Sofia Offshore Wind Farm

Environmental Appraisal of Increased Hammer Energy

March 2018

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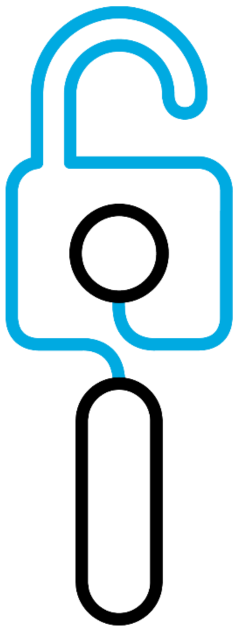

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Sofia offshore wind farm (formally Teesside B) forms one of four consented projects within the Dogger Bank Zone. The Dogger Bank Zone comprises an area of 8,660km^2, located in the North Sea between 125km and 290km off the coast of Yorkshire. In August 2017 Innogy, previously one of four partners in the Forewind consortium, which obtained consent for the project, secured 100% ownership of the project.

The Development Consent Order (DCO) (SI 2015 No. 1592) (the "Order") for Sofia was granted on the 4th August 2015 and came into effect on 26th August 2015.

Sofia has consent for up to 200 wind turbines and the installed capacity of each turbine will be between 6MW and 10MW (to a total installed capacity of 1.2GW). The export cable will reach landfall along the Teesside coastline between Redcar and Marske-by-the-Sea. Offshore construction of the project may commence at the earliest from 2020 and therefore, this assumption has applied within the in-combination assessment. It is noted that this date is subject to change based on programme optimisation and the award of a Contract for Difference (CfD).

Piling (also referred to as percussive piling or impact piling) is permitted under the existing DCO for the installation of the foundations for the wind turbine generators (WTGs), however, as a result of engineering refinement and project optimisation, Innogy is seeking to make non-material variations to the consented parameters with regard to an increase in hammer energy in order to ensure successful monopole foundation installation. This document has therefore been prepared in support of an application for non-material amendments to the Order pursuant to section 153 and schedule 6 of the Planning Act 2008 and for variations of the Deemed Marine Licences (dML) pursuant to section 72(3) of the Marine and Coastal Access Act 2009. The requirement for a non-material amendment to the DCO for Sofia is considered to be required since the maximum hammer energy permitted during construction is specified on the face of the DCO. This document sets out details and comparative assessment to inform the environmental implications of bringing forward the increase in hammer energy for monopole installation at the project.

2 Background

As noted above, piling is permitted under the Sofia (dML), within the Sofia DCO, for the installation of the foundations for the offshore infrastructure required for the project. The infrastructure that may require piling includes wind turbine generator (WTGs) foundations, offshore converter stations, offshore collector platforms, met masts and accommodation platforms.

The Sofia consent is based on a maximum hammer energy of 3,000kJ for piling of monopole foundations, which is stated on the face of the DCO (Schedule 1, Part 3, 6, (2)(B) of the DCO and Schedule 9, Part 2, 6, (2)(B) of the dML). Innogy has identified that there may be a technical requirement to increase this maximum hammer energy and therefore needs to vary the existing consent to reflect this. In light of this, GoBe Consultants Ltd. has drafted this document to inform the environmental implications of adopting an increased maximum hammer energy for piling of monopole foundations at Sofia to 5,500kJ. To support this variation of consent, this report will provide supporting environmental information to demonstrate whether the proposed increase in hammer energy will result in any change in the predictions made within the Environmental Statement (ES), and in particular to determine if the change would result in any impacts significantly greater than those originally determined within the ES.

Innogy wish to secure formal approval of the conclusions set out in this paper so that the project can proceed with regulatory agreement that the planned construction activities at Sofia will not result in any greater impacts than those originally determined within the ES.

As part of this process, underwater noise modelling predictions that informed the original Sofia impact assessment (as referred to within the application for consent)[1] have been compared with those derived from new modelling, which assess the noise propagation extents for the proposed increase in hammer energy that will be required for the successful installation of monopole foundations at the site. The original underwater noise modelling undertaken to inform the Sofia impact assessment that supported the DCO application was undertaken by the National Physical Laboratory (NPL) and completed in 2013. The updated noise modelling has been undertaken by Subacoustech Environmental Ltd. (Subacoustech) and was completed in January 2018 (Appendix A).

2.1 Document Structure

This document is set out as follows:

- Section 1: Introduction to the Sofia Offshore Wind Farm;
- Section 2: Background to the need to vary the maximum consented hammer energy;
- Section 3: Consented Design Envelope and the Change being Sought
- Section 4: Method of Comparison - how the original noise modelling, which supported the DCO application, has been compared to the revised noise modelling undertaken
- Section 5: Environmental Appraisal – Screening of the ES to identify impacts affected by the revised project design
- Section 6: Impact Assessment - a detailed discussion of these impacts;
- Section 7: Consideration of The Habitats Regulations; and
- Section 8: Conclusions – A brief summary of the relevant findings and conclusions.

[1] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010051/EN010051-000250-6.5.1%20ES%20Chapter%205%20Appendix%20A.pdf

3 Consented Design Envelope

The ES as submitted with the application included a worst case design envelope (its 'Rochdale Envelope'), as summarised in Table 3.1 for the offshore infrastructure requiring piling. It is important to reiterate that the increased maximum hammer energy would only be applicable to monopole foundation locations.

Table 3.1: Sofia offshore wind farm maximum design parameters.

Parameter for HRA	Consented
Piling	
Construction timeframe	To commence with 7 years of consent (August 2015)
Construction duration	6-year construction window as a maximum with the piling window covering 2-3 years within that timeframe
Piling duration (max and average) per foundation type including soft start of 30 mins	3.5 hours (pin pile) 5.5 hours (monopole)
Foundation types	Pin pile or monopole
Max number of foundations and piles	200 WTGs = 200monopoles. 1,200 if pin piles (jackets). 5 met masts = 5 monopoles. 20 if pin piles. 4 Offshore Collector Platforms = 96 pin piles 1 Offshore Convertor Platform = 24 pin piles 2 Accommodation Platforms = 48 pin piles
Construction scenarios	Sequential or concurrent
Layout	Across whole order limits

The Sofia ES considered a worst case maximum hammer energy of 3,000kJ for the installation of monopole foundations. However, Innogy has identified that there may be a technical requirement to increase this maximum hammer energy to 5,500kJ for monopole installation only.

The proposed increase in maximum hammer energy means that there is a potential change in the maximum underwater noise impact risk ranges when compared to that resulting from the original Sofia Design ("Rochdale") Envelope, (as summarised in Table 3.1 above) and cited within the project's DCO/deemed Marine Licences (dMLs). To address the requirement, a non-material amendment of the Development Consent Order (DCO) is sought to vary the maximum hammer energy stipulated on the face of the DCO (and where relevant, the dMLs). A draft amendment Order to give effect to the proposed DCO changes has been provided along with the application.

There is no statutory definition of what constitutes a material or non-material amendment for the purposes of Schedule 6 to the Planning Act 2008 and Part 1 of the 2011 Regulations. Criteria for determining whether an amendment should be material or non-material is outlined in the Department for Communities and Local Government (DCLG's) "Guidance on Changes to Development Consent Orders" (December 2015). The following characteristics are stated to indicate that an amendment is more likely to be considered 'material'.

1) Where any new or significant effects on the environment as a result of the change mean that an update to the original Environmental Statement (from that at the time the original DCO was made) is required (to take account of those effects);
2) Where the impact of the development to be undertaken as a result of the proposed change introduces the need for a new Habitats Regulations Assessment, or the need for a new or additional licence in respect of European Protected Species (EPS) (in addition to those at the time the original DCO was made);
3) Where the change would involve compulsory acquisition of any land or an interest in or rights over land, that was not authorised through the existing DCO; or
4) The potential impact of the proposed changes on local people will also be a consideration in determining whether a change is material.

The proposed variation to the DCO in relation to increase in hammer energy has been considered herein with reference solely to the first of these requirements, as the other characteristics are not relevant for the purposes of this paper.

4 Method of Comparison

This environmental assessment has been undertaken to assess the potential for an increase in the hammer energy at Sofia from 3,000kJ to 5,500kJ for monopole foundations, which could result in a change in the level of significance, as set out within the DCO application documents. This assessment has been undertaken via means of screening and an impact assessment. The screening considers whether receptors are likely to be impacted by the changes in hammer energy. Where no additional, new or different impact to that assessed in the original environmental assessment is identified, or the impact is expected to be negligible, the receptor is screened out from further consideration. In all other cases, the receptor is considered further, with the potential impacts assessed, taking account of the likelihood of the impact occurring, the sensitivity of the receptor and the magnitude of the potential effect. In doing this, consideration has also been given as to whether the nature or level of the impact will significantly exceed that previously assessed and consented.

4.1 Underwater Noise Modelling

The original underwater noise modelling for the Sofia ES was undertaken by NPL who used an energy flux solution model (Weston 1976) to predict the impact risk range of underwater pile driving noise. Modelling was undertaken for the worst case hammer energies operating at 2,300kJ for pin pile foundations and 3,000kJ for monopole foundations. Additionally, a number of lower hammer energies were modelled to represent soft-start and ramp up energies. The results produced by NPL considered the following species groups:

- Low frequency and mid frequency cetaceans and pinnipeds (applying thresholds drawn from Southall *et al.* (2007));
- High frequency cetaceans (harbour porpoise) (applying thresholds drawn from Lucke *et al.* (2009));
- Injury in species of fish (applying values drawn from Popper *et al.* (2006) and Carlson *et al.* (2007));
- Behavioural response in species of fish (applying values drawn from McCauley *et al.* (2000) and Pearson *et al.* (1992)).

The NPL noise modelling undertaken for Sofia is presented at Appendix 5A of the ES[2]. The model employed by NPL in the Sofia ES is not openly available and as a result, the INSPIRE model has been utilised by Subacoustech to produce comparable modelling results for Sofia for the 5,500kJ hammer energy. INSPIRE is semi-empirical underwater noise propagation modelling software which incorporates depth-dependency and a combination of numerical data modelling and actual measured data.

Stage 1 of the assessment comprised two steps. The first was a like for like comparison, to confirm the suitability of the INSPIRE model by applying the same input parameters and scenarios as used in the NPL model and verifying comparability between the output results. The second step was to use INSPIRE to model the greater hammer energy scenarios in order to assess the consequences of using a higher energy at Sofia for monopole installation to complete Stage 1 in comparison to the consented case, whilst adopting the same metrics and thresholds used in the Sofia ES.

Modelling undertaken by Subacoustech was based on piling undertaken at a single location at the northernmost boundary of the Sofia site. This site is in some of the deepest water (32 m) at the Sofia site. The ranges calculated are considered to represent the worst case for the purposes of this assessment as the deepest water location typically results in the greatest underwater noise propagation. The impact risk ranges produced by the INSPIRE model allow a direct comparison with the impact risk ranges produced by the NPL model.

The results of this comparison between the NPL and INSPIRE models showed a good level of correlation between the datasets (Appendix A Section 2.3), thus verifying that the INSPIRE model can be relied upon for the subsequent comparative modelling of higher hammer energies for the purposes of comparison. The results of the modelling for the higher hammer energies from the INSPIRE model therefore allow for conclusions to be drawn as to whether or not any changes in ecological effect relating to an increase in hammer energy for the foundation installations at Sofia are material.

Stage 2 of the assessment incorporates new criteria (which have been published since the Sofia ES) developed by the US National Marine Fisheries Service (NMFS) for impacts on marine mammals (NMFS, 2016), into the INSPIRE model. This allows consideration of the potential for an effect on relevant receptors based on the most contemporary data and assessment methodologies, as well as comparison with the findings of the Stage 1 assessment. Further detail on the assessment process is presented, as relevant, in the sections below.

5 Screening

The Sofia ES has been reviewed to identify those receptors that were highlighted as being sensitive to offshore piling noise impacts and hence the assessment outcomes which need to be considered as part of the assessment of the increased maximum hammer energy. This appraisal only considers the noise impacts from offshore piling during the construction phase of the project. Noise impacts from other construction activities (e.g. vessel engines) and other phases of the project's lifetime (e.g. operation and decommissioning) will be unaffected by the increased hammer energy as the consent envelope remains the same for these factors. These scenarios are therefore not considered further in this document.

As part of the original EIA process, screening was undertaken to identify potential impact pathways and hence the relevant receptors, that could be affected by offshore piling. Within this appraisal those receptors for which there was no identified impact pathway for underwater piling noise impacts (and for which, therefore, no assessment of the impacts of noise was undertaken within the ES), have been excluded.

As part of the current appraisal, a further screening exercise has been carried out to determine if there is the potential for the assessment of the significance of the effect to be changed by the proposed increased hammer energy. This

[2] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010051/EN010051-000250-6.5.1%20ES%20Chapter%205%20Appendix%20A.pdf

screening exercise is presented in Table 5.1 along with justification as to whether any further consideration needs to be given to the impacts of an increased hammer energy.

Table 5.1 - Screening of ES Chapters that considered the impacts of underwater noise from piling to determine the potential for any change to the conclusions of each Chapter from the proposed increased hammer energy.

ES Chapter	Potential for change to ES conclusions due to increased hammer energy	Justification
Designated Sites (Chapter 8) and Habitats Regulations Assessment (HRA doc Ref 5.2)	No	The Designated Sites chapter of the ES considered the effects of construction activity impacts on nature conservation areas and protected species however, all impacts assessed in this chapter are drawn from findings from the relevant chapter of the ES (e.g. Fish and Shellfish, Marine Mammals and Ornithology) and as such are covered in the relevant sections identified below. Specific consideration to the HRA is given in Section 7 of this report.
Fish and Shellfish Ecology (Chapter 13)	Yes	The main findings of the ES chapter for underwater noise impacts on sensitive fish receptors are presented below. This includes a consideration of the ES findings in relation to the increase in the maximum hammer energy.
Marine Mammals (Chapter 14)	Yes	The main findings of the ES chapter for underwater noise impacts on marine mammals are presented below. This includes a consideration of the ES findings in relation to the increase in the maximum hammer energy.
Transboundary Effects (Chapter 32)	No	The Transboundary Effects chapters of the ES considered the effects of construction activity impacts on transboundary species however, all impacts assessed in this chapter are drawn from findings from other receptor lead chapters such as the Fish and Shellfish Resources (Chapter 13). As such, this chapter is not considered any further here.

6 Impact Assessment

The following sections present an environmental appraisal comparing the assessment presented within the ES for a 3,000kJ hammer energy (based on the NPL modelling) with that of an increased hammer energy (based on the modelling undertaken by Subacoustech). Each assessment is presented in two stages – Stage 1 being a like for like comparison, Stage 2 applying the revised metrics.

6.1 Fish and Shellfish Resources (Environmental Statement Chapter 13)

Fish and Shellfish (Sofia ES Chapter 13)

Table 5.2 of the Fish and Shellfish Resources Chapter (Chapter 13) identifies pin piles as the worst case scenario based on the high number of piling events associated with the installation of jacket foundations (up to six piling events per foundation compared to one piling event for monopoles). This worst case therefore represents the maximum duration of piling events instead of the greatest impact risk range associated with a single piling event. Chapter 13 acknowledges that the temporal disturbance (i.e. maximum duration) from construction noise will have a greater effect on fish and shellfish than the maximum noise range disturbance. The worst case is summarised below.

- 200 x 6 pin pile foundations (3.5m pin piles; jacket foundations for WTGs; 1,200 piles) at maximum 2,300kJ hammer energy
- 5 x 4 pin pile foundations (3.5m diameter pin piles, jacket foundation for met masts; 20 piles) at maximum 1,900kJ hammer energy
- 4 x 24 pin pile foundations (2.75m diameter pin piles, jacket foundation for Offshore Collector Platform; 96 piles) at maximum 1,900kJ hammer energy
- 1 x 24 pin pile foundations (2.75m diameter pin piles, jacket foundation for Offshore Converter Platform; 24 piles)
- 2 x 24 pin pile foundations (2.75m diameter pin piles, jacket foundation for Accommodation platform; 48 piles) at maximum 1,900kJ hammer energy
- Maximum of 2 simultaneous piling operations;

The duration of piling (including soft-start) for pin pile foundations is approximately 202 days which is significantly greater (by 185%) than the 71 days required for the piling of monopole foundations. As identified in the ES, the temporal aspect of underwater noise is considered to have the greatest effect on fish and shellfish species.

The intension of this environmental appraisal is to evaluate the potential impact associated with an increase in maximum hammer energy for monopole foundations only. As the ES has identified the worst case for fish and shellfish as being temporal and therefore derived from pin pile foundations, fish and shellfish are not assessed any further as the proposed increase in hammer energy is only relevant for monopole foundation installation.

It is noted that certain ornithological receptors were considered sensitive to underwater noise as an indirect consequence of potential changes in prey resource (fish). Given the fact that the hammer energy increase does not affect the worst case assumptions relating to fish, there would be no indirect consequence for any ornithological receptors either.

6.2 Marine Mammals (Environmental Statement Chapter 14)

As defined in Table 5.2 of Chapter 14; the worst case scenario for spatial extent effects is based on maximum hammer energy for monopole foundations as this produces the largest impact risk footprint for marine mammals. The realistic worst case scenario is as follows:

- 100% pile driving monopoles;
- Pile diameter: 12m Max Penetration: 55m;
- Hammer Capacity: 3,000kJ;
- Max Blow Force: 3,000kJ;
- Soft-start duration: 0.5 hours;
- Soft-start hammer energy: 300kJ; and
- Total max pile driving duration: 5 hours 30minutes (full force time per pile 5 hours, soft-start 30minutes).

A second scenario (construction phase) is also given in the ES (Table 5.2 of Chapter 14), based on the installation of pin pile foundations as representing the worst case for piling duration due to the longer period over which piling noise would be generated. The proposed increase in hammer energy will not affect any assessment for pin pile foundation installation as the larger hammer will only be used for monopole installation. This aspect is, therefore, not considered further in this appraisal document.

The ES chapter assessed the impacts of noise from pile driving on grey seal (*Halichoerus grypus)*, harbour porpoise (*Phocoena phocoena*), minke whale *(Balaenoptera acutorostrata*) and white-beaked dolphin (*Agenorhynchus albirostris*).

Both cetaceans and pinnipeds are vulnerable to impacts of piling noise, with impacts including lethal or physical injury, hearing injury and disturbance, depending on the received noise levels. Hearing injury in marine mammals depends on the sensitivity of the species and factors such as the duration, frequency and level of the noise. Hearing injury can manifest itself as a temporary threshold shift (TTS), where the ability of the individual to hear at certain frequencies is reduced temporarily before fully recovering, and as a permanent threshold shift (PTS) or a permanent change in the ability of an individual to hear at certain frequencies. In terms of the impact on the species present, non-lethal effects (including behavioural) were defined within the ES as having the potential to be significant if this resulted in the avoidance of important feeding or breeding grounds.

6.3 Stage 1 – Sofia ES Modelling Results

This section considers the potential impacts to marine mammals in relation to the proposed increased hammer energy and assesses whether an increase in maximum hammer energy from 3,000kJ, as originally stated in the Sofia ES, to 5,500kJ, would alter the outcomes of the assessment made within the ES.

As noted previously in this document, the model used by NPL to produce result of the Sofia ES is not openly available and as a result, this stage of the assessment for marine mammals uses the same criteria as the Sofia ES, but assessed via the INSPIRE model by Subacoustech.

A summary of the noise thresholds (SEL in dB re 1µPa^{2}s) modelled for marine mammal receptors in the Sofia ES are provided in Table 6.1.

Table 6.1 - Summary of noise thresholds (SEL in dB re 1µPa^{2}s) modelled for marine mammal receptors.

Potential Impacts	Harbour Porpoise	White-Beaked Dolphin	Minke Whale	Grey Seal
PTS	179[1]	198	198	186
TTS/fleeing[2]	164[1]	183	183	171
Likely avoidance[3]	N/A	170	152	N/A
Possible avoidance[3]	145[1]	160	142	N/A

[1] Precautionary criteria based on single pulse in the studies by Lucke *et al.* (2009);
[2] Based on the single pulse criteria for the onset of TTS in studies by Southall *et al.* (2007).
[3] Based on multiple pulse severity scaling in the study by Southall *et al.* (2007) – only applicable to MF and LF cetaceans.

To estimate the number of individuals that would be expected to display disturbance reactions, contours based on thresholds outlined in Table 6.1 were generated and used to work out the area of likely and potential disturbance for each species. The result was then compared with the results from the ES assessment to determine the proportion of the reference population impacted and therefore whether there was any alteration in impact level from the ES assessment. Reference population numbers were based on those used in the Sofia ES and are presented in Table 6.2.

Table 6.2 - Reference populations used in assessment. Source: Sofia ES Chapter 14.

Species	Reference population extent	Year of estimate and data source	Reference population size used in assessment (confidence intervals)
Harbour Porpoise	North Sea Management Unit	2005 (IAMMWG, 2013 based on SCANS II Hammond *et al.* 2013)	227,298 (176,360 – 292,948)
Minke Whale	(a) British Irish Management Unit (b) Central and north east Atlantic	(a) 2005 & 2007 (IAMMWG, 2013 based on SCANS II (Hammond *et al.* 2013) CODA (Hammond *et al.* 2009) (b) 1996-2001 IWC	(a) 23,168 (13,772 – 38,958) (b)174,000 (125,000-245,000)
White-Beaked Dolphin	British Irish Management Unit	2005 (IAMMWG, 2013 based on SCANS II Hammond *et al.* 2013)	15,895 (9,107 – 27,743)
Grey Seal	North Sea (South-east England, North east England and Scottish East coast MU + Waddensea)	2007, 2008, 2010, 2011 and 2012 UK North Sea (IAMMWG, 2013) & Mainland Europe (Waddensea Secretariat)	24,950 + 4,039 = 28,989

The results presented in this section summarise the assessment of the predicted noise impact risk ranges based on the updated noise modelling for a 5,500kJ hammer energy. The potential impacts on marine mammals for the 5,500kJ hammer energy are assessed using the same densities and reference populations as the original assessment in the Sofia ES. This allows for a like for like assessment of the potential impact of the new hammer energy. For cetaceans, reference populations are based on abundance estimates from SCANS II. It is important to note that since the assessment undertaken in the Sofia ES, SCANS III[3] abundance estimates for cetaceans have been published. Although the reference population used in the Sofia ES are not directly comparable to the SCANS III populations, the overall populations of both harbour porpoise and white-beaked dolphin have increased since the SCANS II survey. As a result, the higher numbers, if considered, would effectively reduce the proportional impact on these species. The original assessment included the German and Dutch Waddensea grey seal population as part of the total reference population, recognising that there is movement between the east coast of the UK and the Waddensea. However, because the surveys are not carried out at the same time of year, (UK grey seal counts are made during the August harbour seal moult, and Waddensea surveys take place in March-April) there is the possibility that there is some double counting of individuals or that there are 'missed' individuals counted in neither survey. However, large increases have been reported in both UK and Waddensee grey seal populations since the original assessment and as noted above for cetaceans, an assessment against updated figures would reduce the proportional impact on these species.

The results of the like for like assessment of the new hammer energy are then compared to the original values presented in the Sofia ES and reference populations for the 3,000kJ hammer energy. Tables 6.3-6.15 provide a summary of predicted disturbance ranges provided in the ES and resulting from the updated noise modelling for each receptor.

[3] https://synergy.st-andrews.ac.uk/scans3/files/2017/05/SCANS-III-design-based-estimates-2017-05-12-final-revised.pdf

Within the assessment a soft-start procedure was considered as built in mitigation to avoid auditory injury to marine mammals. As described in the ES, a soft-start would be conducted for 30 minutes where the hammer energy applied would be around 10% of maximum hammer energy (in the ES a starting hammer energy of 300kJ was assessed for maximum hammer energy of 3,000kJ) for all piling locations. Following the soft-start, there would be a gradual increase in hammer energy, up to a maximum of full hammer energy needed to install monopoles to full design penetration at the site.

6.3.1 High-frequency Cetaceans – Harbour Porpoise

6.3.1.1 Instantaneous PTS single strike

According to the Sofia ES, NPL modelling of PTS unweighted (pulse SEL 179 dB re 1 µPa^{2}s) response based on criteria from Lucke *et al.* (2009) for a hammer energy of 3,000kJ resulted in an impact risk range of <700m.

Using the same criteria, but modelled with the INSPIRE model, a 3,000kJ hammer energy results in a maximum impact risk range of 700m. Using the same modelling approach and criteria, a 5,500kJ hammer energy is predicted to result in maximum impact risk range of 1.1km. The impact risk ranges for PTS are shown in Table 6.3 below, along with the change from the NPL modelling in the Sofia ES for the increased hammer energy.

Table 6.3 - PTS: INSPIRE impact risk ranges for harbour porpoise.

Hammer Energy	INSPIRE - PTS unweighted (pulse SEL 179 dB re 1 µPa^{2}s) maximum range	Change from ES maximum hammer impact risk range (<700m*)
3,000kJ	700m	No change
5,500kJ	1.1km	+57%

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (<700m) has been equated to an actual maximum distance (i.e. 700m), which was a precautionary assumption.

Table 6.5 shows the number of individuals within each impact risk range. Despite an increase in the impact risk ranges as a result of the new hammer energy, the individuals predicted to receive PTS represent <0.001% of the reference population for a 5,500kJ hammer. The Sofia ES concluded No Impact for PTS in harbour porpoise. Based on the same assessment of significance used in the Sofia ES, the low corresponding percentage of the reference population affected means there will be no change to the original conclusion. Furthermore, the implementation of a Marine Mammal Mitigation Protocol (MMMP) with a standard 500m mitigation zone would reduce this impact risk range for harbour porpoise to negligible. If required (in reference to the 1.1km range noted for the 5,500kJ hammer in the table above), larger mitigation radii can be provided for through the use of acoustic deterrent devices (ADDs) as part of the MMMP, affording protection to 1.1km or greater, dependent upon the time over which such equipment is deployed. ADDs have been shown to substantially reduce the number of harbour porpoise up to 5-10 km from the ADD, with a complete deterrence range of at least 1km (Brandt et al. 2013; Brandt et al. 2012; Dähne et al. 2017; Mikkelsen et al. 2017).

6.3.1.2 TTS

In the Sofia ES, NPL modelled the TTS (pulse SEL 164 dB re 1 µPa^{2}s) of harbour porpoise and identified a maximum impact risk range of 5.5km for a hammer energy of 3,000kJ.

Using the same criteria as the Sofia ES from Lucke *et al.* (2009), the INSPIRE model showed a maximum impact risk range of 6.0km for a hammer energy of 3,000kJ. Additionally, and under the same approach, the INSPIRE model showed maximum impact risk ranges of 6.9km and 8.1km for a hammer energy of 5,500kJ. The impact risk ranges for TTS are shown in Table 6.4 below, along with the change from the NPL modelling which informed the Sofia ES, for the increased hammer energy.

Table 6.4 - TTS: INSPIRE impact risk ranges for harbour porpoise.

Hammer Energy	INSPIRE - TTS unweighted (pulse SEL 164 dB re 1 µPa^{2}s) maximum range	Change from ES maximum hammer impact risk range (~5.5km*)
3,000kJ	6.0km	+9.1%
5,500kJ	8.1km	+47.3%

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (~5.5km) has been equated to an actual maximum distance (i.e. 5.5km), which is a precautionary assumption.

Table 6.5 shows 126 individuals are predicted to receive TTS (unweighted pulse SEL 164 dB re 1 µPa^{2}s) within an impact risk range of 197km^2 (5,500kJ). The Sofia ES predicted 53 individuals would receive TTS within an impact range area of 82.3km^2. Despite the increase in impact risk ranges for the increased hammer energy, 126 individuals represent 0.06% of the reference population respectively. The Sofia ES concluded a Negligible impact for TTS response in harbour porpoise. It can be concluded in this assessment that the low percentage of the reference population affected by the increased hammer energy means there will be no change to the original conclusion.

6.3.1.3 Potential Disturbance (Possible Avoidance)

The Sofia ES predicted that based on NPL modelling, 1,820 individuals were predicted to be disturbed using a threshold of SEL 145 dB re 1 µPa^{2}s, from a maximum hammer energy of 3,000kJ. This was based on an impact area of 2,841km^2 and resulted in a potential population impact of 0.8%.

The same criterion was used by Subacoustech in the INSPIRE model which showed a reduction in the estimated area potentially disturbed for a 3,000kJ hammer by 3.6% and resulting in an estimated 1,755 individuals or 0.77% of the reference population. The same modelling approach was used for a hammer energy of 5,500kJ which predicted 2,357. This equates to 1% of the reference population for a 5,500kJ hammer energy.

The Sofia ES concluded a Negligible impact for possible avoidance of harbour porpoise. An increase from 0.8% for the 3,000kJ hammer, to 1% for the 5,500kJ hammer is not considered to change the impact magnitude from the Sofia ES. Based on the same assessment of significance used in the Sofia ES, it can be concluded that based on the low corresponding percentage of the reference population affected, there will be no change to the original conclusion.

Table 6.5 - Harbour porpoise impact risk range area and population impacts

High-Frequency Cetaceans (Harbour Porpoise)		3,000kJ hammer energy	5,500kJ hammer energy
INSPIRE - Instantaneous injury/PTS (pulse SEL 179 dB re 1 µPa^{2}s) [1]	Area	1.5km^2	3.4km^2
	Individuals	0.961	2.178
	% of ref population	<0.001	<0.001
INSPIRE - TTS/fleeing response (pulse SEL 164 dB re 1 µPa^{2}s) [1]	Area	108km^2	197km^2
	Individuals	69.180	126
	% of ref population	0.030	0.056
NPL - Behavioural response unweighted (pulse SEL 145 dB re 1 µPa^{2}s)	Area	2,841km^2	-
	Individuals	1,820	-

	% of ref population	0.8	-
INSPIRE - Possible avoidance of area (pulse SEL 145 re 1 µPa^{2}s)	Area	2,740km^2	3,680km^2
	Individuals	1,755.13	2,357.26
	% of ref population	0.772	1.037

[1]No equivalent given in Sofia ES.

6.3.2 Mid-frequency Cetaceans – White-beaked Dolphin

6.3.2.1 Instantaneous PTS single strike

The NPL modelling which informed the Sofia ES, used the PTS M-weighted threshold (SEL_{ss} M_{mf} 198 dB re 1 µPa^{2}s) from Southall *et al.* (2007) to predict the impact risk ranges of a 3,000kJ hammer on mid-frequency cetaceans (white-beaked dolphin). NPL found that for the maximum hammer energy of 3,000kJ an impact risk range of <100m was predicted.

Under the same criteria, but modelled with the INSPIRE software, a 3,000kJ hammer energy results in a lower impact risk range of <50m. The same impact risk range of <50m was predicted using INSPIRE for a hammer energy of 5,500kJ. The impact risk ranges for PTS are shown in Table 6.6 below, along with the change from the NPL modelling in the Sofia ES for the increased hammer energy.

Table 6.6 - PTS: INSPIRE impact risk ranges for white-beaked dolphin.

Hammer Energy	INSPIRE - Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^{2}s) maximum range	Change from ES maximum hammer impact risk range (<100m*)
3,000kJ	<50m	-50%
5,500kJ	<50m	-50%

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (<100m) has been equated to an actual maximum distance (i.e. 100m), which was a precautionary assumption. The same approach is applied to the INSPIRE outputs.

As shown in Table 6.8, <0.001 white-beaked dolphins are predicted to be impacted by PTS when considering the 5,500kJ hammer energy. This number represents <0.001% of the reference population for the species. Additionally, impact risk ranges are well within the 500m mitigation zone implemented via the MMMP. The Sofia ES concluded No Impact from for lethal/ injury and auditory injury (PTS) for the species. Based on the reduced impact risk range predicted by INSPIRE it can be concluded there will be no change to the original conclusion.

6.3.2.2 TTS/fleeing response

NPL modelled the TTS weighted (SEL_{ss} M_{mf} 183 dB re 1 µPa^{2}s) for mid-frequency cetaceans and found an impact risk range of <200m for a hammer energy of 3,000kJ.

Using the same criteria as the Sofia ES from Southall *et al.* (2007), the INSPIRE model showed a reduced maximum impact risk range of 140m for a hammer energy of 3,000kJ. Additionally, and under the same approach, the INSPIRE model showed maximum impact risk range of 200m for a 5,500kJ hammer energy. The results of the INSPIRE modelling show that an increase to a maximum hammer energy of 5,500kJ will result in the same impact risk ranges that were originally modelled in the Sofia ES for a 3,000kJ hammer energy. The impact risk ranges for TTS/fleeing response are shown in Table 6.7 below, along with the change from the NPL modelling in the Sofia ES for each hammer energy.

Table 6.7 - TTS/fleeing response: INSPIRE impact risk ranges for white-beaked dolphin.

Hammer Energy	INSPIRE - TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 μPa^2s) maximum range	Change from ES maximum hammer impact risk range (<200m*)
3,000kJ	140m	-30%
5,500kJ	200m	No change

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (<200m) has been equated to an actual maximum distance (i.e. 200m), which was a precautionary assumption. The same approach is applied to the INSPIRE outputs.

Table 6.8 shows that the number of white-beaked dolphins and the percentage of the population they represent is the same at for TTS/ fleeing response and for PTS. As identified for PTS, impact risk ranges are well within the 500m mitigation zone implemented via the MMMP. Therefore, there will be no change to the original conclusion in the Sofia ES of No Impact.

6.3.2.3 Potential Disturbance

The Sofia ES showed that NPL modelling estimated that <1-3 individuals (for a potential impact risk area of 15-200km^2 respectively) were predicted to be disturbed by receiving noise levels at or above the threshold of unweighted pulse SEL 170-160 dB re 1 μPa^2s from a maximum hammer energy of 3,000kJ. <1-3 individuals corresponded to <0.01% of the ES reference population. The same criterion was used by Subacoustech in the INSPIRE model which, for a hammer of 3,000kJ, which estimated between <1 and 4 individuals which corresponds to <0.1% of the reference population respectively (Table 6.8). The same modelling approach was used for the new hammer energy which predicted a range of <1-7 individuals for a 5,500kJ hammer. This equates to <0.1% of the reference population.

The maximum increase in the potential population effected is 0.042% for the maximum 5,500kJ hammer and is not considered to change the impact magnitude from the Sofia ES. The Sofia ES concluded a Negligible impact for avoidance of white-beaked dolphin. Based on the same assessment of significance used in the Sofia ES, it can be concluded that the low corresponding percentage of the reference population affected, there will be no change to the original conclusion.

Table 6.8 – White-beaked dolphin impact risk range area and population impacts

Mid-Frequency Cetaceans (White-Beaked Dolphin)		3,000kJ hammer energy	5,500kJ hammer energy
INSPIRE - Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 μPa^2s)[1]	Area	<0.1km^2	<0.1km^2
	Individuals	<0.001	<0.001
	% of ref population	<0.001	<0.001
INSPIRE - TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 μPa^2s) [1]	Area	<0.1km^2	0.1km^2
	Individuals	<0.001	0.001
	% of ref population	<0.001	0.001
NPL - Behavioural response unweighted (pulse SEL 170-160 dB re 1 μPa^2s)	Area	15-200km^2	-
	Individuals	0.223-2.974	-
	% of ref population	0.001-0.019	-
INSPIRE - Possible avoidance of area (pulse SEL 160-170 re 1 μPa^2s)	Area	22.5-264km^2	46.2-444km^2
	Individuals	0.335-3.926	0.687-6.602
	% of ref population	0.002-0.025	0.004-0.042

[1]No equivalent given in Sofia ES.

6.3.3 Low-frequency Cetaceans – Minke Whale

6.3.3.1 Instantaneous PTS single strike

According to the Sofia ES, NPL modelling of PTS weighted (SELss M_{lf} 198 dB re 1 µPa^{2}s) from Southall *et al.* (2007) for a hammer energy of 3,000kJ resulted in an impact risk range of <100m. Again, it is worth mentioning that this reduction is likely to be a product of model resolution between NPL and Subacoustech approaches.

Under the same criteria, but modelled with the INSPIRE model, a 3,000kJ hammer energy results in an impact risk range of <50m. Using the same approach, a 5,500kJ hammer energy results in maximum impact risk ranges of 60m. The results of the INSPIRE modelling show that an increase to a maximum hammer energy of 5,500kJ will be less than that originally modelled in the Sofia ES for a 3,000kJ hammer energy. The impact risk ranges for PTS are shown in Table 6.9 below, along with the change from the NPL modelling in the Sofia ES for each hammer energy.

Table 6.9 - PTS: INSPIRE impact risk ranges for minke whale.

Hammer Energy	INSPIRE - Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^{2}s) maximum range	Change from ES maximum hammer impact risk range (<100m*)
3,000kJ	<50m	-50%
5,500kJ	60m	-40%

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (<100m) has been equated to an actual maximum distance (i.e. 100m), which is a precautionary assumption. The same approach is applied to the INSPIRE outputs.

As shown in Table 6.11, the potential population impact of minke whales impacted by PTS a 5,500kJ hammer energy is extremely small relative to the reference populations for the species. Additionally, impact risk ranges are well within the 500m mitigation zone implemented via the MMMP. The Sofia ES concluded No Impact from for lethal/ injury and auditory injury (PTS) for the species. Based on the results of the INSPIRE modelling it can be concluded there will be no change to the original conclusion.

6.3.3.2 TTS/fleeing response

NPL modelled the TTS weighted (SEL_{ss} M_{lf} 183 dB re 1 µPa^{2}s) response of low-frequency cetacean and found an impact risk range of <400m for a hammer energy of 3,000kJ.

Using the same criteria as the Sofia ES from Southall *et al.* (2007), the INSPIRE model showed a maximum impact risk range of 380m for a hammer energy of 3,000kJ. Additionally, and under the same approach, the INSPIRE model showed maximum impact risk range of 570m for a hammer energy of 5,500kJ. The impact risk ranges for TTS/fleeing response are shown in Table 6.10 below, along with the change from the NPL modelling in the Sofia ES for each hammer energy.

Table 6.10 - TTS/fleeing response: INSPIRE impact risk ranges for minke whale.

Hammer Energy	INSPIRE - TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^{2}s) maximum range	Change from ES maximum hammer impact risk range (<400m*)
3,000kJ	380m	-5%
5,500kJ	570m	+42.5

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (<400m) has been equated to an actual maximum distance (i.e. 400m), which was a precautionary assumption. The same approach is applied to the INSPIRE outputs.

Despite an increase in the impact risk ranges for the updated maximum hammer energy, Table 6.11 shows that the number of minke whales and the percentage of the population they represent are extremely low and therefore, there will be no change to the original conclusion in the Sofia ES of No Impact.

6.3.3.3 Potential Disturbance

The Sofia ES showed that NPL modelling estimated between approximately 8 and 36 individuals were predicted to be disturbed by piling noise based on maximum area of possible avoidance of 4,172km^2 (based on unweighted pulse SEL 152-142 dB re 1 µPa^{2}s). This impact corresponded to <0.1% of the Central and north east Atlantic reference population, and 0.16% of the British Irish Management Unit.

The same criterion was used by Subacoustech in the INSPIRE model which showed a reduction in the estimated maximum area potentially disturbed for a 3,000kJ hammer by 8.1% and resulting in an estimated 33 individuals. The same modelling approach was used for the new hammer energy and predicted a maximum of 44 individuals for a 5,500kJ hammer. The percentage impact on each reference population is shown in Table 6.11 below.

The Sofia ES concluded a Negligible impact for avoidance of minke whales. Based on the same assessment of significance used in the Sofia ES, it can be concluded that the low corresponding percentage of the reference population affected, there will be no change to the original conclusion.

Table 6.11 – Minke whale impact risk range area and population impacts.

Low-Frequency Cetaceans (Minke Whale)		3,000kJ hammer energy	5,500kJ hammer energy
INSPIRE - Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^{2}s) [1]	Area	<0.1km^2	<0.1km^2
	Individuals	<0.001	<0.001
	% of ref population[2]	<0.001 (<0.001)	<0.001 (<0.001)
INSPIRE - TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^{2}s) [1]	Area	0.4km^2	1.0km^2
	Individuals	0.003	0.009
	% of ref population[2]	<0.001 (<0.001)	<0.001 (<0.001)
NPL - Behavioural response unweighted (pulse SEL 152-142 dB re 1 µPa^{2}s)	Area	953-4,172km^2	-
	Individuals	8.253-36.13	-
	% of ref population[2]	0.005-0.021 (0.036-0.156)	-
INSPIRE - Likely avoidance of area (pulse SEL 152-142 re 1 µPa^{2}s)	Area	1,090-3,830km^2	1,580-5,060km^2
	Individuals	9.44-33.168	13.683-43.516
	% of ref population[2]	0.005-0.019 (0.041-0.143)	0.008-0.016 (0.059-0.124)

[1]No equivalent given in Sofia ES.

[2]British Irish Management Unit reference population in brackets.

6.3.4 Pinniped (in water) – Grey Seal

6.3.4.1 Instantaneous PTS single strike

The NPL modelling which informed the Sofia ES, used PTS weighted (SEL_{ss} M_{pw} 186 dB re 1 µPa^{2}s) from Southall *et al.* (2007) to predict the impact risk ranges of a 3,000kJ hammer on pinnipeds.

NPL modelling found that for the maximum hammer energy of 3,000kJ stated in the Sofia ES, an impact risk range of <200m was predicted. Under the same criteria, but modelled with the INSPIRE software, a 3,000kJ hammer energy results in a lower maximum impact risk range of 140m. Using the same approach, a 5,500kJ hammer energy would result in maximum impact risk range of 210m. The impact risk ranges for PTS are shown in Table 6.12 below, along with the change from the NPL modelling in the Sofia ES for each hammer energy.

Table 6.12 - PTS: INSPIRE impact risk ranges for grey seal.

Hammer Energy	INSPIRE - Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 μPa^2s) maximum range	Change from ES maximum hammer impact risk range (<200*m)
3,000kJ	140m	-30%
5,500kJ	210m	+5%

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (<200m) has been equated to an actual maximum distance (i.e. 200m), which was a precautionary assumption. The same approach is applied to the INSPIRE outputs.

Table 6.14 shows the number of individuals within each impact risk range. For grey seal, this number of individuals represents <0.001% of the reference population for the increased hammer energy. The Sofia ES concluded Minor adverse from for lethal/ injury and auditory injury (PTS) for harbour porpoise. Based on the same assessment of significance used in the Sofia ES, it can be concluded that the low corresponding percentage of the reference population affected, there will be no change to the original conclusion.

6.3.4.2 TTS/fleeing response

NPL modelled the TTS weighted (SEL_{ss} M_{pw} 171 dB re 1 μPa^2s) response of pinnipeds and found an impact risk range of 1.7km for a hammer energy of 3,000kJ. Using the same criteria as the Sofia ES from Southall *et al.* (2007), the INSPIRE model showed a lower impact risk range of 1.4km for a hammer energy of 3,000kJ. Additionally, and under the same approach, the INSPIRE model showed a maximum impact risk range of 2.1km for a 5,500kJ hammer. The impact risk ranges for TTS/fleeing response are shown in Table 6.13 below, along with the change from the NPL modelling in the Sofia ES for each hammer energy.

Table 6.13 - TTS/fleeing response: INSPIRE impact risk ranges for grey seal.

Hammer Energy	INSPIRE - TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 μPa^2s) maximum range	Change from ES maximum hammer impact risk range (~1.7 m or less*)
3,000kJ	1.4km	-17.6%
5,500kJ	2.1km	+23.5%

*For the purposes of calculating a percentage change, the maximum range presented within the original assessment (~1.7km) has been equated to an actual maximum distance (i.e. 1.7km), which is a precautionary assumption. The same approach is applied to the INSPIRE outputs.

Table 6.14 shows 3 individuals are predicted to be found in an impact risk range area of 13.2km^2 (5,500kJ). This represents <0.1% of the reference population for a 5,500kJ hammer.

An increase from 0.005% for the 3,000kJ hammer, to 0.011% for the 5,500kJ hammer is not considered to change the impact magnitude from the Sofia ES The Sofia ES concluded a Negligible impact for TTS/ fleeing response for grey seal. Based on the same assessment of significance used in the Sofia ES, it can be concluded that the low corresponding percentage of the reference population affected, there will be no change to the original conclusion.

Table 6.14 – Grey seal impact risk range area and population impacts.

Pinnipeds (Grey Seal)		3,000kJ hammer energy	5,500kJ hammer energy
	Area	<0.1km^2	0.1km^2
	Individuals	<0.023	0.023

INSPIRE - Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 μPa^2s) [1]	% of ref population	<0.001	<0.001
NPL - TTS weighted (M_{pw} SEL_{ss} 171 dB re 1 μPa^2s)	Area	9km^2	-
	Individuals	2.07	-
	% of ref population	0.007	-
INSPIRE - TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 μPa^2s)	Area	6.1km^2	13.2km^2
	Individuals	1.403	3.036
	% of ref population	0.005	0.011

[1]No equivalent given in Sofia ES.

6.3.5 Significance of impact – Stage 1

The updated modelling results demonstrate that an increase in hammer energy utilising the updated modelling software does not change the predicted impact effect significances for any species of marine mammal assessed when compared to levels predicted in the ES assessment.

The results of the updated modelling for a maximum hammer energy of 5,500kJ showed an increase in the predicted impact areas and number of individuals that could possibly be injured/disturbed for all species. However, this increase was in most cases small and did not increase the magnitude of effect for any species assessed. Furthermore, the implementation of a MMMP (including the use of ADDs) would ensure no impact risk would exceed the range of mitigation.

As outlined above, the assessment is based on 100% of individuals within the maximum predicted range of possible disturbance potentially being impacted, although this is unlikely given the size of the area. Therefore, the assessment is precautionary, based on a worst-case scenario, maximum potential risk area and with an assumption that all individuals are potentially disturbed. As such, the significance of impact would realistically be anticipated to be lower, however to ensure that precaution is maintained within the updated assessment, the significance levels have been maintained.

Overall, no increase in the significance of any effect on marine mammal receptors is considered to arise from the use of the larger 5,500kJ hammer in comparison to that assessed in the original application.

Table 6.15 – Comparison of overall significance from Sofia ES with the updated modelling results of this assessment.

Residual Impact	Maximum Hammer Energy	Harbour Porpoise	Minke Whale	White-Beaked Dolphin	Grey Seal
Sofia ES results	3,000kJ	Negligible	Negligible	Negligible	Negligible
Results from this assessment	5,500kJ	Negligible	Negligible	Negligible	Negligible

6.4 Stage 2 – New Criteria for Marine Mammals

As stated above in Section 4, since the original modelling was undertaken for the Sofia ES by NPL, the NMFS has developed new thresholds and criteria of noise for auditory injury to marine mammals (NMFS, 2016) (Table 6.16Method of Comparison). These updated criteria do not include new thresholds for potential disturbance and as a result, the following assessment focuses on PTS and TTS.

Table 6.16 - Assessment criteria for marine mammals from NMFS (2016) for impulsive noise.

Impulsive Noise	TTS Criteria	PTS Criteria
Functional Group	**(unweighted) SPL_{peak} dB re 1 µPa**	**(unweighted) SPL_{peak} dB re 1 µPa**
Low-frequency Cetaceans	213	219
Medium-frequency Cetaceans	224	230
High-frequency Cetaceans	196	202
Phocid Pinnipeds	212	218

To ascertain whether this use of the new threshold criteria affect the conclusions of the Stage 1 assessment for marine mammals, a comparison of maximum outputs from the 5,500kJ hammer energies is made between the original criteria used above and the new criteria identified by NMFS (2016).

6.4.1 Predicted harbour porpoise impact risk ranges using criteria derived from NMFS (2016)

6.4.1.1 Instantaneous PTS and TTS

The impact risk ranges for PTS and TTS of harbour porpoise for a 5,500kJ hammer energy are present in Table 6.17 and Table 6.18 below. Both tables compare the updated NMFS (2016) criteria against the previous Lucke *et al.* (2009) criteria and show the percentage change between the maximum impact risk ranges.

Table 6.17 - Harbour porpoise: Comparison in the change of PTS potential maximum impact risk range between Lucke *et al.* (2009) and NMFS (2016) criteria.

Hammer Energy	Lucke *et al.* (2009) Instantaneous injury/PTS (unweighted pulse SEL 179 dB re 1 µPa^2s)	NMFS (2016) PTS unweighted SPL_{peak} (202 re 1 µPa)	Percentage change
5,500kJ	1.1km	710m	-35%

Table 6.18 - Harbour porpoise: Comparison in the change of TTS potential maximum impact risk range between Lucke *et al.* (2009) and NMFS (2016) criteria.

Hammer Energy	Lucke *et al.* (2009) TTS/fleeing response (unweighted pulse SEL 164 dB re 1 µPa^2s)	NMFS (2016) TTS unweighted SPL_{peak} (196 re 1 µPa)	Percentage change
5,500kJ	8.1km	1.6km	-80%

For the NMFS (2016) PTS SPLpk criteria there was a 35% decrease in the impact risk ranges compared to those predicted by Lucke *et al.* (2009) for the new hammer. For TTS, the decrease was 80%.

As a result of this decrease in impact risk ranges for both PTS and TTS according to the NFMS (2016) criteria, the percentage of the reference population is also reduced from that predicted under the original criteria (Lucke *et al.* (2009)).

Table 6.19 shows that even when assessing the increased hammer energy against the updated NMFS (2016) criteria, there is still no significant impact to harbour porpoise as a result of underwater piling at Sofia.

Table 6.19 - Comparison of impacts from Lucke *et al.* (2009) and NMFS (2016) for harbour porpoise.

High-Frequency Cetaceans (Harbour Porpoise)		5,500kJ hammer energy
NMFS (2016) PTS unweighted SPL_{peak} (202 re 1 µPa)	Area	1.6km^2
	Individuals	1.025
	% of ref population	<0.001
Lucke *et al.* (2009) Instantaneous injury/PTS (unweighted pulse SEL 179 dB re 1 µPa^{2}s)	Area	3.4km^2
	Individuals	2.178
	% of ref population	0.001
NMFS (2016) TTS unweighted SPL_{peak} (196 re 1 µPa)	Area	7.7km^2
	Individuals	4.932
	% of ref population	0.002
Lucke *et al.* (2009) TTS/fleeing response (unweighted pulse SEL 164 dB re 1 µPa^{2}s)	Area	197km^2
	Individuals	126.190
	% of ref population	0.056

6.4.2 Predicted mid-frequency cetaceans impact risk ranges using criteria derived from NMFS (2016)

6.4.2.1 Instantaneous PTS and TTS

The impact risk ranges for PTS and TTS of white-beaked dolphin for a 5,500kJ hammer energy is presented in Table 6.20 and Table 6.21 below. Both tables compare the updated NMFS (2016) criteria against the previous Southall *et al.* (2007) and show the percentage change between the maximum impact risk ranges.

Table 6.20 – White-beaked dolphin: Comparison in the change of PTS potential maximum impact risk range between Southall *et al.* (2007) and NMFS (2016) criteria.

Hammer Energy	Southall *et al.* (2007) Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^{2}s)	NMFS (2016) PTS unweighted SPL_{peak} (230 re 1 µPa)	Percentage change
5,500kJ	<50m	<50m	No change

Table 6.21 – White-beaked dolphin: Comparison in the change of TTS potential maximum impact risk range between Southall et al. (2007) and NMFS (2016) criteria.

Hammer Energy	Southall *et al.* (2007) TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa^{2}s)	NMFS (2016) TTS unweighted SPL_{peak} (224 re 1 µPa)	Percentage change
5,500kJ	200m	50m	-75%

For the NMFS (2016) PTS criteria there was no difference in the impact risk ranges from those predicted by Southall *et al.* (2007) for either hammer energy. For TTS/fleeing, there was a large decrease for a maximum hammer energy of 5,500kJ. The number of individuals associated with the PTS and TTS/fleeing response ranges above are identified in the table below, along with the consequent potential percentage of the population affected.

As a result of this decrease in impact risk ranges for both PTS and TTS/fleeing response according to the NFMS (2016) criteria, the percentage of the reference population is also reduced from that predicted under the original criteria (Southall *et al.* 2007)). Table 6.22 shows that even when assessing the increased hammer energies against the updated NMFS (2016) criteria, there is still no significant impact to white-beaked dolphin as a result of underwater piling at Sofia.

Table 6.22 - Comparison of impacts from Southall *et al.* (2007) and NMFS (2016) for white-beaked dolphin.

Mid-Frequency Cetaceans (White-beaked Dolphin)		5,500kJ hammer energy
NMFS (2016) PTS unweighted SPL_{peak} (230 re 1 µPa)	Area	<0.1km^2
	Individuals	<0.001
	% of ref population	<0.001
Southall *et al.* (2007) Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Area	<0.1km^2
	Individuals	<0.001
	% of ref population	<0.001
NMFS (2016) TTS unweighted SPL_{peak} (224 re 1 µPa)	Area	<0.1km^2
	Individuals	<0.001
	% of ref population	<0.001
Southall *et al.* (2007) TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Area	<0.1km^2
	Individuals	<0.001
	% of ref population	<0.001

6.4.3 Predicted low-frequency cetacean impact risk ranges using criteria derived from NMFS (2016)

6.4.3.1 Instantaneous PTS and TTS

The impact risk ranges for PTS and TTS of minke whale for a 5,500kJ hammer energy is presented in Table 6.23 and Table 6.24 below. Both tables compare the updated NMFS (2016) criteria against the previous Southall *et al.* (2007) and show the percentage change between the maximum impact risk ranges.

Table 6.23 - Minke whale: Comparison in the change of PTS potential maximum impact risk range between Southall *et al.* (2007) and NMFS (2016) criteria.

Hammer Energy	Southall et al (2007) Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^{2}s)	NMFS (2016) PTS unweighted SPL_{peak} (219 re 1 µPa)	Percentage change
5,500kJ	60m	80m	+33%

Table 6.24 – Minke whale: Comparison in the change of TTS potential maximum impact risk range between Southall *et al.* (2007) and NMFS (2016) criteria.

Hammer Energy	Southall et al (2007) TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^{2}s)	NMFS (2016) TTS unweighted SPL_{peak} (213 re 1 µPa)	Percentage change
5,500kJ	570m	160m	-72%

For the NMFS (2016) PTS criteria there was an increase in the impact risk ranges from those predicted by Southall *et al.* (2007) for both hammer energies. For TTS, there was a decrease of 72% for a maximum hammer energy of 5,500kJ. The number of individuals associated with the PTS and TTS ranges above are identified in below, along with the consequent potential percentage of the population affected.

Despite an increase in impact risk ranges for PTS, the potential number of individuals affected are still significantly below the level at which anything other than a negligible impact would be concluded. For TTS according to the NFMS (2016) criteria, the percentage of the reference population is reduced from that predicted under the original criteria (Southall *et al.* 2007)). Table 6.25 shows that even when assessing the increased hammer energies against the updated NMFS (2016) criteria, there is still no significant impact to minke whale as a result of underwater piling at Sofia.

Table 6.25 - Comparison of impacts from Southall *et al.* (2007) and NMFS (2016) for minke whale.

Low-Frequency Cetaceans (Minke Whale)		5,500kJ hammer energy
NMFS (2016) PTS unweighted SPL_{peak} (219 re 1 µPa)	Area	<0.1km^2
	Individuals	<0.001
	% of ref population *	<0.001 (<0.001)
Southall *et al.* (2007) Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Area	< 0.1km^2
	Individuals	<0.001
	% of ref population *	<0.001 (<0.001)
NMFS (2016) TTS unweighted SPL_{peak} (213 re 1 µPa)	Area	<0.1km^2
	Individuals	<0.001
	% of ref population *	<0.001 (<0.001)
Southall *et al.* (2007) TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Area	1.0km^2
	Individuals	0.009
	% of ref population *	<0.001 (<0.001)

*British Irish Management Unit reference population in brackets.

6.4.4 Predicted pinnipeds (in water) impact risk ranges using criteria from NMFS (2016)

6.4.4.1 Instantaneous PTS and TTS

The impact risk ranges for PTS and TTS of grey seal for a 5,500kJ hammer energy is presented in Table 6.26 and Table 6.27 below. Both tables compare the updated NMFS (2016) criteria against the previous Southall *et al.* (2007) and show the percentage change between the maximum impact risk ranges.

Table 6.26 – Grey seal: Comparison in the change of PTS potential maximum impact risk range between Southall *et al.* (2007) and NMFS (2016) criteria.

Hammer Energy	Southall *et al.* (2007) Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa^{2}s)	NMFS (2016) PTS unweighted SPL_{peak} (218 re 1 µPa)	Average percentage change
5,500kJ	210m	90m	-57%

Table 6.27 – Grey seal: Comparison in the change of TTS potential maximum impact risk range between Southall *et al.* (2007) and NMFS (2016) criteria.

Hammer Energy	Southall *et al.* (2007) TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa^{2}s)	NMFS (2016) TTS unweighted SPL_{peak} (212 re 1 µPa)	Average percentage change
5,500kJ	2.1km	190m	-91%

For the NMFS (2016) PTS criteria there was a decrease in the impact risk ranges from those predicted by Southall *et al.* (2007), for the increased hammer energy (57%). For TTS, there was a decrease of 91% for a maximum hammer energy of 5,500kJ. The number of individuals associated with the PTS and TTS ranges above are identified in below, along with the consequent potential percentage of the population affected.

There was a decrease in impact risk ranges for both PTS and TTS according to the NFMS (2016) criteria, the percentage of the reference population is also reduced from that predicted under the original criteria (Southall *et al.* 2007)). Table 6.28 shows that even when assessing the increased hammer energy against the updated NMFS (2016) criteria, there is still no significant impact to grey seal as a result of underwater piling at Sofia.

Table 6.28 - Comparison of impacts from Southall *et al.* (2007) and NMFS (2016) for grey seal

Pinnipeds (Grey Seal)		5,500kJ hammer energy
NMFS (2016) PTS unweighted SPL_{peak} (218 re 1 µPa)	Area	0.1km^2
	Individuals	0.023
	% of ref population	<0.001
Southall *et al.* (2007) Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa^{2}s)	Area	0.1km^2
	Individuals	0.023
	% of ref population	<0.001
NMFS (2016) TTS unweighted SPL_{peak} (212 re 1 µPa)	Area	0.1km^2
	Individuals	0.023
	% of ref population	<0.001
Southall *et al.* (2007) TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa^{2}s)	Area	13.2km^2
	Individuals	3.036
	% of ref population	0.010

6.4.5 Stage 2 (Updated criteria) assessment summary

Overall, no increase in the significance of any effect on marine mammal receptors is considered to arise from the use of the larger 5,500kJ hammer in comparison to that assessed in the original application. There are some increases evident in terms of areas affected at relevant thresholds for minke whale, however the proportions of the populations potentially subject to noise exposure remain small and ensures that no exceedance of the original ES significance findings would occur. Furthermore, the implementation of a MMMP with a standard 500m mitigation zone would reduce this impact risk range for those receptors which exceed 500m.

6.4.6 Summary of marine mammal assessment

Therefore, based on the information presented above in Stage 1 and Stage 2 for a 5,500kJ hammer energy, the significance of the potential impacts remains as stated in the ES, and are as follows:

Residual Impact	Harbour Porpoise	Minke Whale	White-Beaked Dolphin	Grey Seal
Overall impact	**Negligible**	**Negligible**	**Negligible**	**Negligible**

This environmental assessment compares the environmental topics and the potential effects and impacts that were identified within the Sofia ES with the increase proposed to the maximum hammer energy for monopole foundation installation. Consideration has been given to the effects of the proposed changes and whether these changes could result in impacts of significance (in EIA terms) or greater significance to those identified in the existing assessment as submitted to the Secretary of State in 2015 and consented in 2015.

Section 6.3.5 concludes that the potential impacts in relation to marine mammals associated with the proposed changes to increase the maximum hammer energy for monopole foundations are of no greater significance than those identified in the original Sofia ES.

7 Consideration of The Habitats Regulations

Consideration has also been given to the potential consequence of the proposed increase in hammer energy on any features of European designated sites. As established within the Appropriate Assessment (AA) carried out by the Secretary of State for the Project (DECC, 2015), underwater noise from piling operations was identified as having the potential to interact with designated features from a range of European sites either directly or indirectly. Those features where direct effects were considered included harbour porpoise and grey seal. Those features where indirect effects were considered comprised a range of seabird species, with the indirect effect being related to the potential reduction in prey resource (fish) as a result of underwater noise impacts on these species.

This NMA for hammer energy increase has identified that the worst case assumptions for underwater noise impacts on fish receptors has not changed (as it related to jacket foundation solutions). Therefore, the conclusions reached within DECC, 2015 that there would be no AEoI on any ornithological feature of a designated site from underwater noise effects on prey resource remain valid.

For grey seal the AA identified that no AEoI would occur due to the extremely small effect at population scale on the species (when considering PTS effects) and that displacements effects would equally be tolerable given the extensive foraging ranges. This NMA for hammer energy increase has identified that the increase in hammer energy would not result in a change to the predictions made within the original ES for either PTS or displacement effects and therefore, the conclusions drawn by DECC in the AA would remain valid.

The DECC AA for Sofia made recognition of the fact that a designated site had been brought forward for harbour porpoise following the consent application. Whilst consideration was given at a high level within the DECC AA to this site (the southern North Sea draft Special Area of Conservation) there was limited conservation advice available at that time. A conclusion of no AEoI was reached based on the requirement for the Applicant to follow the JNCC 2010 guidelines and that these were sufficient mitigation measures for harbour porpoise. Since 2015, the site has progressed, with conservation advice released and the site now having been submitted to Europe for formal designation (and therefore, is now a 'candidate' SAC). The following paragraphs give consideration to the potential hammer energy increase on this site based on the latest conservation objective information.

The Sofia Offshore Wind Farm (Sofia) falls partially within the Southern North Sea (SNS) candidate Special Area of Conservation (cSAC) (Figure 1). The SNS cSAC is designated solely for harbour porpoise, a species known to be sensitive to underwater noise such as that resulting from percussive piling. As part of the NMA for the increase in hammer energy, the potential implications for the conservation objectives of the SNS cSAC have been considered here.

To avoid deterioration of the habitats of the harbour porpoise or significant disturbance to the harbour porpoise, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to maintaining Favourable Conservation Status (FCS) for the UK harbour porpoise.

To ensure for harbour porpoise that, subject to natural change, the following attributes are maintained or restored in the long term:

1. The species is a viable component of the site.
2. There is no significant disturbance of the species.
3. The supporting habitats and processes relevant to harbour porpoises and their prey are maintained.

As part of the NMA request for the increase in hammer energy, consideration is given here to the potential for such a request to change the existing conclusion of no AEoI made by DECC in 2015. To do so, consideration of the sites Conservation Objectives is required, with these as follows[4].

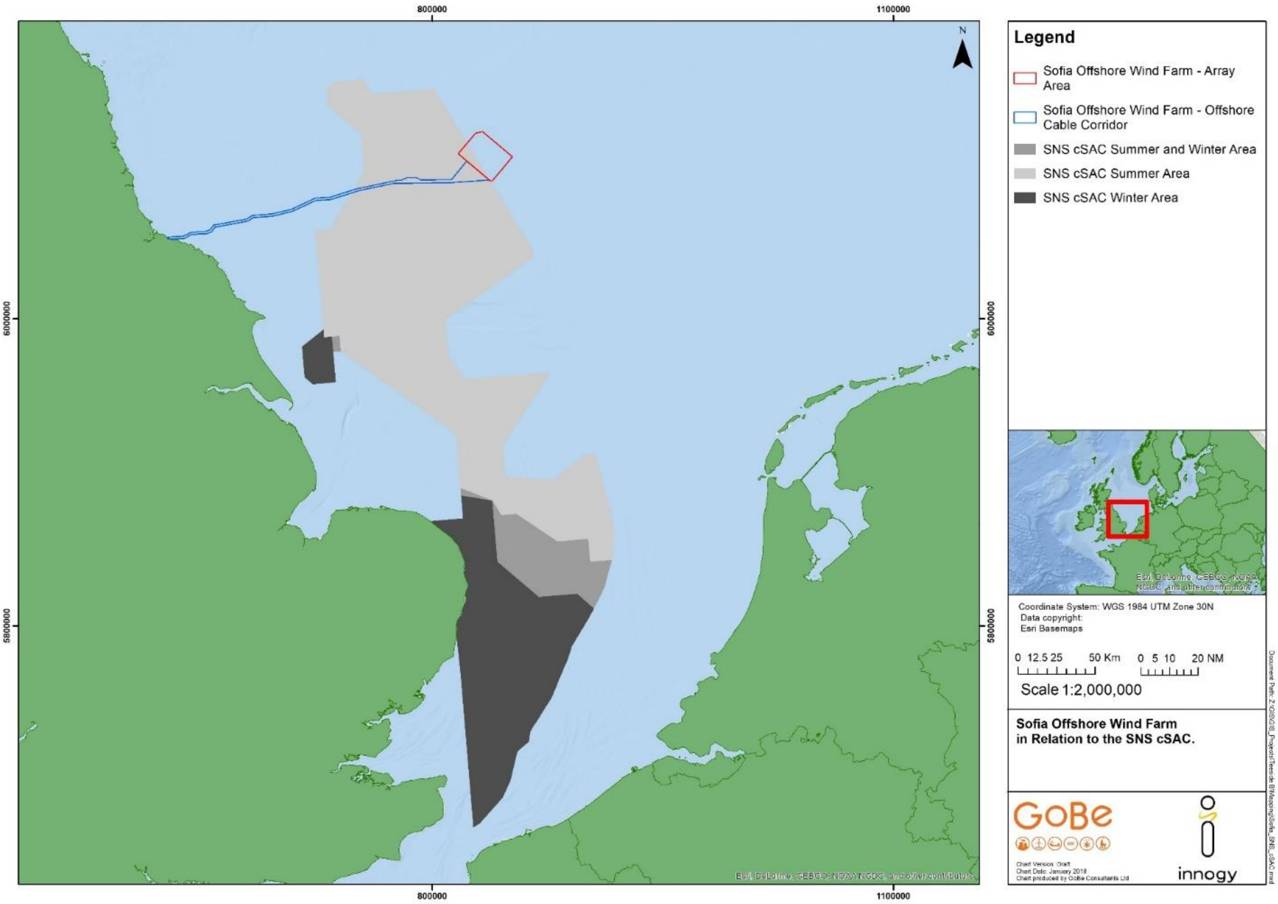

Figure 1: Sofia Offshore Wind Farm and the SNS cSAC.

The following text considers the potential effect of the proposed hammer energy increase on each of these Conservation Objectives.

7.1.1.1 The Species is a Viable Component of the Site

Harbour porpoise are considered to be a viable component of the site if they are able to survive and live successfully within it. The intent of this objective is to minimise the risk posed by activities within the site to the species viability, specifically activities that kill, injure or significantly disturb harbour porpoise.

The measure of viability is typically considered through determination of the potential for an activity to result in death or injury of an individual – with permanent threshold shift (PTS) included within this category. The additional modelling undertaken for the increase in hammer energy includes consideration of the risk of PTS for harbour porpoise. The report includes a number of calculations, to enable both a comparison with the existing assessment and the increase in hammer energy but also to take account of the NOAA criteria (NMFS, 2016). The ranges modelled for high frequency cetaceans (including harbour porpoise), for PTS only and applying the NOAA criteria, are given below.

[4] http://jncc.defra.gov.uk/pdf/SouthernNorthSeaConservationObjectivesAndAdviceOnActivities.pdf

High-frequency cetaceans - impact criterion		2,300 kJ hammer energy	3,000 kJ hammer energy	4,000 kJ hammer energy	5,500 kJ hammer energy
PTS unweighted SPL_{peak} (202 re 1 µPa)	Maximum	430m	500m	590m	710m
	Minimum	420m	490m	580m	700m
	Mean	430m	500m	590m	710m
	Area	$0.6km^2$	$0.8km^2$	$1.1km^2$	$1.6km^2$

It is clear from the ranges provided above that the risk of PTS with the increase in hammer energy remains well within the standard MMMP mitigation range (with such mitigation comprising standard industry best practice techniques such as Marine Mammal Observers, Passive Acoustic Monitoring, Acoustic Deterrent Devices and a soft start to piling). The increase in hammer energy would therefore not change the existing conclusion of no AEoI with respect to the first conservation objective for either the Project alone or in-combination with other plans, projects or proposals. Consideration of disturbance is typically made separately, under the second conservation objective below.

7.1.1.2 There is no Significant Disturbance of the Species

The measure of 'significant disturbance' within the SNS cSAC is made based on a standard Effective Deterrent Radius (EDR) of 26km as advocated by the Statutory Nature Conservation Bodies (SNCBs)[5]. The measure is applied irrespective to the type or size of pile being installed or the hammer energy applied, having been drawn from empirical studies during percussive piling at a number of offshore wind farm projects across Europe. The increase in hammer energy would therefore have no effect on the determination of AEoI for either the Project alone or in-combination with other plans, projects or proposals.

7.1.1.3 The Supporting Habitats and Processes Relevant to Harbour Porpoises and their Prey are Maintained

The third and final conservation objective relates to the availability of prey and the supporting habitats for both harbour porpoise and that prey. The increase in hammer energy will not result in a physical change in the habitat of harbour porpoise. The NMA has identified no change in relation to the worst case scenario assessed for fish and therefore there can be no change in the conclusions of the ES with respect to fish ecology. As a result, there can be no change in the existing conclusions of the DECC AA of no AEoI relating to this Conservation Objective, for either the Project alone or in-combination with other plans, projects or proposals.

[5] E.g. see workshop outputs contained within: JNCC, 2017a. A potential approach to assessing the significance of disturbance against conservation objectives of the harbour porpoise cSACs. Discussion document version 3.0 and JNCC, 2017b. Harbour porpoise SACs noise management stakeholder workshop. Report.

8 Conclusion

Following further design studies post consent, Innogy has been made aware that a higher hammer energy may be required in order to ensure successful monopole foundation installation.

This report presents the environmental appraisal undertaken by Innogy for the increase in hammer energy to 5,500kJ for monopole foundations for each of the relevant ES Chapters and demonstrates that there will be no increase in effect significance compared to the assessment within the ES on any receptors as a result of the increased hammer energy.

As the current consented maximum hammer energy is specified on the face of the DCO for Sofia, the variation to the existing consent is considered to be through the non-material amendment process for DCOs. The relevant guidance for identifying the nature of the DCO amendment (material/non-material) is outlined in the Department for Communities and Local Government (DCLG's) “Guidance on Changes to Development Consent Orders” (December 2015), the relevant part of which, for the purposes of this paper, comprises:

Where any new or significant effects on the environment as a result of the change mean that an update to the original Environmental Statement (from that at the time the original DCO was made) is required (to take account of those effects)

The assessment presented within this report has identified that for the relevant receptors, no change in the significance of any effect from those identified in the original ES, which supported the DCO application, arise from the use of a higher energy hammer for monopole installation at Sofia. It is therefore concluded that the increase in hammer energy, which will ensure that monopoles can be successfully installed, can be taken forward under the non-material amendment mechanism. The lack of any change in the significance of predicted effects, notably including assessment of impacts using updated noise effect threshold criteria, indicate that the increased hammer energy sought is acceptable on the basis that the planned construction activities will not result in any greater impacts than those determined within the ES.

Consideration has also been given to the conclusions of the DECC AA for the Project and additional detail provided in relation to the SNS cSAC (whose designation process has advanced since 2015), and it is confirmed that the proposed increase in hammer energy would not alter any of the findings relating to no LSE or indeed no AEoI.

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Appendix A: Additional underwater noise modelling at Sofia offshore wind farm, Dogger Bank. Subacoustech Environmental Report No. P221R0102

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