of time, damage ROV, damage to nets	3	M
p-10.5	Fishermen forms obstacle during fishing	D	Loss of time, injury, collision	3	M
p-10.6	Loss or drifting of gear into turbine or cables, use of grapnels to recover the gear damages cables	B	Damage to cables	3	L

Id	**Sources and comments**
p-10.1-6	Frequency and impact in present situation determined from available documentation.
p-10.1-5	Though static fishing is prohibited and not performed currently, a risk level is determined for the present situation still. This is to determine the risk level if static fishing would be performed in the current situation, and to assess the studies performed on this topic so far.

Table 25. Hazard group #10. Static fishing; static netting and lines.

	Open WF			Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**I**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-10.1	2	C	L	YES	NO	NO	N/A	N/A	N/A	N/A	N/A	C	L
f-10.2	3	C	M	YES	NO	NO	NO	NO	N/A	N/A	N/A	C	M
f-10.3	2	D	M	YES	YES	YES	N/A	N/A	YES	YES	N/A	C	L
f-10.4	3	C	M	YES	NO	NO	NO	NO	YES	YES	N/A	C	M
f-10.5	3	D	M	YES	YES	YES	N/A	N/A	YES	YES	N/A	B	L
f-10.6	3	B	L	NO	NO	NO	NO	NO	N/A	N/A	N/A	B	L

Id	**Sources and comments**
f-10.1-6	Frequency and impact in present situation determined from available documentation.
f-10.1	Small hazard considering daytime navigation and information.
f-10.2	Possibility to get entangled in cables, information on cable location will help.
f-10.3	Use of AIS & VHF can reduce hazard, it allows for communication with - and better visibility of O&M vessels.
f-10.4	There is no information about location of nets and lines. This results in a larger danger to ROVs.
f-10.5	Use of AIS and VHF reduces the delay of O&M vessels and will reduce the frequency, but in general O&M vessel will need to wait or sail around.
f-10.6	Once the gear is lost, the fishermen may try to get it with grapnels which can cause damage to the cables. Drifting gear can get into the cables as well and get tugged later, which is a danger to maintenance activities.

Table 26. Hazard group #11. Static fishing; trap fishing.

		General risk			
		1	2	3	4
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**
p-11.1	Obstacle in water, i.e. marking buoys with lines attached	C	Damage to vessel, loss of time	2	L
p-11.2	Use of anchor to secure traps on bottom	D	Damage to cables	3	M
p-11.3	Interference with ROV or survey activities as result of trap location	C	Loss of time, damage ROV	3	M
p-11.4	Fishermen forms obstacle during fishing	D	Loss of time, injury, collision	3	M
p-11.5	Loss or drifting of gear into cables, recovery with grapnels into cables	B	Cable damage	3	L

Id	**Sources and comments**
p-11.1-5	Though static fishing is prohibited and not performed currently, a risk level is determined for the present situation still. This is to determine the risk level if static fishing would be performed in the current situation, and to assess the studies performed on this topic so far.

Table 27. Hazard group #11. Static fishing; trap fishing.

	Open WF			Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**I**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-11.1	2	C	L	YES	NO	NO	N/A	N/A	N/A	N/A	N/A	C	L
f-11.2	3	C	M	YES	NO	NO	NO	NO	N/A	N/A	N/A	D	M
f-11.3	3	C	M	NO	NO	NO	NO	NO	YES	YES	N/A	C	M
f-11.4	3	D	M	YES	YES	YES	N/A	N/A	YES	YES	N/A	B	L
f-11.5	3	B	L	NO	NO	NO	NO	NO	N/A	N/A	N/A	B	L

Id	**Sources and comments**
f-11.1	Small hazard when considering only day time navigation is allowed. Providing information will help as well.
f-11.5	No knowledge about drifting of lost gear. Search by grapnels is a danger.

Table 28. Hazard group #12. Interaction with/caused by deployment of tidal energy devices. Activity only allowed with permit.

		General risk			
		1	2	3	4
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**
p-12.1	Obstacle in water, i.e. marking buoys	C	Damage to vessel, loss of time	2	L
p-12.2	Interference with O&M vessel performing activities	D	Loss of time, damage to vessels	2	M
p-12.3	Interference with ROV or survey activities as result of devices' location	C	Loss of time, damage ROV	3	M
p-12.4	Interference of tidal energy infrastructure with wind park infrastructure	C	Loss of business	4	M

Id	**Sources and comments**
p-12.1-4	Little is known about options and techniques for the deployment of tidal energy devices in wind farm areas while it is not allowed/practiced currently. It is expected that the frequency of hazard failure modes is underestimated in the available documentation.
p-12.1	Marking of tidal devices will create obstacles which to mark these obstacles. During day time, the marked tidal devices will form a relative small hazard.
p-12.2	For some vessels, the tidal energy devices may create hazards.
p-12.3	Deployment of tidal energy devices will restrict survey activities.
p-12.4	The hazards and risks of co-existence of two industrial structures depend a lot on the form of tidal energy installation. It is impossible to define specific hazards and risks to wind farm infrastructure.

Table 29. Hazard group #12. Interaction with/caused by deployment of tidal energy devices. Activity only allowed with permit.

	Open WF			Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**I**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-12.1	2	C	L	YES	NO	NO	N/A	N/A	N/A	N/A	N/A	C	L
f-12.2	2	D	M	NO	NO	NO	N/A	N/A	N/A	N/A	N/A	D	M
f-12.3	3	C	M	NO	NO	NO	N/A	N/A	N/A	N/A	N/A	C	M
f-12.4	4	C	M	NO	NO	NO	N/A	N/A	N/A	N/A	N/A	C	M

Id	**Sources and comments**
f-12.1	Small hazard, considering navigation in daytime. The information about tidal devices will help in planning of transit.
f-12.2	The O&M vessels will have to take into account the presence of tidal devices. It is unknown how much interference this will cause as type and characteristics of the devices are unknown.
f-12.3	The ROV operations and surveys will be impaired by tidal devices. The devices will block access and restrict towing of sonars or ROVs. There is a danger of entanglement in or collision with tidal devices.
f-12.1-4	The co-existence of two different industrial installations brings different hazards and risks to wind farms. It is unknown how the proposed risk controls can constrain these hazards. They most likely don't. When deployment of tidal energy devices is considered this should be a cooperation between wind farm owner and the tidal energy party, which might result in a different set of rules between the two parties.

Table 30. Hazard group #13. Interaction with/caused by deployment of aquacultures. Activity only allowed with permit.

		Present situation			
		1	2	3	4
Id	**Failure mode**	**F**	**Consequence**	**I**	**Current risk**
p-13.1	Obstacle in water, i.e. marking buoys or hidden parts of the device	C	Damage to vessel, loss of time	2	L
p-13.2	Use of anchor to secure lines on bottom	D	Damage to cables	3	M
p-13.3	Interference with O&M vessel performing activities	D	Loss of time	2	M
p-13.4	Interference with ROV or survey activities with aquaculture gear	C	Loss of time, damage ROV	3	M
p-13.5	Aquafarmer forms obstacle during activities	D	Loss of time, injury, collision	3	M
p-13.6	Loss or drifting of gear into cables	C	Cable damage	3	M

Id	**Sources and comments**
p-13.1-6	Little is known about options and techniques for growing aquacultures in wind farm areas while it is not allowed/practiced currently. It is expected that the frequency of hazard failure modes is underestimated in the available documentation.
p-13.1	Navigation markings cause no problems, though the device may reach further and be unseen. This will increase the risk level.
p-13.2	Anchoring is necessary. This may interfere with cables.
p-13.3	The aquaculture may cause O&M vessels to navigate through channels, which reduces the accessibility. This depends on type of aquaculture and techniques used.
p-13.4	Some of aquaculture installations involve lines, textiles and nets. This may cause serious interference with surveys and ROV work.
p-13.5	Aquaculture installation and harvesting vessels may cause obstacles during their activities.
p-13.6	Nothing is known about losing aquaculture gear and its behavior, how far it can drift and whether it can hook wind farm infrastructure. Also, search and recovery methods may damage cables.

Table 31. Hazard group #13. Interaction with/caused by deployment of aquacultures. Activity only allowed with permit.

	Open WF			Reduction of risk by proposed control measures?								Proposed	
	1	2	3	4	5	6	7	8	9	10	11	12	13
Id	**I**	**F**	**Risk**	**Info.**	**Active VHF onboard**	**Active AIS onboard**	**No anchoring**	**No trawling**	**50m zone turbines**	**500m zone trans.**	**Max. 24m vessels**	**F**	**Residual Risk**
f-13.1	2	C	L	YES	NO	NO	N/A	N/A	N/A	N/A	N/A	C	L
f-13.2	3	D	M	YES	NO	NO	NO	NO	N/A	N/A	N/A	C	M
f-13.3	2	D	M	NO	NO	NO	N/A	N/A	N/A	N/A	N/A	C	L
f-13.4	3	C	M	NO	NO	NO	N/A	N/A	N/A	N/A	N/A	C	M
f-13.5	3	D	M	YES	YES	YES	N/A	N/A	N/A	N/A	N/A	B	L
f-13.6	3	C	M	NO	NO	NO	NO	NO	N/A	N/A	N/A	C	M

Id	**Sources and comments**
f-13.1	Information about the wind farm area layout and location of aquaculture will reduce the risk.
f-13.2	Information about cable layout will help to reduce risks.
f-13.3-4,6	None of the proposed risk control measures will reduce these risks. The current information available will not mitigate risks. An agreement between wind farm owner and aquaculture party is necessary to agree on working rules. Information could then be updated, and measures taken to reduce risks.
f-13.5	Information about possible activities, AIS and VHF will reduce hazards from transiting vessels.
f-13.1-6	Deployment of aquacultures will limit the space available for transit. This will make planning for transiting vessels more demanding.
f-13.1-6	It seems that the hazards are not fully recognized. Also, the presently proposed risk control methods have not much effect on controlling the risks posed to wind farms by aquaculture installations. Separate arrangements between wind farms and aquaculture organization will be needed.

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