APPENDIX D

Noise Impact Assessment for a Proposed 100MW Wind Energy Project, Kajiado District, Kenya

Report Prepared for

Kipeto Energy Limited

March 2012

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March 2012

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1 Introduction

This specialist study assesses the potential noise impacts generated by the proposed Kipeto Wind Energy wind farm development on the noise-sensitive locations near the site. GED Ltd. in association with Mr. Mike Simms, Acoustic Consultant conducted an assessment into the likely noise impact associated with this proposed wind farm during both the construction and operational phases. The noise predictions were calculated for the proposed Kipeto Wind Farm of 68 no. turbines and 53 households.

During the operation of the wind farm, the principal source of noise will be generated by the wind turbines themselves, by the blades rotating in the air (aerodynamic noise) and by internal machinery, and to a lesser extent, the generator (mechanical noise). Calculations in this assessment are based on a 68 turbine layout with each turbine modelled on an 80m hub height and a 100m rotor blade diameter to represent Kipeto. All receptors within 1km (10 rotor diameters) of a proposed turbine are assessed for noise impact. As the prevailing wind direction in this part of Kenya is easterly, it is considered the potential for greatest noise impact is at receptors to the west of the wind farm.

In assessing the noise impact of a wind development on the existing environment, information from the turbine manufacturer on operating noise sound levels is required. In addition, the existing noise levels in the environs of the subject lands must be established. In undertaking a baseline noise survey acoustic data must be correlated with wind speed in order to provide a comprehensive assessment.

1.1 Purpose of the Noise Impact Assessment

The purpose of the noise impact assessment is to quantify the generated noise levels at nearby noise-sensitive locations resulting from the construction and operational phases of the wind farm to ensure compliance with the recommended guidance of Republic of Kenya

The Environmental Management and Coordination (Noise And Excessive Vibration Pollution Control) Regulation, 2008 Arrangements of Regulation as listed on the National Environment Management Authority Kenya (NEMA).

Predictions of worst-case noise levels will be carried out based on the proposed site layout and the manufacturer's guaranteed noise levels for turbines for the site. "Worst-case" noise levels in this instance means that receptors are considered to be downwind of all wind turbines, which clearly cannot happen in practice at all houses simultaneously.

Background monitoring to establish baseline noise levels will be carried out in January 2012 once micro-siting of turbines has been finalised.

1.2 Proposed Development

The proposed development is for a wind farm consisting of 68 no. 1.6MW turbines and all associated development. The dimensions of the proposed turbines are:

- Hub height – 80m
- Blade Length – 50 m

- Rotor Diameter – 100m
- Overall height not exceeding - 130m

1.3 Receiving Environment

Kipeto Energy Limited proposes to develop a 100MW capacity wind farm approximately 18km north-west of Kajiado town in the Rift Valley Province. The proposed project will be undertaken in the Esilanke area, Oloyangani (Kipeto) sub-location, south Keekonyokei location in Kiserian, Kajiado division. The proposed wind farm will be developed on land leased from local land owners; the wind turbines will be sited over a project area measuring approximately 70km^2. A full site description is given in Chapter 2 of the main ESIA Study Report.

1.4 Receptor Survey

A receptor survey was conducted in order to quantify the number of properties within 1km (10 rotor diameters) of the proposed turbines. In total, 53 receptors were found.

1.5 Noise Prediction Model

There are 53 households located within 1km of a proposed turbine (10 rotor diameters). To predict the noise generated at these properties, noise modelling was conducted using WindPRO software, version 2.7.468. Please refer to Appendix 12.1 for detailed results of the prediction model.

The noise prediction model was run using the critical wind speed calculated at 9m/s at 10m. All criteria are based on LA90 levels rather than LAeq: LA90 is the 90th percentile noise level which is exceeded for 90% of the time. As wind turbines will be operating continuously throughout its particular operating range the LA90 level is much more useful in identifying noise which may be attributed directly to the wind farm rather than LAeq which will be affected by short term influences such as a passing car or plane or short-term noise from external influences including wildlife or man-made sources.

The "A" suffix denotes the fact that the sound levels have been "A-weighted" in order to account for the frequency characteristics of human hearing. All sound pressure levels are expressed in terms of decibels (dB) relative to 2x10-5 Pa.

The Noise prediction model implements the International Standard ISO 9613-2, Acoustics – Attenuation of Sound during Propagation Outdoors3. The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on conditions favourable to noise propagation.

The ISO propagation model calculates the predicted sound pressure level by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors according to the following:

Predicted Octave Band Noise Level =

$$L_w + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

These factors are discussed in detail below. The predicted octave band levels from each of the turbines are summed together to give the overall ‘A’ weighted predicted sound level from all the turbines acting together.

1.5.1 L_w - Source Sound Power Level

The proposed development consists of 68 no. GE 1.6MW turbines. The parameters of this turbine type are as follows:

Table 1: Wind Turbine Parameters of the GE 1.6MW Turbine Model

Turbine Elements	*GE 1.6 100*
Rotor diameter	100m
Hub height	80m
Cut-in wind speed	3m/s
Cut-out wind speed	25m/s

The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions for this site have been based on sound power levels of the GE 1.6MW turbine. This assessment is based on warranted sound power levels for this turbine, as indicated in Table 2 below.

Table 2: Wind Turbine Sound Power Levels

Wind Speed at 10m Height (m/s)	*Sound Power Level , dB(A) re 10^{-12}W GE 1.6MW*
3	98
4	100
5	104
6	106
7 and upwards	108

In accordance with the manufacturer’s recommendations, these values include safety factor of 2dB for the purposes of calculating predicted noise levels.

1.5.2 Directivity Factor

The directivity factor allows for an adjustment to be made where the level of sound radiates from the source in a non-uniform manner. In this case the sound power level is measured in a down wind direction, corresponding to the worst case propagation conditions considered here and needs no further adjustment.

1.5.3 A_{geo} – Geometrical Divergence

The geometrical divergence accounts for spherical spreading in the free-field from a point sound source resulting in attenuation depending on distance according to:

$$A_{geo} = 20 \times \log(d) + 11$$

where d = distance from the turbine

Each of the wind turbines may be considered as a point source beyond distances corresponding to one rotor diameter.

1.5.4 A_{atm} – Atmospheric Absorption

Sound propagation through the atmosphere is attenuated by the conversion of the sound energy into heat. This attenuation is dependent on the temperature and relative humidity of the air through which the sound is travelling and is frequency dependent with increasing attenuation towards higher frequencies. The attenuation depends on distance according to:

$$A_{atm} = d \times \alpha$$

where d = distance from the turbine and

α = atmospheric absorption coefficient in dB/m

Values of 'α' from ISO 9613 Part 1, corresponding to a temperature of 15ºC and a relative humidity of 70% have been used for these predictions, which give relatively low levels of atmospheric attenuation and correspondingly worst case noise predictions, as given below.

Table 3: Assumed Octave Band Atmospheric Attenuation Coefficients

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m)	0.0001	0.0004	0.0011	0.0023	0.0041	0.0087	0.0264	0.0937

1.5.5 A_{gr} – Ground Effect

Ground effect is the interference of sound reflected by the ground interfering with the sound propagating directly from source to receiver. The prediction of ground effects is inherently complex and depends on the source height, receiver height, propagation height between the source and receiver and the ground conditions. The ground conditions are described according to a variable G, which varies between 0 for 'hard' ground (includes paving, water, ice, concrete & any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The predictions have been carried out using a source height corresponding to the proposed height of the turbine nacelle, a receiver height of 4 m and an assumed ground factor G = 0.5.

1.5.6 A_{bar} – Barrier Attenuation

The effect of any barrier between the noise source and the receiver position is that noise will be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the ISO 9613 model have, however, been shown to be significantly greater than that measured in practice under down wind conditions. The results of a study of propagation of noise from wind farm sites carried out for ETSU concludes that an attenuation of just 2 dB (A) should be allowed where the direct line of sight between the source and receiver is just interrupted and that 10 dB (A) should be allowed where a barrier lies within 5m of a receiver and provides a significant interruption to the line of sight. It should be noted that no barrier attenuation has been used in any of the noise predictions for this site.

1.5.7 A_{misc} – Miscellaneous Other Effects

ISO 9613 includes effects of propagation through foliage, industrial plant and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

2 Noise Criteria

2.1 Noise in the Environment

Wind farms are generally situated in rural environments where there are few sources of noise. When wind speeds are high, noise tends not to be a problem since any noise generated is masked by wind induced noise effects, particularly that of the trees and vegetation being blown. However, at lower wind speeds or in particular sheltered locations, the wind induced background noise may not be sufficient to mask any noise generated by wind turbines. At these low speeds, the generated noise levels may be so low as to generate very little impact.

Noise levels are normally expressed in decibels. Noise in the environment is measured using the dB(A) scale which includes a correction for the response of the human ear to noises with different frequency content. As a general rule, for noises of the same nature, a change of 3dB(A) is the minimum perceptible under normal conditions, and a change of 10dB(A) corresponds roughly to halving or doubling the loudness level of a sound1.

All measurements are based on LA90 levels rather than LAeq. LA90 is the 90th percentile noise level which is exceeded for 90% of the time. As wind turbines will be operating continuously throughout its particular range the LA90 level is more useful in identifying noise which may be attributed directly to the wind farm rather than LAeq which will be affected by short term influences such as a passing car or localised agricultural activities.

2.2 Construction Phase

The major activities which result in construction noise are the construction of roads, construction of foundations and wind turbine erection. Typical sound levels 10m from construction equipment are found in BS5228:2009 *Code of practice for noise and vibration control on construction and open sites*, presented in Table 4 below.

Table 4: Typical Sound Levels from Construction Equipment

Noise Source	***BS5228 Ref.***	***dB(A) $L_{Aeq,10m}$***
Excavator (22t)	C2.3	78
Dozer	C2.12	81
Dump Truck (tipping fill)	C2.30	79
Roller (rolling fill)	C2.37	79
Concrete Mixer Truck	C4.20	80
Mobile Telescopic Crane	C4.39	77
Mini Tracked Excavator (5t)	C4.68	74

As can be seen, the expected noise levels are below the criteria in Table 12.7.2.1 for weekdays and Saturdays. It should also be noted that most houses are considerably further away from any part of the proposed works and as such the scenario described above is very much a worst case. Additionally, the construction works will progress around the site, thus any construction noise impact on any particular house will be transitory.

2.3 Operational Phase

Noise is generated by wind turbines as they rotate to generate power. This only occurs above the ‘cut-in’ wind speed and below the ‘cut-out’ wind speed. Below the cut-in wind speed there is insufficient strength in the wind to generate efficiently and above the cut-out wind speed the turbine is automatically shut down to prevent any malfunctions from occurring. The cut-in speed at turbine hub height is normally 3m/sec and the cut out wind speed is normally around 25 m/sec at hub height (85m) on the GE 1.6xl turbine model.

The principal sources of noise resulting from wind turbines are:

1. Aerodynamic noise
2. Mechanical noise

2.3.1 Aerodynamic Noise

Aerodynamic noise is caused by blades passing through the air and it is generally broadband in nature which can have a swishing character. This noise is a function of many factors including blade design, rotational speed, and wind speed and inflow turbulence. Aerodynamic noise has been substantially reduced over time due to improvements in turbine design.

As a result, aerodynamic noise is wind speed dependant, and the sound power output from a turbine must be measured and quoted relative to wind speed. The reference sound power output from a turbine is typically provided by the manufacturer over a range of wind speeds.

Careful design of the rotor blades ensures that aerodynamic noise is minimised. Special consideration is given to the blade tips which, due to their relatively high velocities, generate the most noise. Nevertheless, it should be noted that aerodynamic noise is an unavoidable by-product of wind generated electricity. The use of sufficient separation distances is therefore the fundamental design option available to wind farm developers for the control of noise at residential properties.

2.3.2 Mechanical Noise

Mechanical noise is generated by components inside the turbine nacelle (usually the gearbox and generator) and can be radiated by the shell of the nacelle, blades and the tower structure.

Unlike aerodynamic noise, mechanical noise tends to be tonal in nature, i.e. it is concentrated at a few discrete frequencies. Mechanical noise can be successfully controlled at the design stage of the turbine, using advanced gearbox design and anti-vibration techniques. As mentioned above technological developments in engineering practices have in general limited mechanical noise output.

3 Legislation and Guidance

3.1 Kenya

LEGAL NOTICE NO. 61

THE ENVIRONMENTAL MANAGEMENT AND COORDINATION (NOISE AND EXCESSIVE VIBRATION POLLUTION) (CONTROL) REGULATIONS, 2009

FIRST SCHEDULE

(reg. 5, 6(1), 11(1))

MAXIMUM PERMISSIBLE NOISE LEVELS

Zone		*Sound Level Limits dB(A)* *(Leq, 14 h)*		*Noise Rating Level (NR)* *(Leq, 14 h)*	
		Day	Night	Day	Night
A.	Silent Zone	40	35	30	25
B	Places of worship	40	35	30	25
C.	Residential : Indoor Outdoor	45 50	35 35	35 40	25 25
D.	Mixed residential (with some commercial and places of entertainment)	55	35	50	25
E.	Commercial	60	35	55	25

Time Frame

Day: 6.01 a.m. – 8.00 p.m. (Leq, 14 h)
Night: 8.01 p.m. – 6.00 a.m. (Leq, 10h)

The proposed development at Kipeto is on Masai owned land where there are 53 households. These households correspond with the prescribed levels for zone C above which demonstrates sound level limits of 40dB(A)$_{Leq,14\ hr}$ during the day and 35dB(A)$_{Leq14hr}$ at night.

SECOND SCHEDULE

(r. 13(1), 14 (1)(b))

MAXIMUM PERMISSIBLE NOISE LEVELS FOR CONSTRUCTIONS SITES
(Measurement taken within the facility)

Facility		*Maximum Noise Level Permitted (Leq) in dB(A)*	
		Day	Night
(i)	Health facilities, educational institutions, homes for disabled etc.	60	35
(ii)	Residential	60	35
(iii)	Areas other than those prescribed in (i) and (ii)	75	65

Time Frame:

Day: 6.01 a.m. – 6.00 p.m. (Leq, 14 h)
Night: 6.01 p.m. – 6.00 a.m. (Leq, 14 h)

The Second Schedule of the regulations deal with the maximum permissible noise levels for construction sites with (II) pertaining to this assessment. The maximum allowable noise level is 60 Leq dB(A) during the day and 35Leq dB(A) at night.

3.2 UK Guidance

"The Assessment and Rating of Noise from Wind Farms" – ETSU-R-97 September 1996, published by the UK Department of Trade and Industry2

The ETSU-R-97 report was produced by a UK working group on Wind Turbine Noise. The aim of the working group was to provide information and advice to developers and planners on the environmental assessment of noise from wind turbines. The document describes a framework for the measurement of wind farm noise and gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities. The suggested noise limits and their reasonableness have been evaluated with regard to regulating the development of wind energy in the public interest. They have been presented in a manner that makes them a suitable basis for noise-related planning conditions or covenants within an agreement between a developer of a wind farm and the local authority.

The Noise Working group recommends that the fixed limit for night time is 43dB(A). This limit is derived from the 35dB(A) sleep disturbance criteria referred to in planning policy Guidance note (24 PG24). An allowance of 10dB(A) has been made for attenuation through an open window and 2dB subtracted to account for the use of LA90,10min rather than LAeq,10min

ETSU-R-97 document, which also comments, in respect of houses where the occupant has an interest in the development:

… that both day- and night-time lower fixed limits can be increased to 45dB(A) and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm.

The suggested noise limits take into account the fact that all wind turbines exhibit the character of noise described as blade swish to a certain extent. ETSU-R-97 recommends that a penalty should be added, however, to the predicted noise levels, where any tonal component is present. The level of this penalty is related to the level by which any tonal components exceed audibility.

This guidance has been adopted in many countries including Ireland.

3.3 Wind Farm Planning Guidelines 2006 (Ireland)

In general, a lower fixed limit of 45 dB(A) or a maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours. However, in very quiet areas, the use of a margin of 5dB(A) above background noise at nearby noise sensitive properties is not necessary to offer a reasonable degree of protection and may unduly restrict wind energy developments which should be recognised as having wider national and global benefits. Instead, in low noise environments where background noise is less than 30 dB(A), it is recommended that the daytime level of the LA90, 10min of the wind energy development noise be limited to an absolute level within the range of 35-40 dB(A)."

The Guidelines recommend that:

Separate noise limits should apply for day-time and for night-time. During the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. A fixed limit of 43dB(A) will protect sleep inside properties during the night."

The Guidelines consider that noise is considered unlikely to be a significant problem where the distance from the nearest turbine to any noise sensitive property is more than 500 metres. Planning authorities may seek evidence that the type(s) of turbines proposed will use best current engineering practice in terms of noise creation and suppression".

4 Prediction of Likely Noise Impacts

When considering a development of this nature, the potential noise impact on the surroundings must be considered for each of two distinct stages: the short term impact of the construction phase and the longer term impact of the operational phase. Given the nature of this development, it is unlikely that there will be any significant overlap of these phases.

4.1 Construction Phase

A variety of items of plant will be in use, such as excavators, lifting equipment, dumper trucks, compressors, and generators. There will be vehicular movements to and from the site that will make use of existing roads.

Due to the nature of the activities undertaken on a large construction site, there is potential for generation of significant levels of noise. The flow of vehicular traffic to and from a construction site is also a potential source of noise levels. The potential for vibration at neighbouring sensitive locations during construction is typically limited to excavation works and lorry movements on uneven road surfaces. Due to the proximity of sensitive locations to the site access point, the more significant of these is likely to be uneven road surfaces.

Due to the fact that the construction program has been established in outline form only, set out in Chapter 3 of the EIS, it is difficult to calculate the actual magnitude of noise emissions to the local environment. However, Table 12.7.2.2 indicates typical noise levels that would be expected from the proposed construction site during the various phases of the construction project.

For the purposes of the assessment, it is assumed that equipment will be operating at distances in excess of 350m during soil excavation / access track construction and 500m during the foundation/turbine erection/general construction phases from non-involved properties in the vicinity of the proposed development.

4.2 Predicted Noise Levels during Operational Phase

Noise levels for 53 households in the vicinity of the site were predicted for this wind speed. The results are re-produced in Appendix 12.1 below. It should be noted that these predictions represent downwind propagation in all directions, which clearly cannot happen at all locations simultaneously.

The lower fixed noise level limit is 43dB LA90 for non-involved houses and the lower fixed noise level limit for involved houses is 45dB LA90.

The predicted noise levels lie within the adopted criteria in all cases. The noise impact of the wind farm is considered acceptable.

4.3 Conclusions

The environmental noise impact of the proposed wind farm at Kipeto has been analysed and shown to be generally within the criteria in the *ETSU-97* at the noise survey locations.

5 Proposed Mitigation Measures for Noise Impacts

5.1 Mitigation measures – Construction Phase

Construction activities will give rise to noise on site from the increased traffic as well as the construction activity. The second schedule of the 2009 regulations deal with the maximum permissible levels of noise allowed due to construction activities.

To ensure that construction noise remains below "nuisance" levels, reference is made to BS 5228: Part 1: 1997 (Noise Control on Construction and Open Sites – Part 1. Codes of Practice for Basic Information and Procedures for Noise Control) which offers detailed guidance on the control of noise from demolition and construction activities.

Accordingly, all construction traffic to be used on site should:

- Have effective well-maintained silencers.
- Operators of all mobile equipment will be instructed to avoid unnecessary revving of machinery.
- Where possible the contractor will be instructed to use the least noisy equipment.
- With efficient use of well-maintained mobile equipment considerably lower noise levels than those predicted can be attained.
- The Project Engineer will closely supervise all construction activity.
- Construction activity due to its nature is a temporary activity and thus any impacts will be short term typically 6-12 months.

The following mitigation measures for control of construction noise will be implemented, as recommended in BS 5228: Part 1:1997

- The hours of construction activity will be limited to between 08.00 hours and 20.00 hours Monday to Friday and 08.00 hours and 18.00 hours on Saturdays. It should be noted that it may be necessary to commence turbine base concrete pours from 06.00 due to time constraints incurred by the concrete curing process. Additional emergency works may also be required outside of normal working hours as quoted above.
- Communication links will be established and maintained between the developer, contractor, Local Authority and local residents.
- Equipment and technology with generation of low noise levels will be selected where possible.
- Noise generating equipment will be located as far as possible away from local noise sensitive areas identified.
- In the unlikely event that irregularities or complaints arise, the source of the problem will be sought and dealt with.
- Temporary barriers or screens can be erected if necessary around noisy equipment such as generators and compressors.

5.2 Mitigation Measures – Operational Phase

Mitigation against noise from the proposed development consists of the following measures:

- Site layout design to ensure minimal disruption to sensitive receptors
- It is recommended that, additional post development noise monitoring in accordance with international noise standards in particular ISO 1996: "Description and measurement of environmental noise" be carried out to monitor accurately the acoustic impact of development according to site atmospheric conditions and corrected for background speeds at any potentially sensitive locations.

Mitigation measures have already been put in place by siting the wind turbines in an appropriate position to cause the minimum impact at the nearest noise sensitive location and also by choosing a turbine size that is appropriate to the demands of power generation and noise impact.

A warranty agreement will be drawn up with the manufacturer of the turbines for this site to ensure that the noise output will not contain any significant audible tones.

6 References

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2. ETSU-R-97: UK Department of Trade and Industry, 1996. The Assessment and Rating of Noise from Wind Farms.
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5. The Environmental Management and Coordination (Noise and Excessive Vibration Pollution) (Control) Regulations, 2009 www.nema.go.ke