Rampion 2 Wind Farm

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Information to support efficacy of noise mitigation / abatement techniques with respect to site conditions at Rampion 2 Offshore Windfarm

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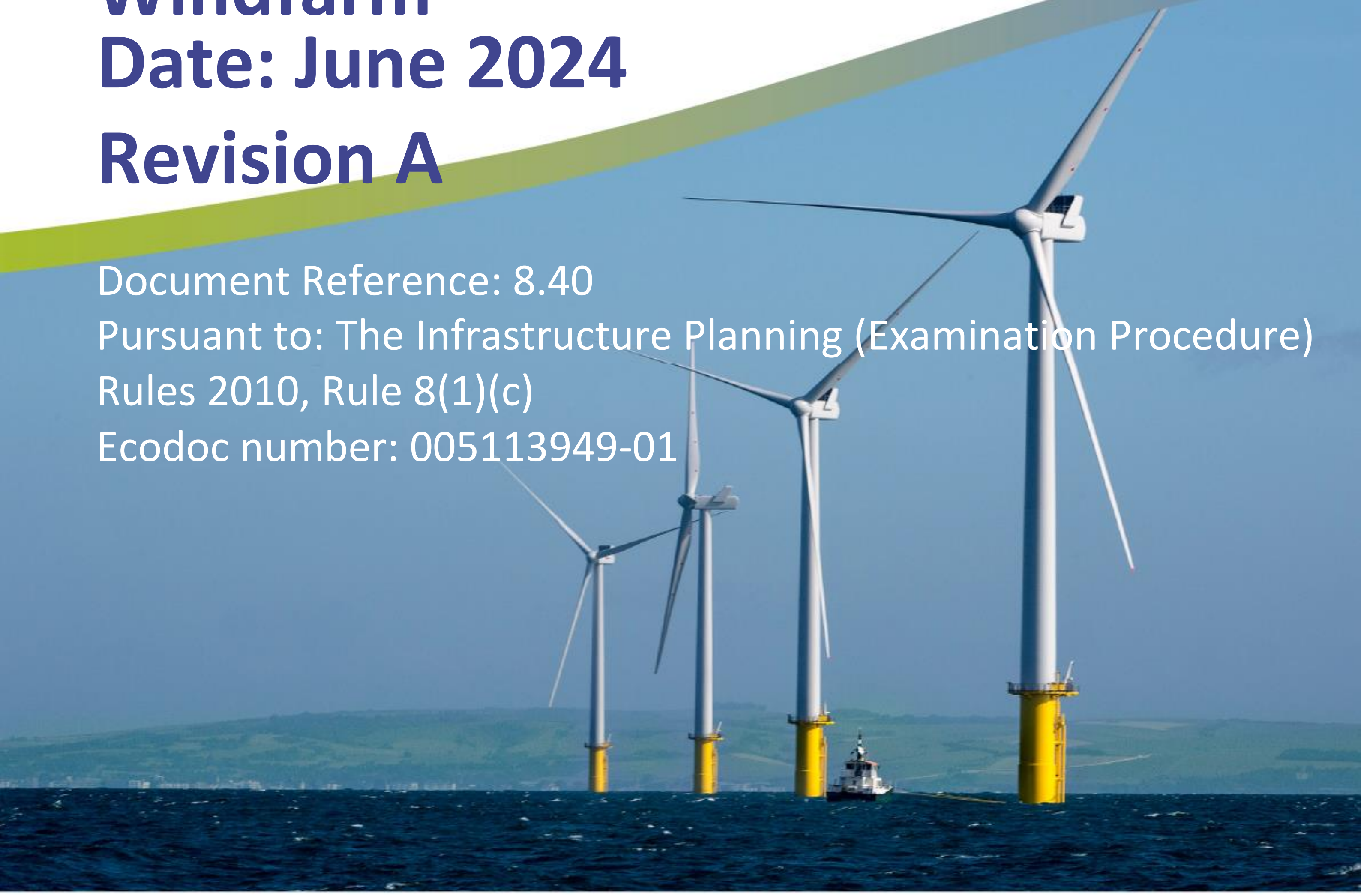

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Rampion 2 Wind Farm

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Information to support efficacy of noise mitigation / abatement techniques with respect to site conditions at Rampion 2 Offshore Windfarm

1. Aim of the expert opinion report

RWE Renewables UK (RWE) is currently planning the OWF Rampion 2 at the south coast of England in the English Channel. The presently available plan is to install the offshore wind turbine generators on monopiles with a maximum pile diameter of 13.5 m (the biggest and loudest scenario based on a maximum blow energy of 4,400 kJ; pile design is not fixed yet).

Itap – Institute for Technical and Applied Physics GmbH was contracted to give an update of the lessons learnt report of the currently available noise mitigation measures - noise abatement and noise mitigation measures – incl. the achievable overall noise reduction (Bellmann et al., 2020). Based on that an initial (preliminary) assessment of possible noise mitigation concepts for the planned impact pile-driving activities within the OWF Rampion 2 will be performed. Therefore, the results of empirical monitoring data obtained at other offshore wind farm sites during pile installation on the performance of noise mitigation measures and the comparative site conditions between those projects and Rampion 2 will be considered to provide an assessment of the potential performance of applied noise mitigation measures at the Rampion 2 site.

However, due to the fact that no transport & installation (T&I) contractor, final pile-design and suppliers of noise mitigation measures are preselected, this initial assessment is focussing on the general aspects of the currently given site- and project-specific conditions to assist the ongoing planning phase regarding noise mitigation at the moment. Aim of this study shall be to support RWE by selecting and preparing a suitable and effective noise mitigation concept. Nevertheless, a final empirical evaluation regarding application of any noise abatement / mitigation technique (noise mitigation concept) is only possible after all details (pile-design, final pile-driving analysis, final set-up of any planned mitigation measure etc.) for the planned impact pile-driving activities are available.

2. Overview of currently available noise mitigation measures

The lessons learnt report (Bellmann et al., 2020) summarized the three state-of-the-art noise abatement systems (Hydro Sound Damper – HSD; IHC Noise Mitigation Screen – IHC NMS and Big Bubble Curtain -BBC) incl. general hints of the required system configurations and limitations. However, based on the experiences from the last 4 years of offshore constructions it is unlikely that the above-mentioned three noise abatement systems can be enhanced with respect to higher achievable noise reduction, means this mitigation measures are fully engineered and produce reliable overall noise reductions in different OWF projects in case a project- and site-specific adaptation of the system configurations is conduced; especially for the BBC. By using the IHC Noise Mitigation Screen from IQIP b.v. or an optimized double Big Bubble Curtain (DBBC) noise reductions of about 15 dB in water depth till 40 m are achievable. By using the HSD System an overall noise reduction of 10 dB can be achieved.

A comparable noise abatement system to the HSD is the AdBm system. The physical principal is very similar. First offshore applications show that the achievable noise reduction of an AdBm is currently < 10 dB. This new system is currently not state-of-the-art; however, possible enhancements are identified and might be integrated into the new updated version of the AdBm. From acoustical point of view, the AdBm might be able to achieve also noise reduction of up to 10 dB, as well.

Currently a new generation of BBC system is under development and will be tested offshore: the enhanced Big Bubble Curtain (eBBC). The eBBC will consist of a nozzle hose with a diameter of 6″ instead of 4″ so that twice as much compressed air flow can be used (up to 1.2 $m^3/(min*m)$ instead of up to 0.6 $m^3/(min*m)$). First results from offshore applications show that with a single eBBC the noise reduction of a normal DBBC can be achieved (not public available measurement data from the RWE Renewables Germany OWF KASKASI II from itap GmbH as well as currently running test trials). However, this technique is currently not state-of-the-art but might be applicable for the OWF market within the next years as state-of-the art measure. Benefit of this eBBC is the application of only one nozzle hose instead of two.

Other noise abatement systems like Greenov are currently planned or prototypes existing. These new noise mitigation measures are not state-of-the-art today and from acoustic point of view it is expected that any optimized noise abatement system will not achieve more than the IHC-NMS or the DBBC (~15 dB).

With a combination of HSD and DBBC an overall noise reduction of about 18 to 19 dB is achievable; by using IHC-NMS + DBBC up to 22 dB. This only holds in case all noise abatement systems are used according to the state-of-the-art specifications, all systems are project-specifically enhanced and for water depth of up to 40 m (Bellmann et al., 2020).

For the application of any kind of bubble curtains the above-mentioned overall noise reductions are only valid for current up to 0.75 m/s.

The insertion loss of all noise abatement systems is highly frequency-depending; lower noise reductions towards lower frequencies (Bellmann et al., 2020).

Within the last 2.5 years the new hammer technologies PULSE from IQIP b.v. (former IHC b-v.) and Menck Noise Reduction Unit (MNRU) from Menck GmbH were available on the market as prototypes. Such new impact hammer techniques try to reduce the peak amplitude of the force transmission between the hammer and pile and to prolong the duration of each single strike.

PULSE-unit

The damping effect can be adjusted by using different amounts of liquid levels inside the *PULSE*-unit ranging from 0 mm to 700 mm (reflecting 0 % to 100 %). Based on experiences the minimum liquid level is 100 mm (P_{min}), 400 mm (P_{med}) and 700 mm (P_{max}).

For the *PULSE* unit first measurement data with and without this new noise mitigation measure are available from offshore tests within the German Baltic Sea from the year 2022 (only one data set from itap GmbH which is currently not published). These data point out that an overall noise reduction between 3 dB to 6 dB of the Sound Exposure Level might be achievable with *PULSE* setting P_{max}; slightly higher overall noise reductions are achieved for the peak Sound Pressure Level ($L_{p,pk}$). For the PULSE-setting P_{med} an overall noise reduction of 2 dB to 5 dB was measured.

In 2022, it was also observed during the *PULSE* offshore-test that the enthru energy into the monopile was reduced due to the application of the *PULSE*-unit since this device is operating as a spring-damper system. Based on a conducted pile monitoring the energy loss into the monopile by application of the *PULSE*-unit ranged between 3 % for P_{zero} (means 0 mm liquid), 15 % for P_{med} and 30 % for P_{max}. This means that 30 % of the hammer energy might be reduced by the P_{max} (only one data set from itap GmbH which is currently not published).

In 2023, one additional OWF project used the same *PULSE*-unit (prototype #1) only with the P_{max} settings. Due to the fact that no real reference monopile without the *PULSE*-unit was installed, a statistically proven evaluation of the achievable noise reduction of the applied *PULSE*-unit was not possible. A rough estimate of the obtained noise reduction by taking into account the underwater noise predictions indicates that the achieved noise reduction of the *PULSE*-unit P_{max} might be slightly lower than for the OWF project in 2022 (data set from itap GmbH which is currently not published).

A 2nd *PULSE*-unit (prototype #2) in combination with the new IQIP IQ6 impact hammer (which is designed for the application of the *PULSE*-unit) was used within a North Sea OWF project in 2023 and is used currently in a running OWF project in the North Sea, too. Based on these two North Sea projects some enhancements regarding the piling procedure (means by setting the best available settings for blow count, blow rate, *PULSE* setting and blow energy) were made to avoid bouncing effects between hammer, *PULSE*-unit and monopile. The combination of IQ6 hammer, "optimized" piling procedure and optimized *PULSE*-unit setting the underwater noise measurements at 750 m were reduced significantly.

However, based on the first *PULSE*-unit offshore tests, it is expected that the pile driving spectrum only by application of the *PULSE*-unit or comparable noise mitigation measure will be shifted to low frequencies and the decrease in spectrum towards high frequencies is lower; means the overall spectral shape is more flattening. Typically, the maximum noise entry into water for unmitigated XL Monopiles will be between 80 Hz and 160 Hz; in case of the new hammer technologies (*PULSE*, very likely also for *MNRU*) the maximum noise entry into the water will range between 25 Hz and 200 Hz (with more or less constant 1/3-ocatve band levels). This changed pile driving spectrum might have an influence on the achievable noise mitigation of additional applied noise abatement systems (e.g. HSD and DBBC). The effect of the changed pile driving spectrum on the overall noise reduction is currently not statistically valid quantifiable.

Furthermore, currently it is unclear which influence the changed *PULSE*-setting, changed piling procedures and different soil conditions in North and Baltic Sea will have on the overall noise reduction of the *PULSE*-unit. Furthermore, the latest tests in 2024 provide some hints that also seabed vibrations might be emitted with very low frequency components (< 10 Hz).

An evaluation of the new settings and piling procedure in combination with the new *PULSE*-unit (#2) is currently still pending. Furthermore, the 1st application of the updated *PULSE*-

unit (#1) is planned for an OWF project within the North Sea in summer 2024 as well. For this project the *PULSE*-unit is currently in preparation for achieving the optimized *PULSE* setting and piling procedure. Results from that project might be available at the end of 2024.

Menck Noise Reduction Unit - MNRU

For the *MNRU* no empirical measurements with and without the *MNRU* system under real off-shore conditions are available, thus a reliable evaluation regarding the achievable overall noise reduction is not possible yet.

3. Comparison of Rampion 2 site to site where noise mitigation has been deployed

Based on the ongoing planning phase (no final design is available) the following relevant site- and project-specific influencing conditions can be summarized for Rampion 2:

- Water depth: 20 to 50 m, current experiences are based on up to 45 m,
- Soil conditions: complex layers of sand with clay but also sandstone, silt and other layers, currently only few experiences from other OWF projects with such complex soil conditions exist,
- Bathymetry: complex – decreasing water depth towards the coast (north direction); increasing water depth towards southern direction; partly some sand dunes. Also only few empirical data from already constructed OWF projects exist; especially with an application of noise mitigation measures and not flat bathymetry,
- Pile diameter: up to 13.5 m; biggest diameter with empirical data by application of noise mitigation measures is 10 m,
- Required blow energy: currently no pile-driving analysis available,
- Current: depending on foundation location the mean current value ranged between 0.48 to 0.76 m/s based on the investigated locations P2, P7, P9 and P10. Applications of BBC configurations incl. effect on noise reduction until 3 m/s – Taiwan Strait – are currently available. Up to 0.75 m/s current is a typical value for German waters so that many experiences with this site-specific condition is available.

4. Application of noise abatement systems to Rampion 2

The most influencing site- and project-specific influencing parameters on impact pile-driving as well as the achievable overall noise reduction by application of a noise abatement systems are summarized in the cross-project lessons learnt report Bellmann et al. (2020) and can be summarized as follow:

(i) pile design,
(ii) required blow energy (max blow energy in case of evaluating single strike Sound Exposure Level (SEL) and zero-to-peak values and total energy incl. blow rate for evaluating cumulative SEL),
(iii) soil conditions,
(iv) water depth / bathymetry and current in case of an application of any kind of Big Bubble Curtain (BBC; single or double BBC).

To i) to iii) Typically, pile diameter, pile length, embedded length, soil condition and required blow energy are highly correlated with each other. In general, the bigger the pile diameter the lower the embedded length in case of constant soil layers; the smaller the pile diameter the higher the embedded length. Both embedded length as well as pile diameter will have a significant influence on the required blow energy (in total as well as single strike blow energy) to overcome the soil resistance and to reach final penetration depth.

Currently, the achievable overall noise reduction of the HSD system, IHC-NMS as well as any kind of BBC configurations is independent from the pile diameter/design and the blow energy. But it was observed in previous projects that with increasing diameter the pile-driving spectrum might be shifted towards lower frequencies. Due to the not existing impact of a diameter of 13.5 m on this frequency shift it can’t be excluded that the achievable overall noise reduction of any noise abatement system might be slightly decrease (likely 1 dB; unlikely 2 dB).

But the IHC-NMS is currently only available for pile-diameter of up to 10 m (NMS1000) and based on information from IQIP b.v. it is unlikely that the diameter will be increased in the near future due to the increasing size and weight of the full system. Furthermore, the IHC-NMS was always applied from a jack-up vessel with pile diameter of up to 8.8 m. For bigger diameter as well as a floating installation vessel a standalone system was designed but no empirical data regarding the overall noise reduction of this new design is currently available.

The most dominate influencing site-specific parameter on the achievable noise reduction of any noise abatement system is the soil conditions and possible ground couplings or tunnelling effects. Typically, no tunnelling effects occur or were measured in the North Sea in case of layers consisting of sand and clay. However, in general tunnelling effects will influence the performance of any near-field noise abatement system (all systems except BBC which is the only far-field system) more compared to a BBC.

To iv) The most critical condition is the current within the OWF Rampion 2. It is highly advised to design the layout of a (D)BBC together with the supplier and T&I contractor project- and site-specifically to have the optimized noise abatement system in place. However, based on best available technology and best environmental practise only new nozzle hoses shall be used. During the first application of the (D)BBC underwater noise measurements in all four cardinal directions shall be performed and provided to BBC-supplier to be able to maintain the nozzle hoses during recovery and re-deployment for the next foundation location. The aim of these initial tests offshore is to finetune the optimal omnidirectional overall noise reduction.

In case of current periods with > 0.75 m/s it should be controlled by underwater noise measurements if an omnidirectional (D)BBC performance is available and pile-driving can be continued.

Although no empirical evaluation of the achievable overall noise reduction by any BBC system in water depth >> 40 m is currently available, it is known that the achievable noise reduction slightly decreases with increasing water depth. Based on experiences it might happen that the effectiveness of any BBC system will slightly decrease by 1 dB (unlikely 2 dB) in 50 m water depth compared to 40 m. The application of an eBBC as an inner ring in combination with a normal BBC as outer ring would be expected to compensate or minimize the effect of the increased water depth since first application with such a BBC configuration achieved 1 to 2 dB higher overall noise reduction as a DBBC in 40 m water depth.

An influence of the achievable overall noise reduction of the HSD system or the IHC-NMS in 50 m water depth is not measured until now but from acoustical point of view it is unlikely that the water depth will have an influence. But the not flat bathymetry inside the OWF Rampion 2 might be challenging for an application of the IHC-NMS since the height of this system is not tuneable; means the height of the IHC-NMS will be 50 m plus. This will lead to the condition that at foundation locations with 20 m water depth the IHC-NMS will be up to 30 m out of the water. In this case it might be not possible to put the monopile into this system due to the limited crane height capacity. Until now the IHC-NMS was only used in OWF projects with a flat bathymetry.

The current will not have any effect of the overall achievable noise reduction for both near-field noise abatement systems (HSD and IHC-NMS).

5. Summary and key conclusions

- The application of noise abatement systems within the OWF Rampion 2 might be challenging due to soil conditions and bathymetry for some of the foundation locations. In case of applying one noise abatement system - which is site- and project-specifically optimized – an overall noise reduction of 15 dB is achievable and likely until 40 m water depth. In case a combination of near- and far-field noise abatement systems is used an overall noise reduction of 20 dB (maybe 22 dB) is achievable until 40 m water depth based on experiences of comparable already constructed OWF projects. For the foundation locations with water depth << 40 meters the achievable overall noise reduction might be slightly reduced by 1 dB (unlikely 2 dB) due to the increased static pressure in case any Big Bubble Curtain system is used.
- The most reliable and often used noise abatement system world-wide is the Big Bubble Curtain (single or double). Based on experiences 15 dB overall noise reduction can be expected in case a DBBC with a project-specifically system configuration will be used for water depth of up to 40 m. However, it is advised to observe the market over the next years and to keep in mind that an eBBC + BBC might be state-of-the-art soonest and will bring up to 2 dB more overall noise reductions compared to a DBBC which will compensate the negative effect of water depth up to 50 m.
- The application of an HSD system will only lead to an overall noise reduction of up to 10 dB and in case tunnelling effects might occur due to the complex soil conditions the noise reduction might also be reduced.
- An application of the IHC-NMS might be an alternative of the BBC system but based on the current knowledge this noise abatement system will not be ready for application in up to 50 m water depth and with pile diameter of up to 13.5 m. Furthermore, the not flat bathymetry (20 to 50 m water depth) might be a technical problem to put the monopiles into this system prior piling due to limited crane height capacity. The market must be observed over the next years if an updated IHC-NMS might be designed to cover 13.5 m and not flat bathymetry or installation vessels with much higher cranes will be available.
- Furthermore, the market shall be observed for any other noise abatement systems since many new systems are currently aiming for performing test trials under real offshore conditions. But until such new noise abatement systems are not state-of-the-art it is highly advised not to use same in serial application for the OWF Rampion 2.
- With the new hammer technologies (PULSE and MRNU) an overall noise reduction of less than 10 dB might be achievable. But the unmitigated pile-driving spectrum will also be shifted significantly towards lower frequencies (> 25 Hz) which will have a negative influence on the overall noise reductions of any additionally used noise

abatement systems. Therefore, an application of only the new hammer technology might not be an option due to the limited overall noise reduction. In combination with one or maybe two noise abatement systems higher overall noise reductions might be possible, but these combinations are currently not state-of-the-art. Furthermore, such a combination of noise mitigation measures is extremely expensive with currently limited benefit with respect of overall noise reduction.

Conclusion:

Based on the current status of existing noise mitigation measures the application of a DBBC (or maybe a combination of eBBC and BBC) is the most favourable option to use for achieving an overall noise reduction of 15 dB by using only one system at the moment.

In case more overall noise reductions is required a combination of two independent systems (two noise abatement systems – near – and far-field; or one noise abatement systems in combination of a new hammer technology) must be applied, and this could achieve an overall noise reduction of 20 dB (maybe 22 dB). The challenging issue is that the IHC-NMS which brings the most increase in the achievable overall noise reductions is technically most likely not possible to use for Rampion 2. Furthermore, the new hammer technologies MNRU/PULSE are currently not state-of-the-art. The combination of HSD system and DBBC will increase the overall noise reduction by up to 4 dB compared to a DBBC application but will increase the costs for noise mitigation measures significantly.

<u>Disclaimer:</u> *This expert opinion was prepared to the best of our knowledge and belief. Personal opinions and interpretations are marked as such and are therefore not subject to any guarantee. Furthermore, this rough assessment will not substitute an empirical evaluation of the planned noise mitigation concept when the final pile design as well as selected suppliers for noise mitigation measures are available.*

[redacted]

6. References

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7. Appendix 1 – Anticipated future standards (Defra) for impact pile-driving at OWFs in UK waters.

Based on the ongoing discussion regarding the environmental impact assessment with the UK regulators the following requirements with respect to impact pile-driving underwater noise might be relevant to comply with:

Optional noise mitigation values proposed by DEFRA:

- Unweighted SEL ≤ 170 dB re 1 µPa^{2}s at 750 m
- Marine Mammal weighted SEL_{SS} ≤ 164 dB re 1 µPa^{2}s (LF weighted)
- Peak SPL limit ≤L_{0-pk} 190 dB re 1 µPa at 750 m

A final empirical evaluation if a compliance condition with these new noise mitigation requirements is likely is currently not possible due to the fact that the pile design is currently not fixed, no reliable pile-driving analysis is available, and the supplier of any noise mitigation measures incl. system configuration is unknown.

A first initial evaluation leads to the following conclusion:

(1) unweighted SEL 170 dB re 1 µPa^{2}s at 750m

A compliance with this noise requirement is likely by using one or two independent state-of-the-art noise abatement systems depending on which blow energy is required for which pile design to reach final penetration depth.

Even with a combination of the new hammer technologies (MNRU or PULSE) and one noise abatement a compliance of the noise requirement might be possible depending on the required blow energy and pile design.

(2) Marine Mammal Weighted SEL_{SS} 164 dB re 1 µPa^{2}s (LF weighted)

The frequency weighting function LF ranged between 7 Hz and 35 Hz, Figure 1. The highest sensitivity ranged between 250 Hz and 4 kHz. Due to the frequency-depending insertion loss of all noise abatement systems a general compliance of this noise requirement is also very likely with a combination of independent noise abatement systems or one noise abatement system and a new hammer technology.

(3) Peak SPL limit $L_{0\text{-}pk}$ 190 dB re 1 µPa at 750m

The typical differences between the f-unweighted SEL_{SS} and the $L_{0\text{-}pk}$ ranged between 18 to 22 dB. Therefore, the compliance with this noise requirement will significantly be depending on the noise requirement of 170 dB for the SEL_{SS}.

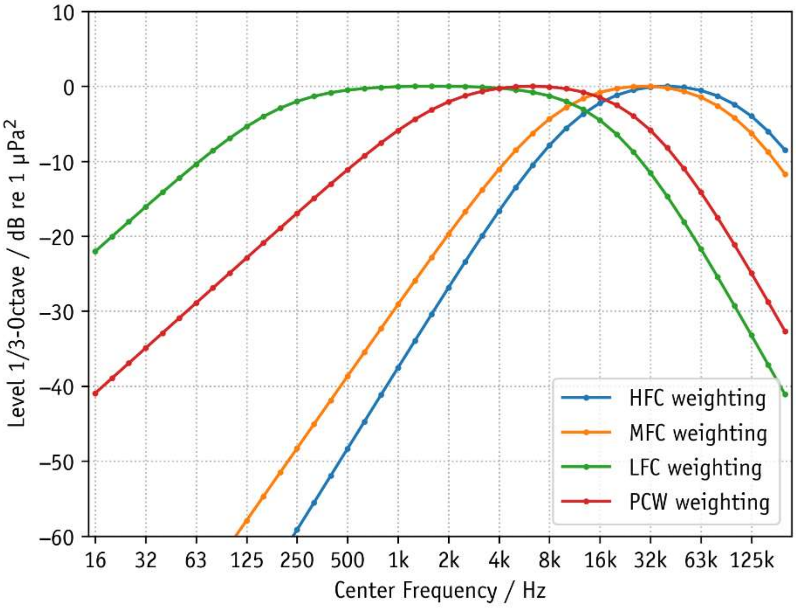

Figure 1: Weighting functions for different faunal groups according to National Marine Fisheries Service (2018) and Southall et al. (2019)

Rampion 2
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