Annex C

EIA Report on
Development of a 100MW Offshore Wind Farm in Hong Kong

Supplementary information provided by the project proponent
at the request of the EIA Subcommittee

(a) Assessment on predicted noise level and noise impacts, both airborne and underwater, on noise sensitive receivers arising from the use of percussive piling for the construction of wind farm structures with piles of 5 to 7 m in diameter.

As discussed in the EIA report (*Section 5*), the components for the wind farm will not be procured until the Detailed Design Phase, which will commence once the EIA has been approved. However, based on early discussions with wind turbine manufacturers, monopiles for 2.3 to 3.6 MW class wind turbines may have diameters of 5 to 7 m. Such dimensions have hence been taken forward for assessment.

In the case of the potential for airborne and underwater sound generated from the project, due to the differing media and unit of measurement, further information on the assessment of potential impacts related to these sounds are discussed separately below.

Airborne Sound

The potential effects from the airborne noise generated by percussive piling works for the installation of wind turbine foundations are considered in accordance with the *Technical Memorandum on Noise from Percussive Piling* (PP-TM) issued under the *Noise Control Ordinance* (NCO) for the nearest Noise Sensitive Receivers (NSRs) at Lo So Shing on Lamma Island and Seascape Peninsula on Cheung Chau. For the calculation of noise levels at the two NSRs, it is assumed that a double-acting hydraulic hammer, which is the type of percussive piling method with the highest sound power level (SWL) listed under *Table 2* of the PP-TM, will be used to drive the steel pile (noisier percussive piling methods involving the use of diesel or steam hammers will not be adopted for the foundation works) and only one pile will be driven at any one time.

Based on the above, the percussive piling noise levels at Lo So Shing and Seascape Peninsula are predicted to be 41 dB(A) and 50 dB(A) respectively, which are substantially lower than the Acceptable Noise Level (ANL) of 85 dB(A) published in the PP-TM for the corresponding type of NSRs (i.e. NSRs with windows or other openings but without central air conditioning system. The detailed noise calculations are provided in *Figure 1* below.

Notwithstanding the fact that the percussive piling noise levels predicted at the nearest NSRs are substantially lower than the ANL in the PP-TM, rigorous procedures are in place and

enforced by the Environmental Protection Department (EPD) under the NCO to control percussive piling activities for any construction projects in Hong Kong such that the general public will not be unduly affected. Under the current control regime, a Construction Noise Permit (CNP) will need to be obtained from the EPD for any percussive piling works to be undertaken for the Project. The CNP to be issued by EPD will include the permitted hours of piling operation as a condition, and may include such other conditions as the Authority considers appropriate, such as the permissible piling methods and pile types which may be used, the area within which percussive piling may take place, and any special noise control measures that must be adopted.

Judging from the predicted airborne noise levels, no adverse noise impact is anticipated from the percussive piling activities for the Project. In addition, stringent statutory controls that are already in place will provide further assurance that noise nuisance will not arise from the percussive piling for the Project.

Underwater Sound

The assessment of underwater sound impacts to NSRs through percussive piling works are presented in *Section 9.7.1* and *10.5.1* of the EIA report. Specifically those sections relate to underwater sound impacts on the following NSRs: marine mammals, specifically the Finless Porpoise (*Neophocaena phocaenoides*), sea turtles, specifically the Green Turtle (*Chelonia mydas*) and fisheries resources. Each of these are discussed in turn below.

Impacts on Finless Porpoise

It is noted within the EIA report that recent studies undertaken by the UK Government's body on Wind Farm Research (COWRIE - Collaborative Offshore Wind Research Into The Environment) have collected measurements of sound levels created during percussive piling for wind turbines on five wind farms throughout the North Sea [(1)]. Source levels during the measured pile driving operations varied between 243 and 257 dB re 1 Pa at 1 metre, having an average value of 250 dB re 1 Pa at 1 metre. Whilst it is acknowledged that the dimensions of the monopiles used in these wind farms range from 4 m to 4.7 m, and hence are likely to be smaller in diameter than those proposed for the wind farm at Southwest Lamma (5 m to 7 m), it is also acknowledged that the seabed in which the UK wind farm piles were driven into consistently composed of compacted sand in shallow water environments (2.5 m to 4 m water depth). According to the pile driving records at the Kentish Flats wind farm in UK, more than 3,000 blows were required to drive the pile to the required level. Compared to the Kentish Flats wind farm in UK, the ground conditions encountered for the proposed offshore wind farm are expected to be much softer and the soft materials are much thicker (the seabed at Southwest Lamma is typically made up of soft mud

(1) R Nedwell J R , Parvin S J, Edwards B, Workman R , Brooker A G and Kynoch J E (2007) Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters. Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0-9554279-5-4.

and silt with a soft alluvium layer down to depths of over 20 m). Therefore, the hammer that will be selected for pile driving at the project site can be at least 20 percent less powerful than those used in the UK wind farm projects. In course of piling, ramping-up procedure will be adopted; as such pile driving will be started off with hammer at a low rated energy (about 30% of the full power) for the first 20 m to 30 m of an estimated total of pile travel of about 80 m. The pile driving duration and noise level that can be generated by a less powerful hammer shall be greatly reduced accordingly. In addition, according to the nature of foundation in need for the proposed wind farm, no final set is required for the pile driving. The designed pile is required to be driven to a designed length. No prolong driving for final set is expected. Noting that lower drive power will result in lower source levels and hence sound propagation, it is considered reasonable to assume that both source levels and sound levels at distances generated from percussive piling activities at the Southwest Lamma wind farm would be comparable to those measured from the UK regardless of the larger pile diameter.

In terms of the assessment of potential impacts to NSRs from underwater sound generated from percussive piling activities, it is important to acknowledge that the measurement of sound must be evaluated for significance. In biological terms this is evaluated in terms of what effects a sound may have and the range in which effects may occur. Such a definition is important as it thus considers the ability for an animal, such as a porpoise, to perceive a sound rather than simply assess the absolute sound. On this basis the review provided by the UK Government uses the metric dB_{ht}, which is a frequency weighting level of sound relative to hearing threshold ($_{ht}$) of individual species.

It is important to note that the dB_{ht} metric is not a unit that can be measured in the field, but rather sounds that are recorded are passed through filters that mimic the hearing ability of a particular species and as such the level of sound measured after the filter is termed dB_{ht} (*Species*) depending on the species it has mimicked. As both the Finless Porpoise (*Neophocaena phocaenoides*) and Harbour Porpoise (*Phocoena phocoena*) typically use high-frequency, narrowband clicks and are ultrasonic specialists with similar hearing capablities [(1)], the dB_{ht} (*Phocoena phocoena*) levels presented in the UK Government Study are appropriate for use for the Finless Porpoise in Hong Kong.

Of the measurements of underwater sound taken during percussive piling operations at the UK wind farms, it is considered that those recorded for the Barrow wind farm may be the most conservative for current assessment purposes. The reason for this is that these levels are typically higher than those recorded for other wind farms due to a larger pile diameter (4.7 m) and deeper water.

On the basis of the various measurements at the Barrow wind farm, the UK Government report states that the area where a mobile Harbour Porpoise may experience an unacceptable

(1) Goold JC & Jefferson TA. 2002. Acoustic signals from free-ranging finless porpoises (*Neophocaena phocaenoides*) in waters around Hong Kong. The Raffles Bulletin of Zoology Supplement 10:131-139

noise dose, i.e. where injury may occur (stated as the $130dB_{ht}$ (*Phocoena phocoena*) sound level), has been calculated to be 84 m from a pile with a Peak-to-Peak Source level of 252dB re 1 Pa at 1 meter. In terms of mitigation and management, therefore, it is commonly recommended that this area be clear of all porpoises during piling works, i.e. act as the exclusion zone. Outside of this area porpoises were expected to show short term behavioural responses to the sounds, such as temporarily moving out of an area while the noise source is present.

Based on an understanding of the above, mitigation and management measures to prevent unacceptable impacts on Finless Porpoises from occurring during percussive piling works for the Southwest Lamma site have been developed. These measures have been prepared with the input of Hong Kong's leading marine mammal expert, Dr Samuel Hung, and have been based on marine mammal survey data gathered during the EIA work as well as the long term dataset held by the Agriculture, Fisheries and Conservation Department (AFCD) which covers the last 14 years and draw reference to measures that have been successfully implemented in Hong Kong in the past.

In the first instance, HK Electric has committed to limiting piling activities to a period outside of the peak, and hence biologically significant season, for the Finless Porpoise in the development area and around southern Lamma. Noting the historical data and upon recommendations by the AFCD, this period has thus been taken as an avoidance of piling works between December through May each year. As such, through committing to only undertake works during a period that is not considered to be the peak season for Finless Porpoises, any porpoises that are present and decide to move away from piling activities will not be adversely affected as this is not considered to be a biologically significant period. Furthermore, studies in Hong Kong have shown that marine mammals returning to areas of percussive piling activities following cessation of works, suggesting that disturbance impacts are transient and only present during the construction phase [(1)].

Although unlikely, it is acknowledged that isolated Finless Porpoises may be present during piling works outside of the biologically significant season and as such, additional mitigation will be applied to ensure adverse impacts do not occur should individuals be present. In this second instance, HK Electric has committed to employing an Exclusion Zone around all piling activities and employing soft-start procedures to promote avoidance of the area by marine mammals when sounds levels are not injurious. Based on such zones successfully employed in Hong Kong previously around percussive piling activities, this area has taken to be a 500 m radius from the pile. This area is considerably larger than that where mobile porpoises were predicted from the UK wind farm experience to have the potential to experience an unacceptable noise dose (84 m). This is thus considered to be both conservative and in line with previously accepted practices in Hong Kong which have shown no change in marine mammal abundance from before or after piling operations through

(1) Wursig B, Greene CR, Jefferson TA. 2000. Development of an air bubble curtain to reduce underwater noise of percussive piling. Marine Environmental Research 49, 79-93.

enforcement of such an exclusion zone [(1)].

If a marine mammal is observed in the exclusion zone, piling will be delayed until they have left the area. This measure will ensure the area in the vicinity of the piling is clear of marine mammals prior to the commencement of works and will serve to reduce any disturbance to marine mammals. When a marine mammal is spotted by qualified personnel [with a degree in biological sciences, prior experience and approved by the Independent Environmental Checker (IEC)] within the exclusion zone, construction works will cease and will not resume until the observer confirms that the zone has been continuously clear of the marine mammal for a period of 30 minutes. This measure will ensure the area in the vicinity of the piling is clear of the marine mammal during works and will serve to reduce any disturbance to marine mammals.

Finally, it is acknowledged that the calculated distances where Finless Porpoises may experience an unacceptable noise dose or demonstrate a temporary behavioural response have been based on field measurements taken for a wind farm in the UK with piles of a smaller diameter than that proposed for the Southwest Lamma wind farm. However, it is considered fair to assume that so long as underwater sounds do not exceed those measured for the UK wind farms (i.e. Peak-to-Peak Source level of 252dB re 1 Pa at 1 meter from the pile), no additional concerns should be present for the percussive piling activities being undertaken for the proposed project. On that basis, HK Electric are committed to undertaking underwater sound measurements as part of the piling activities for the Southwest Lamma wind farm as part of the Environmental Monitoring and Audit (EM&A) Programme.

These measurements will be undertaken as follows:

- Underwater sound measurements will be taken during the installation of the first pile for the wind turbines to be installed for the proposed wind farm;

- Measurements shall be undertaken at 250 m, 500 m and 1,000 m from the piling works, using calibrated hydrophones with calibrated precision amplifiers, analog to digital converters and a high speed data-logging system (with frequency response approximately flat from 100 Hz to 50 kHz). In view that the surface and bottom depth may be affected by potential surface or bottom reflection, the sound measurements shall be measured at a mid depth (or a minimum of 10 m);

- Measurements will record ambient noise level for one hour prior to any pile driving activities, for a minimum period of 30 pile driving blows and for a period of one hour after piling ceases;

(1) ACE-EIA Subcommittee Paper (2005) Permanent Aviation Fuel Facility - Selection of a Bubble Jacket to Attenuate Noise from Underwater Percussive Piling.

- Piling activities must represent those for installation of all piles, such that the equipment to be used during the first pile should match closely to the equipment to be used during the remainder of construction piling; and

- Measurements should be taken at a sampling rate of 100 kHz. Both broadband and one octave bandwidth from 10Hz to 100 kHz shall be measured.

The results of the underwater sound measurements will be provided to the EM&A Programme IEC and EPD to demonstrate that the piling activities do not exceed a Peak-to-Peak Source level of 252dB re 1 Pa at 1 meter from the pile.

Through the above measures, no significant adverse impacts are expected to occur to Finless Porpoises. These can be summarised below:

- No percussive piling activities will occur during the peak season for marine mammals in the development area;

- Marine mammals are not expected to be present in significant numbers during the piling period and hence although individuals may be present and may perceive underwater sound and demonstrate a temporary behavioural response, these waters would not be considered to be biologically significant for this species during the piling period;

- Marine mammal observers will enforce an exclusion zone to ensure the area of water where should a Finless Porpoise be present it may experience an unacceptable noise dose is completely clear of all finless porpoise before piling can commence;

- Soft starts of all piling activities will act as a further deterrent for Finless Porpoises thereby allowing these mobile animals to leave the area;

- All piling works will cease should a Finless Porpoise enter the exclusion zone during piling operations to further prevent any potential for adverse impacts;

- Underwater sound measurements will be undertaken during piling of the first wind turbine foundation to verify that underwater sounds follow those recorded in UK wind farms which have been used to support the design of the mitigation measures; and

- Long term monitoring of marine mammals use of the waters will be collected to provide greater understanding of the use of the waters by Finless Porpoise in Hong Kong and identify any longer term changes.

Impacts on Sea Turtles

As stated in the EIA report (*Section 9.10.1*), there does not appear to be evidence from the literature that construction of offshore wind farms are resulting in adverse behavioural impacts on sea turtles. The Southwest Lamma wind farm site is located some distance from the shore and recorded nesting site at Sham Wan (over 5 km as the crow flies), and the sea turtles are expected to stay relatively close to inshore coastal areas during migration. The wind farm site is therefore not a preferred habitat for sea turtles during migration. The underwater sound generated during percussive piling for wind farm turbines therefore is not expected to cause unacceptable impacts to migrating sea turtles or green turtle nesting site at Sham Wan.

It is considered that the soft-start/ramp-up procedures to be employed during percussive piling works would allow sea turtles sufficient time to avoid close proximity to construction works. In addition, the exclusion zone that will be adopted for marine mammals will also be enforced for sea turtles, hence the 500 m area will be confirmed to be clear of sea turtle prior to piling operations and piling will cease should sea turtles enter this area during piling activities. With the adoption of these mitigation measures, impacts on sea turtles from underwater sound through piling works are expected to be of negligible significance.

Impacts on Fisheries Resources

The impact of underwater sound generation from construction activities on fish is highly dependent upon the hearing capabilities of the different species present in the area, with the hearing specialists being of greatest concern. Effects of increased underwater sound could include physiological stress, avoidance and injury (at high pressure levels). The significance of these effects is dependent upon the proximity of fish to the sound source. The potential for injury will be avoided by adopting appropriate mitigation to promote movement away from the area where works are being undertaken before any injury can occur. Such mitigation, will include, for example, soft-start or ramp-up approaches for piling activity (slowly increasing the energy of the emitted sound) (see *Section 10.7* of the EIA report).

Calculation of airborne noise and underwater noise

We wish to clarify that the data quoted for underwater noise is a sound pressure level but the data used as the noise source term for the calculation of airborne noise impact from percussive piling is a sound power level.

Sound pressure levels are commonly expressed in decibels (dB). A sound pressure level in decibels expresses a ratio between the measured pressure and a reference pressure. Owing to the differences in the behaviour of sound waves in air and in water, the reference pressure values used for the derivation of sound pressure levels in decibels for the two media are

different. A reference pressure level of 20μPa at 1 meter is typically used for sound in air, which is selected to match typical human hearing sensitivity. A different reference pressure level of 1μPa at 1 meter, on the other hand, is typically adopted for sound in water. Because of the differences the reference pressure values, sound pressure levels in air do not equal to those in water (for the same sound source, the value of the former is much lower than that of the latter).

Another important factor relates to the fact that the value of 250dB (re 1μPa at 1 meter) is an unweighted underwater sound pressure level. For describing sound in air, A-weighting is applied to sound pressure levels. The A-weighting corresponds to the human hearing response and puts an emphasis on frequencies in the approximate range of 3 to 6 kHz for which the human ear is most sensitive. Compared with an unweighted sound pressure level, an A-weighted value would have incorporated substantial attenuations for the very low and high frequencies, thereby reflected as a lower value.

For the calculations of percussive piling noise impacts previously provided, the sound power level referenced is published in the PP-TM for typical land-based construction in Hong Kong. The offshore percussive piles for this Project will be driven through much softer materials than those commonly encountered on land, and therefore it is anticipated that the energy required in driving the piles, hence the sound power levels generated will only be less than or equal to that indicated (i.e. 129 dB SWL[1]).

(1) The sound power level of 129 dB adopted for the percussive piling calculations corresponds to a sound pressure level of 121 dB(A), re 20μPa at 1 meter.

Figure 1

Percussive Piling Noise Assessment - Unmitigated Scenario																						
NSR:	N1	Lamma Island - Lo So Shing																				
Distance from NSR to Nearest Noise Source Position						***Correction Factor***																
Distance from NSR to W28			4338	*m*		Distance Attenuation =				*-81*	*dB(A)*		Facade =		*3*	*dB(A)*		Barrier Correction [2]		-10	*dB(A)*
Construction Item																						
ID	Activity																					
I)	**Wind Turbine Foundation Installation**																					
		Total SWL	*129*																			
		Noise Level at NSR (dB(A))	**41**																			
NSR:	N2	Cheung Chau - Seascape Peninsula																				
Distance from NSR to Nearest Noise Source Position						***Correction Factor***																
Distance from NSR to W01			4901	*m*		Distance Attenuation =				*-82*	*dB(A)*		Facade =		*3*	*dB(A)*		Barrier Correction =		0	*dB(A)*
Construction Item																						
ID	Activity																					
I)	**Wind Turbine Foundation Installation**																					
		Total SWL	*129*																			
		Noise Level at NSR (dB(A))	**50**																			
Notes:																						
[1] Distance Correction = $10*\log(2*\pi*r^2)$, assuming hemi-spherical propagation																						
[2] Correction of 10 dB(A) provided where there is no direct line of sight from the NSR to the work site																						

(b) A more detailed construction programme for the detailed design and construction phases.

Further to the indicative schedule for the construction of the offshore wind farm at Southwest Lamma presented in the EIA report (*Section 5.7*), a more detailed schedule is presented in *Figure 2* below. Within this programme, the activities associated with the percussive piling works as well as those period committed to be closed for piling works are presented.

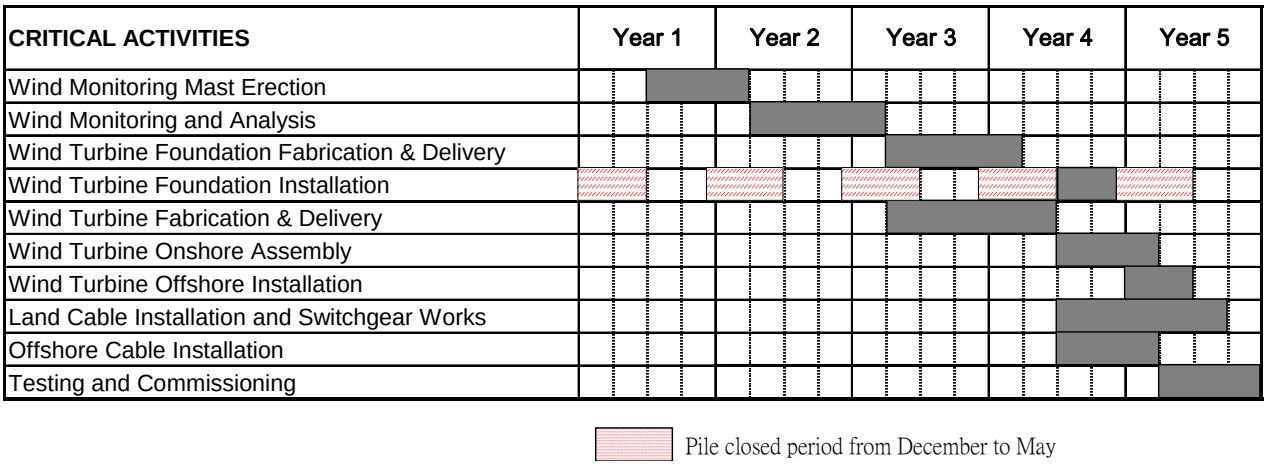

Figure 2: Preliminary Schedule for Design and Construction Works for the Southwest Lamma Wind Farm