1 Introduction

The following considerations should be seen as a non-exhaustive reply to TTJA's draft negative decision about SWE's application to amend and increase the OWF area (dated 16-08-2023). The provided information in this technical note is a reaction to some arbitrary chosen statements in TTJA's draft document. The fact that some of the topics in the draft decision are not addressed shall not be interpreted such way that they are accepted.

2 TTJA asked SWE for information on how many wind turbines and with what capacity can fit in the initiated area based on current knowledge

To answer this question, the so-called "capacity density" is of importance. The capacity density of an offshore windfarm shows how much energy can be produced per km². In this context we would like to refer to two independent scientific studies:

1. A study performed by the European Union in 2018 concluded a "corrected windfarm capacity density" for the Baltic Sea region of 5.5 MW/km². Pursuant to the study, this is close to the findings in academic literature of 5.0-5,4 MW/km². (Capacity Densities of European Offshore Wind Farms | The European Maritime Spatial Planning Platform (europa.eu))[1].
2. Another scientific study performed by TNO in the Netherlands determined that the optimal wind farm power density is 5.06 MW/km² for a 15 MW wind turbine (Optimal wind farm power density analysis for future offshore wind farms, TNO, 2018)[2].

Please note that pursuant to the studies, the *nominal capacity density* can be calculated by simply dividing the wind farm's overall capacity by its area. But this this leads to an overestimation of the capacity density, especially for smaller wind farms. For this reason a *corrected wind farm capacity density* is calculated in the first of the two studies to make the wind farms comparable to each other and to the literature values.

However, the past has shown that national tender criteria have had an influence on the chosen capacity density. Higher production was preferred by the consenting authorities, which is why developers were stimulated to maximize capacity density within the given limits.

In accordance with the referred studies and the experience from realized windfarms, we will in the following assume the bandwidth of 5.06 MW/km² as the "optimum LCOE capacity density" and 7 MW/km² as the upper bound for capacity density. Using this approach, following windfarm sizes could be assumed for the 2015 initiated area as an approximation:

	2015 application	2020 application
Size (km²)	167,1 km²	197,5 km²
Capacity @ optimum LCOE (5,06 MW/km²)	850 MW	1.000 MW
Capacity @ upper bound (7 MW/km²)	1.170 MW	1.380 MW

As it can be seen from above calculation, the encumbered area of the application in 2015 would be large enough to accommodate an expected windfarm size of **about 850 – 1.170 MW**.

However, in the course of the EIA surveys, major restrictions have been identified. Hence, SWE submitted its application to amend and increase the area. In several communications, the increase is mentioned to be 27,9%. However, as already explained in our letter dated 07.10.2022, it can easily be calculated that the increase only amounts to 18,2% (197,5 km² ÷ 167,1 km² = 118,2%) in comparison to the area stipulated in the government order No. 183.

As explained earlier, SWE considers approximately 64,7 km² of the '2020 area' to be not suitable for the installation of gravity based foundations (GBS) and approximately 34,4 km² of the '2020 area' to be extremely challenging for drilled monopiles (MP).

Yet another restriction which has not been mentioned earlier is the possible declaration of natural reserve zones for fish in reef areas as shown below. When superposing these protected areas with the earlier identified problematic areas, we can assume following windfarm capacities for MP and GBS respectively:

[1] https://maritime-spatial-planning.ec.europa.eu/practices/capacity-densities-european-offshore-wind-farms

[2] http://resolver.tudelft.nl/uuid:dfe0ce2f-04fb-4db2-80db-52bc02cfb515

Monopiles	2015 application	2020 application
Size (km²)	**167,1 km²**	197,5 km²
Area unsuitable for Monopiles (km²)	-25,8 km²	-34,4 km²
Possibly restricted reef area for fish (km²)	-8,1 km²	-10,5 km²
Remaining for OWF development (km²)	133,2 km²	**152,6 km²**
Capacity @ optimum LCOE (5.06 MW/km²)	670 MW	**770 MW**
Capacity @ upper bound (7 MW/km²)	930 MW	**1.070 MW**

As shown in above table, even after granting the extension application of SWE, the resulting area for windfarm development will still be smaller than originally anticipated (152,6 km² for development of Monopiles instead of the originally anticipated 167,1 km²).

When considering Gravity Base Structures , the remaining development area looks even worse:

Gravity Base Structures (GBS)	2015 application	2020 application
Size (km²)	**167,1 km²**	197,5 km²
Area unsuitable for GBS (km²)	-55,9 km²	-64,7 km²
Possibly restricted reef area for fish (km²)	-8,1 km²	-10,5 km²
Remaining for OWF development (km²)	103,1 km²	**122,3 km²**
Capacity @ optimum LCOE (5.06 MW/km²)	520 MW	**620 MW**
Capacity @ upper bound (7 MW/km²)	720 MW	**860 MW**

Above table shows that even after granting the extension application, the remaining area for windfarm development will still be smaller than originally anticipated (122,3 km² for development of GBS instead of the originally anticipated 167,1 km²).

In reply to TTJA's request on how many wind turbines with which capacity can fit in the initiated area based on current knowledge, we would like to submit following reply:

- If the further engineering suggests to choose Monopile foundations, we anticipate based on current knowledge that we could install approximately 51-71 wind turbine generators with a nominal power of 15 MW each.
- If further engineering suggests to choose Gravity Based Structures, we anticipate – based on current knowledge – that we could install 41-57 wind turbine generators with a nominal power of 15 MW each.

Number and size of turbines	2015 application	2020 application
Assume no restrictions	**57-78 × 15 MW**	n/a
Consider reefs for fish and soil for MP foundations	45-62 × 15 MW	51-71 × 15 MW
Consider reefs for fish and soil for GBS foundations	35-48 × 15 MW	41-57 × 15 MW

As can be seen in above tables, the applied gross increase of the area by 18,2% does not even compensate for the net area which is lost for the development of offshore wind due to environmental and technical reasons. On the contrary, even after increasing the area by 18,2%, the suitable area will be about 10-30% smaller than the area originally applied for.

3 TTJA has asked the applicant to submit figures proving economic unreasonableness in order to make sure that the use of the area is impossible. The applicant has decided not to submit the relevant data

TTJA requested SWE to provide reliable data about future developments, which is difficult by definition. However, experience from the past can help in outlining expected trends. We will give it a try.

The TTJA and the MKM repeatedly suggested that it would be possible to solve the obstacle arising from the geology of the seabed with wind turbine placement or foundation alternatives, taking into account, for example, the phased construction or innovative solutions in the form of floating foundations.

In SWE's opinion, it should be obvious by looking at the tables above that a phased construction will not solve the problem, as there is not enough area left to reasonably split the development into phases.

The other suggestion, to consider innovative solutions in the form of floating foundations, is not very helpful either. It must be understood that fixed foundation types are the most common type of foundation used in offshore wind farms. The table below shows the numbers of foundations types used over 156 projects across Europe, Taiwan and USA following from market analysis of consultancy company 4Coffshore. Only three of these 156 projects used two types of foundations.

Commisioned and "under construction" projects in Europe, Taiwan and USA	Total	Monopile	Jacket	GBS	Floating	Misc.
156 projects in total	7227	5773	832	361	32	235
	100.0%	79.9%	11.5%	5.0%	0.4%	3.3%

Bottom fixed structures are typically found in water depths up to 50 meters [3]. Floating wind farms will be positioned at depths beyond the reach of fixed foundations due to technical or economic constraints. At present, water depths starting from 60 meters are considered the technical cut-off point for bottom fixed and entry point for floating foundations [4]. See Figure 1 for a visual reference of these types of foundations and according water depths.

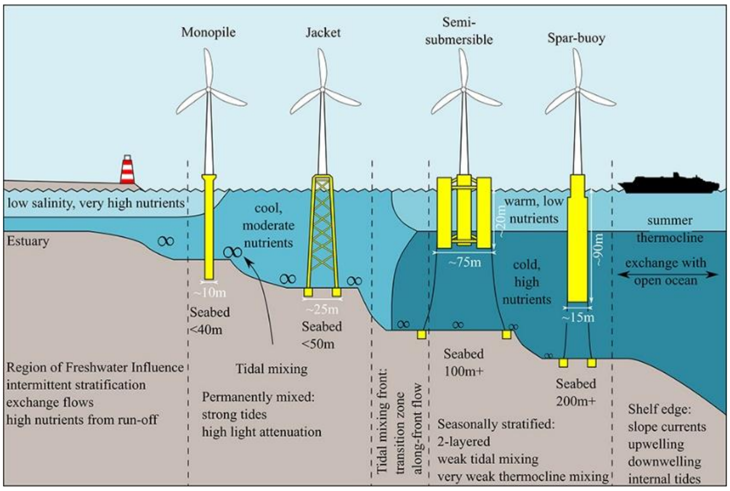

Figure 1 Typical water depths for various foundation types in Offshore Wind. From: https://www.frontiersin.org/articles/10.3389/fmars.2022.830927/full

It must be emphasised that floating foundations still have the character of demonstrator and pilot projects as shown in above table. The CAPEX of floating foundations is currently about 4 to 5 times as high as the CAPEX of bottom fixed foundations (Renews – Financing Offshore Wind Report 2023, page 16). All existing projects with floating turbines have been subsidised in one way or another, which most probably

[3] https://www.windedition.com/introducing-different-types-of-offshore-wind-turbine-foundations-fixed-and-floating/
[4] https://uis.brage.unit.no/uis-xmlui/handle/11250/3044817

is not the way the Estonian government wants to go. The world's largest floating offshore windfarm has just been inaugurated a few weeks ago (on 23.08.2023) and has the (not so) impressing capacity of 88 MW (Equinor inaugurates world's largest floating wind power farm in Norway | Reuters)[5]. If this is the largest windfarm, TTJA can imagine how likely it is that any investor will be willing to finance the development of several hundred MW.

A recent presentation at the at NREL "Wind Energy Systems Engineering Workshop", organised by the U.S. Department of Energy, suggested a factor of 220% between the LCOE of bottom fixed windfarms and floating windfarms in 2022. The presentation further predicted this difference to shrink over the coming 28 years (see figure below).

Looking at the same graph and considering that SWE plans to take its financial investment decision in 2026, it is SWE's best guess that the expected LCOE would still be in the region of 190% (1.9 times) higher than the corresponding LCOE with bottom-fixed foundations, which almost certainly would result in a non-realisation of the project.

It might be that TTJA considers suggesting that only part of the foundations had to be planned as floating while the majority of locations could be executed bottom-fixed. Again, the financial impact would be tremendous, as the execution of such projects basically require double project management, double mobilisation of the particular vessel spreads and double the efforts in following up and steering of a wider supply chain. Finance costs are more expensive due to the immaturity of the technology and the operation and maintenance will require more efforts. Taking all the effects into account, Van Oord and SWE assume that the LCOE of these particular turbines would be about 3,5 times higher than the LCOE of the turbines on bottom fixed foundations.

An example of such an approach was the Albatros offshore windfarm in Germany, developed by the construction company Strabag. Strabag entered the offshore wind market in 2009 and invested millions in the development and certification of their gravity based foundation concept.[6] In August 2011, the competent authority in Germany, the BSH, approved the construction of 10 demonstrator gravity base foundation in a windfarm of 79 locations (press release accessible through web.archive.org).[7] This split of the project into 69 regular foundations and 10 test foundation killed the business case and Strabag Offshore ceased operations and shelved the project in January 2013.[8] Obviously, the press release of Strabag in 2013 does not blame BSH for the write-off of their investments, but it is a well-known fact in the industry that the low quantity of test foundations did not allow the project to go forward. The Albatros windfarm was later built by EnBW with standard monopile foundations.[9]

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[5] https://jp.reuters.com/article/equinor-windpower-floating-idAFL8N3A21DB
[6] STRABAG SE - STRABAG Enters Offshore Wind Market (https://www.strabag.com/databases/internet/_public/content.nsf/web/SE-PRESSE.COM-PRESSEMITTEILUNGEN-2009-STRABAG%20steigt%20bei%20Offshore%20Wind%20ein#?men1=6&men2=1&sid=612&h=undefined&l=EN)
[7] Pressemitteilung: BSH genehmigt Windpark Albatros (archive.org) (https://web.archive.org/web/20120505145332/http://www.bsh.de/de/Das_BSH/Presse/Pressearchiv/Pressemitteilungen2011/13-2011.jsp)
[8] STRABAG SE - STRABAG postpones investments in Offshore Wind (https://www.strabag.com/databases/internet/_public/content.nsf/web/SE-PRESSE.COM-PRESSEMITTEILUNGEN-2013-STRABAG%20schiebt%20Investitionen%20im%20Bereich%20Offshore%20Wind%20auf#?men1=6&men2=1&sid=1616&h=undefined&l=EN)
[9] https://www.enbw.com/company/press/enbw-albatros-offshore-wind-farm-completely-installed.html

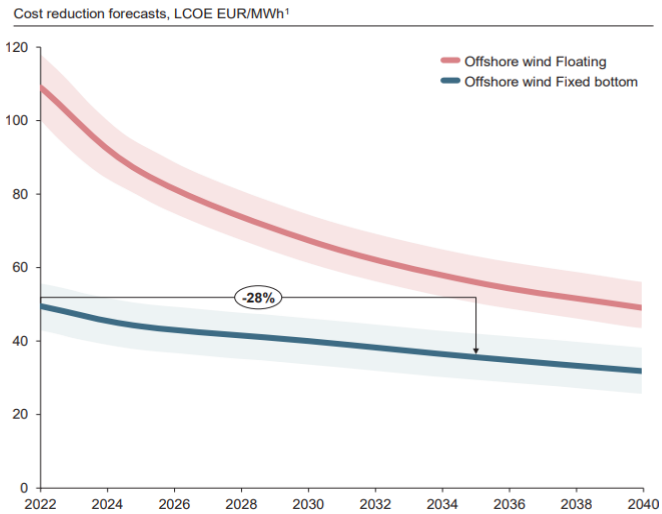

Figure 2 Cost reduction forecast of AEGIR as presented during NREL's "Wind Energy Systems Engineering Workshop" in Boulder, Colorado on 30-08-2022 (part of U.S. Department of Energy)

Concluding the above explanations, it is certain that a split of the windfarm into two foundation concepts (floating + either GBS or MP foundations) will almost certainly kill the business case and make the project financially unfeasible.

Commercial feasibility of splitting up the windfarm in clusters of different foundation types is not any way forward.

4 It is objectively not possible to erect wind turbines in the southern part of the encumbered area determined by OÜ Utilitas Wind when the superficies license procedure was initiated, and leaving this area in the built-up area would have been an unjustified use of state resources

This statement of TTJA is easily proven wrong. Curtailment of windpower production due to migrating birds is no unusual thing. There are actually examples of co-existence of wind turbines in bird migration corridors. For instance, we recommend looking at the Fryslan Offshore Windfarm, which is constantly surveyed by a bird radar system and where the operator has the ability to shut off the turbines when needed.

The publicly available EIA report of Site VII of wind energy area (Hollandse Kust (West))[10] states the following:

> *Routes of migratory birds across the North Sea Demarcating migration routes is not easy. Many birds migrate across the North Sea and their origin (breeding area) and destination (wintering area) are generally known. However, there are often no clearly defined "routes", certainly not in a form in which they can be precisely placed on a map and from which it could then be indicated whether they run over or along the Hollandse Kust (west) wind energy area. The relevant maps regarding main migration routes from Lensink & van der Winden (1997) are included in Appendix II of Appendix 4."*

[10] https://windpowernl.com/2023/05/16/dutch-wind-farms-temporarily-halted-for-bird-migration/

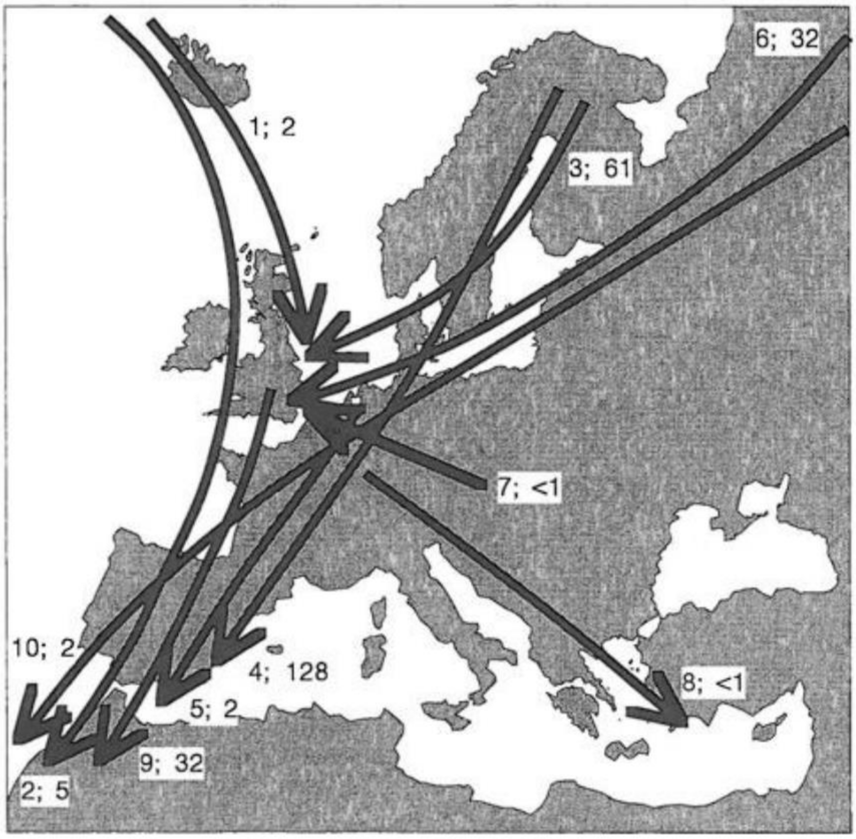

Figure 3 Routes of different species of migratory birds (Appendix II of Appendix 4, pages 205-228, PDF pages 273 ff)

These publicly available and scientifically substantiated maps clearly show that developer of offshore wind farms have to take curtailment due to migratory birds into account. A recent example has been published in Windpowernl on 16, May, 2023, explaining that the wind turbines at the offshore windfarms Borssele III and IV and other wind farms were turned down for four hours on May 13, 2023, in a measure to protect bird migration.[11] More information about the system is available on the homepage of Noordzeeloket,[12] a homepage by the Dutch Government.

And a quick Google research revealed the website of a provider of bird radar systems who promises it's costumers the ability to "Automatic Shut Down Capability Sea Wind Farm")[13].

In short, it can be concluded that TTJA's "objective" allegation does not reflect reality.

5 It is in the interest of the State to conduct auctions, and after conducting a specific auction and paying the auction amount to the state treasury, the winner can start developing a wind farm in the said marine area

In our understanding, it should be in the interest of the state to become energy independent by 2030. No auction of any non-developed offshore areas will contribute to achieving this target as none of these auctions have any chance to result in operational offshore windfarms by 2030.

11 https://windpowernl.com/2023/05/16/dutch-wind-farms-temporarily-halted-for-bird-migration/
12 https://www.noordzeeloket.nl/en/functions-and-use/offshore-wind-energy/start-stop/
13 https://www.robinradar.com/automatic-shut-down-capability-sea-wind-farm