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AES SONEL

KRIBI POWER PROJECT
150MW Gas Plant
& 225 kV Transmission Line
Environmental and Social Impact Assessment Report
Addendum Relating to Gas Reciprocating Engines

October 2007

Report Control Form

Document Title	Kribi Power Project 150 MW Gas Plant & 225 kV Transmission Line Environmental and Social Impact Assessment Report Addendum Relating to Gas Reciprocating Engines		
Client Name & Address	AES SONEL Avenue de Gaulle B.P. 4077 Douala Cameroon		
Document Reference	D117681/R17422	**Status & Issue No.**	Status **Final**
Issue Date	**October 2007**		
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INTRODUCTION

The Ministry of Environment and Protection of Nature formally approved the Environmental and Social Impact Assessment (ESIA) Report (Scott Wilson, October 2006) for the Kribi Power Project on 5 April 2007 (see Appendix 1). However, this approval was subject to correction of minor mistakes, inclusion of the Pygmies in the study and the inclusion of data on natural gas composition.

This addendum to the ESIA Report has therefore been produced to include this data and to assess the potential significance of air quality impacts. In addition, this addendum takes into consideration the following revisions to the Plant design since the preparation of the ESIA report:

- The use of nine reciprocating engines in the place of the four gas turbines assessed within the ESIA; and
- The movement of the plant site approximately 200 m to the east of the location assessed within the ESIA. This places the proposed power plant further from the road and the adjacent village of Mpolongwe.

The layout and format of this Addendum is consistent with the Air Quality chapter contained within the main body of the ESIA Report (Scott Wilson, October 2006). The text has been updated where relevant to account for the revisions listed above.

5.3 AIR QUALITY

This section discusses the current and future ambient air quality in the airshed around the proposed power plant and transmission line route. The potential effects on air quality are considered with regard to World Bank ambient air quality guidelines.

A qualitative assessment has been made of the potential impacts of fugitive releases of dust around the proposed plant site and transmission line route during the construction phase of the project. Operational emissions from the power plant stacks have been modelled to evaluate the proposed stack height and determine the magnitude of the change in air quality statistics of nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and fine particulate matter (PM_{10}) in the area around the proposed plant.

5.3.1 Baseline Conditions

There is no existing large-scale industrial developments or other major point sources of emissions in the vicinity of the proposed power plant. The main local sources of combustion emissions are the nearby Kribi to Edéa main road and domestic emissions from local housing. Traffic travelling along the main road is light, averaging between 400 and 450 vehicles per day. Traffic and domestic emissions are unlikely to be significant.

The transmission line follows the route of the Kribi to Edéa main road and passes through an area that is predominantly rural in character. Baseline pollutant levels are likely to be similar to those in Mpolongwe. There is however a large aluminium smelter, located adjacent to and powered by, the Edéa hydroelectric facility. This is the only major potential air pollution source within the vicinity of the project footprint, but it affects only the zone of the termination of the power transmission line at the Edéa substation.

Cameroon does not have a systematic network of air quality monitoring stations, therefore there are no readily available sources of baseline air quality data for the Kribi area. A diffusion tube survey at two sites adjacent to the proposed plant site (see Figure 5.3.1), to establish indicative background levels of NO_2, SO_2 and ozone (O_3), has therefore been carried out as part of this assessment. Monitoring took place between April and June 2006. The results of the monitoring exercise are presented in Table 5.3.1.

Table 5.3.1: Background Pollutant Concentrations ($\mu g/m^3$) (revised)

Pollutant	Site 1: Mean Background Concentration ($\mu g/m^3$)	Site 2: Mean Background Concentration ($\mu g/m^3$)	Average ($\mu g/m^3$)
NO_2	1.2	0.8	1.0
SO_2	1.4	1.5	1.5
O_3	33.8	44.1	39.0

Note: This table has been updated to include monitoring results not available at the time of preparation of the original ESIA report.

For evaluation purposes these concentrations are compared to the World Bank Standards, as set out in Table 5.3.2.

Table 5.3.2: World Bank Air Quality Guideline Values		
	Reference Period	**Recommended maximum ground level concentration values (µg/m³)**
NO_2	24 hour average	150
	Annual average	100
SO_2	24 hour average	150
	Annual average	80
Total Suspended Particulate	24 hour average	230
	Annual average	80
PM_{10}	24 hour average	150
	Annual average	50

The World Health Organisation (WHO) have also published air quality guidelines, these are listed in Table 5.3.3. The limits are broadly similar to EU Limit Values and are not mandatory. The WHO guideline values have been set at a level that provides protection of human health for all members of the public.

Table 5.3.3: WHO Air Quality Guideline Values		
	Reference Period	**Recommended maximum ground level concentration values (µg/m³)**
NO_2	1-hour average	200
	Annual average	40
SO_2	10-minute average	500
	24-hour average	125
	Annual average	50

As is shown, background concentrations in Table 5.3.1 of NO_2 and SO_2 are far below both World Bank and WHO guideline values, reflecting the very low level of current emissions of these pollutants in the area around the proposed site. Background levels of ozone are typical of equatorial latitudes. The photochemistry of the region is limited by low levels of NO_2 and as a result minor emissions of nitric oxide would be rapidly converted to nitrogen dioxide. However, more significant emissions of nitric oxide would be converted into nitrogen dioxide as the plume disperses downwind. Measured concentrations of oxides of nitrogen would be composed of nitric oxide and nitrogen dioxide in varying proportions at any given distance from the source.

Overall, baseline air quality in the vicinity of the proposed plant site and transmission line route is good but with some possible deterioration within Edéa.

5.3.2 Potential Impacts

Potential significant air quality impacts from the proposed development relate primarily to point source gaseous emissions from the power plant stacks during operations. However, short-term local impacts may arise from fugitive dust and gaseous emissions from plant and vehicles during the construction phase.

The main impacts include:

Construction

- *Exhaust fumes* from construction traffic and plant at the plant site and along the transmission line route.
- *Dust generation* from construction activity and construction vehicle movements across unsurfaced roads and cleared sites areas;

Operation

- *Power Plant Emissions* from power generation plant stacks arising from the burning of the main fuel source (gas) and short-term stack emissions arising from the burning of back up fuels (diesel) during any shut down period of the gas supply.

Exhaust fumes

Construction

The anticipated volumes of construction traffic and plant activity will represent a large increase over current traffic movements on the Edéa / Kribi road (see Section 5.7). However, overall traffic flows are relatively low. Therefore the impact of additional vehicle emissions during the construction phase on air quality, taking into account very low levels of baseline air pollution, would be insignificant. This impact is not therefore assessed further within the ESIA.

Operation

Traffic volumes during the operational phase are very low (see Section 5.7) and therefore no air quality impacts will arise from this source. This impact is not therefore assessed further within the ESIA.

Dust Generation

Construction

The primary potential air quality impact arising from the construction phase is dust generated from construction activity and the movement of construction vehicles on unsurfaced areas.

Site preparation, construction works and the movement of site vehicles can generate dust emissions. Dust is particulate matter in the size range 1-75 micrometres (µm) in diameter, and is produced through the action of abrasive forces on materials. Fine particulate matter (PM_{10}) is defined as particles less than 10 µm in diameter, and is of the most concern regarding health effects. Construction dust is generally larger in diameter than 10 µm and, therefore, does not necessarily increase existing levels of PM_{10} considerably. Particles between 10 and 75 µm in diameter are not typically associated with adverse effects on human health, their main potential effects being the soiling of surfaces. (Soiling is the cumulative deposition of airborne particles on to a surface.)

During the construction of the power plant and transmission line, some activities would have potential to generate emissions of fugitive dust. These include:

- vehicle movements on unsurfaced areas;
- land clearance to remove vegetation from construction areas and excavation;
- land levelling and grading of the site and access road route;
- the storage on site of surplus excavation materials and dusty building materials;
- construction of site buildings and installation of plant and equipment;
- clearance of the wayleave and access tracks, plus excavation for and placement of concrete pads along the transmission line route.

In the wet season it is likely that the regular and intense rainfall in the area would significantly reduce the frequency and severity of impacts from to dust generated by the works, by maintaining a high level of moisture within exposed soils and by washing deposited material from surfaces.

At the present time there are no statutory World Bank or EU standards relating to either ambient concentrations of airborne dust or to rates of surface soiling by dust particles. The emphasis of the control of construction dust should be the adoption of best practices on site. However, where mitigation measures are employed any residual dispersion of dust off-site would not have the potential to significantly impact on local residents.

Operation

There will be minimal maintenance activities during the operational phase that will generate fugitive dust at the plant and during wayleave maintenance. These will only entail one or two vehicles movements every few months there will be no significant air quality impacts arising from this source. This impact is not therefore assessed further within the ESIA.

Power Plant Emissions

This is purely an operational impact, as the power plant will not be functioning during the construction phase.

The main air quality impact during the operation of the proposed power plant will be emissions to air from the combustion of fuel within the gas engines. The primary fuel for the plant will be natural gas from the Sanaga Sud gas field. However, it is not planned to build a gas storage facility at the proposed power plant site, therefore it is intended to fire the plant with diesel oil during periods when the gas supply is interrupted.

Emissions to air from the burning of natural gas and diesel will include carbon dioxide (CO_2), oxides of nitrogen (NOx), SO_2, and particulate matter, a proportion of which will be PM_{10}. The particulate matter emitted to atmosphere may include small quantities of trace metals.

There are currently no national limits for emissions from power plants in Cameroon. Therefore emission guidelines for the new thermal power plants burning fossil fuels, as detailed in the World Bank Pollution Prevention and Abatement Handbook; 1998, are employed in the design of the plant. The appropriate emission standards relating to the proposed plant are detailed in Table 5.3.4.

Table 5.3.4: World Bank Emission Guidelines for New Thermal Power Plants (Engine Plants)

	Emission Guideline (mg/Nm³)	
Fuel	Natural Gas	Diesel
Particulate Matter	50	50
SO_2	0.2 metric tonnes/day/mw or 2000 mg/Nm³	0.2 metric tonnes/day/mw or 2000 mg/Nm³
NO_x	2000	2000

Reference conditions: 15% O2, dry.

An assessment of the potential impacts has been undertaken through an air quality modelling exercise. This assessment is based on the revised power plant configuration consisting of nine Wartsila 18V50DF reciprocating engines as opposed to the originally proposed four GE Frame 6B gas turbines fitted with dry low NO_x (DLN) combustors. Discharge to atmosphere from the plant occurs via nine stacks, one for each power unit.

Model Scenarios

The load profile for the power station in the rainy season is expected to be a base load of 40 to 50 MW, with a peak output of 150 MW lasting for 4 hours per day. However, during the dry season, when production from hydro plant is limited due to low water regulated flows, the plant is expected to run continuously at full load. The emissions from the proposed plant have therefore been modelled on a worst-case basis, with the plant assumed to be operating on natural gas at continuous 100% output.

The plant may burn diesel at typically 30% continuous load for twenty hours per day and up to 100% output for four hours per day, for around 8 days per year. This would occur during periods of interrupted gas supply. A consideration of the possible worst-case short-term impact of operating the plant in this way has been made by modelling NO_x, SO_2 and PM_{10} emissions from the power station at 100% output when burning light fuel oil (diesel/heating oil), enabling 1-hour / 24-hour maximum NO_2, 10-minute / 24-hour maximum SO_2 and 24 hour PM_{10} concentrations to be predicted in the vicinity of the closest sensitive receptors. Long-term statistics have not been modelled as the plant would only burn diesel fuel for short periods of time and not throughout the year.

A summary of the revised emissions modelled is provided in Table 5.3.5.

Table 5.3.5: Engine Emission Data (revised)

Scenario	100% load (natural gas)	100% load (No. 2 distillate)	Notes
Stack Internal Diameter (m)	1.6	1.6	
Exit Velocity (m/s)	25.8	30.3	Calculated, based on supplied volumetric flow rates (actual).
Stack Exit Temperature (K)	648	643	
CO emission rate (g/s)[1]	5.7	4.8	-
NO_x emission rate (g/s)[1]	11.4	69.0	Calculated as NO_2
SO_2 emission rate (g/s)[1]	0.4	10.4	
PM_{10} emission rate (g/s)[1]	0.3	1.1	As total dry particulate dust, assumed to be PM_{10}

[1] *Emission rates are per engine stack; there are 9 stacks in total.*

The effect of stack height on ground level concentrations of the pollutants emitted has been evaluated as part of the sensitivity analysis, by running AERMOD with stack heights of 20 (proposed stack height), 22.5, 25, 27.5 and 30 metres. Annual mean ground level concentrations are compared with the air quality guidelines in Tables 5.3.2 and 5.3.3.

The air quality impacts on the surrounding area resulting from the operation of the proposed plant, as calculated by the dispersion model, are combined with existing ambient air quality statistics and compared with the assessment criteria to establish the significance of effects.

Hazardous Air Pollutant (HAP) Emissions

The emission of unburned hydrocarbons and NO_x may contribute to the formation of ground level O_3. Reactive plume modelling would be required to assess the impact of these pollutants in forming O_3. No such modelling has been performed as part of this assessment, as there is limited potential for the proposed plant to significantly effect local or regional ground level O_3 concentrations.

Dispersion Model Selection

The air quality impacts of the proposed power plant are best evaluated using a refined, near-field (less than 50 km from the emission source) Gaussian Plume Dispersion Model, which is able to calculate maximum ground level concentrations at receptors close to the plant boundary. Gaussian models assume that pollutants do not decompose in the atmosphere, and therefore do not account for the long-range transport of atmospherically reactive pollutants. They are designed to produce results that are close to monitored values.

The assessment has been undertaken using the US EPA preferred model AERMOD, developed by the American Meteorological Society and U.S. Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC). AERMOD is an advanced plume model that incorporates the latest understanding of the atmospheric boundary layer, and includes the PRIME downwash algorithm for the assessment of structure effects.

In addition to AERMOD, there are two input data processors that make up the regulatory components of the modelling system. AERMET is a meteorological data pre-processor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, while AERMAP is a terrain data pre-processor that allows the incorporation of complex terrain effects within the model.

During its development, AERMOD has undergone a number of validation studies, the most recent of which was published in 2003. Comparisons with the previous ISC-PRIME model show similar results for most databases, with occasional notable improvements.

This assessment has used the latest version (5.7.0) of the software package ISC-AERMOD View, produced by Lakes Environmental Software.

Terrain Data

The area around the proposed plant location is gently undulating at an altitude of 10 m to 20 m above sea level. The land between the stacks and the receptors does not slope sufficiently to justify the consideration of terrain effects within the model, and for the purposes of this assessment the terrain has been regarded as flat or simple terrain.

Building Downwash Effects

Nearby buildings and structures have the potential to effect the dispersion of emissions from the plant stacks. As the wind blows over and around these buildings the airflow will be disrupted and pollutants may become entrained within the eddy (cavity) near to the building or within the associated zone of turbulent air (wake), resulting in higher near-field ground level concentrations.

The engine house building on the proposed site is likely to be the most significant source of building downwash on the site, due to its size and proximity to the power plant stacks. The dimensions of this building have been entered into the model and the BPIP-PRIME downwash model run to supply AERMOD with downwash data. Building Downwash effects have therefore been considered within the model.

Meteorological Data

Discussions were held with the UK Met Office, to establish the most representative source of meteorological data for use in the dispersion modelling assessment. Three options were considered:

- Kribi (WMO reference 64971);
- Douala (WMO 64910) 165 km to the north;
- Libreville in Gabon (WMO 64500), 230 km to the south.

All three sites are close to the coast and experience similar meteorological conditions.

Ideally hourly sequential meteorological data is used for dispersion modelling purposes, however in this case this has not been possible. Of the three sites considered, none collect readings on an hourly basis. Libreville data is 3-hourly, while Kribi and Douala report on a 6-hourly basis. For this reason, data from Libreville for the years 2003 to 2005 has been recommended and supplied by the UK Met Office as the most appropriate for use in dispersion modelling for this assessment. Additionally, the Libreville site also has a higher data coverage rate than the other two locations.

The data was supplied in ADMS format, and was converted to SAMSON format using the built-in converter within AERMET. The data was then pre-processed in AERMET, using the input variables in Table 5.3.6.

Table 5.3.6: AERMET Input Data

Parameter	Variable
Station Location	0.50°N 9.41°W
Site Location	2.57°N 9.56°W
Upper Air Data	Upper Air Estimator within AERMET
Wind Direction Sectors	1
Surface Parameters	Albedo: 0.215 Bowen: 0.875 Surface Roughness: 1.3
Anemometer Height	10 m

Receptors

The closest sensitive receptors are located in the village of Mpolongwe, to the north and northwest of the proposed plant. With the revised plant layout the closest existing receptors are approximately 350 m away, as oppose to 115 m originally envisaged, however these dwellings are expected to be relocated (see Section 6) and have been assessed separately in the Resettlement Action Plan for the Project (Scott Wilson, October 2007). The closest receptors during plant operations would therefore be residential properties 410 m from the plant boundary, as oppose to 170 m in the original assessment.

Ground level concentrations of the pollutants modelled have been calculated using a site-centred polar grid at 10° radial increments, with 20 m distance increments from the origin up to 1 km, then 250 m increments up to 4 km and thereafter at 500 m increments up to 10 km. Grid nodes inside the plant boundary have not been modelled.

Additionally, the change in air quality statistics at selected residential properties within Mpolongwe has been considered by including their locations as discrete receptors. Each receptor represents the level of exposure that would also be experienced at other receptors in their vicinity. The location of each discrete receptor is illustrated in Figure 5.3.1, and listed in Table 5.3.7. The x and y coordinates listed are specific to the modelled grid and do not necessarily relate directly to national or international co-ordinate systems. The concentration of pollutant at each receptor was modelled at a height of 1 m above ground level.

Table 5.3.7: List of Discrete Receptors (Revised)					
Receptor	X Coordinate	Y Coordinate	Receptor	X Coordinate	Y Coordinate
R1	608099	334758	R6	608070	334872
R2	607992	334729	R7	608104	334921
R3	607940	334613	R8	608207	334942
R4	607946	334789	R9	607974	334439
R5	607995	334859	R10	607960	334378
The location of receptors have been revised to reflect the revised plant location					

NO_x to NO_2 conversion

NO_x emissions from the power plant will consist of both NO and NO_2, however NO_2 is of the most concern regarding health effects. At the point of emission into the atmosphere NO will be the predominant species, around 95% of NO_x produced by combustion is NO. In rural areas, with low background levels of pollution, oxidation to NO_2 will rapidly occur in the presence of O_3.

As shown in Table 5.3.1, background concentrations of O_3 in the region are relatively high. It can be assumed, therefore, that the conversion of NO to NO_2 would not be O_3 limited at extended distances from the emission point. However, as the selected sensitive receptors in Mpolongwe are within 1 km of the proposed plant, an estimate of how much NO has been converted to NO_2 at these locations has been made using the NO_x to NO_2 conversion module in AERMOD. The model was set to use the OLM (Ozone Limiting Method), the ratio of NO/NO_2 in the plant stacks was assumed as 0.95/0.05 and the ambient O_3 concentration in the atmosphere around the plant was assumed to be a constant 39 $\mu g/m^3$ (value taken from Table 5.3.1).

Sensitivity Analysis

The results of the sensitivity analysis are presented in Tables 5.3.8 to 5.3.10.

Air quality statistics have been calculated for all pollutants using meteorological measurements for three different years: 2003, 2004 and 2005. The results for NO_2 are represented in Table 5.3.8. As expected the model proved sensitive to differences in meteorological conditions, with each dataset returning different predicted pollutant concentrations than the other years. By including three years of meteorological data in the assessment it is likely that worst-case conditions for atmospheric dispersion have been considered in the assessment of mitigated impacts.

The importance of stack height has been considered for an option of 20 m for the height of release and variants of 22.5 m, 25 m, 27.5 m and 30 m (see Table 5.3.9)[1]. The diameter of the release, volumetric flow rate, velocity of release and the temperature of the exhaust gases was the same for each model run. The model predicted impacts on local air quality with a 20 m stack that would achieve World Bank criteria at all sensitive receptors. The WHO hourly standard value for NO_2 would only be achievable at the selected receptors with a stack height in excess of 30 m, however WHO ambient air quality guidelines are not mandatory.

[1] *Note the Stack height has been amended from the original ESIA report from 22.5 m to 20 m.*

The model returned a proportional worsening in the effectiveness of pollutant dispersion for a lower stack. Advanced dispersion models are not designed to model the dispersion of plumes through the structure of forests and as the forest canopy is understood to approach 20 m in height, this value has been adopted as the minimum stack height. A height of 20 m has been used for the main assessment as opposed to 22.5 m in the original assessment.

The terrain surrounding the site is largely forested by broad-leaved trees and the effect of turbulent mixing in the airflow over this surface has been represented in the assessment of impacts through the use of a surface roughness coefficient of 1.3. As there is some uncertainty as to the density and structure of the forest an alternative average surface roughness value for broad-leaved forest of 0.9 was also considered. Overall the model generally predicted (see Table 5.3.10) impacts of greater magnitude when the higher roughness coefficient of 1.3 was used.

Overall the model has demonstrated it's sensitivity to model conditions and in each case the worst-case option has been selected for use in the assessment.

Table 5.3.8: Effect of Meteorological Data Year on Maximum 24-hour NO_2 Concentrations (revised)

Receptor	Year		
	2003	2004	2005
R1	21.2	20.6	19.6
R2	19.5	18.3	18.8
R3	34.5	19.2	20.4
R4	15.3	15.9	16.8
R5	14.3	15.8	18.1
R6	19.7	20.5	24.2
R7	27.5	23.8	27.5
R8	39.0	32.7	25.1
R9	32.3	28.9	19.9
R10	22.6	35.8	21.5
Maximum	*103.2*	*102.7*	*101.0*

Table 5.3.9: Effect of Stack Height on Maximum 24-hour NO_2 Concentrations (revised)

Receptor	20 m Stack			22.5 m Stack			25 m Stack			27.5 m Stack			30 m Stack		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
R1	21.2	20.6	19.6	19.5	18.0	19.0	17.3	17.7	18.9	15.8	18.8	18.9	17.0	18.2	17.6
R2	19.5	18.3	18.8	18.1	16.5	18.3	17.9	16.1	17.2	16.3	16.8	17.2	15.8	16.4	16.2
R3	34.5	19.2	20.4	31.6	17.9	19.1	31.5	16.4	16.0	28.0	15.0	16.0	29.6	16.0	16.9
R4	15.3	15.9	16.8	14.5	14.7	16.6	13.5	14.3	16.5	12.6	14.8	16.5	13.0	14.6	15.8
R5	14.3	15.8	18.1	13.4	15.3	16.7	12.5	14.7	15.7	11.9	14.1	15.7	12.2	13.5	15.0
R6	19.7	20.5	24.2	18.3	19.6	22.4	16.9	18.6	19.1	15.6	17.7	19.1	14.3	16.7	17.5
R7	27.5	23.8	27.5	25.7	22.8	25.7	24.1	21.7	22.2	22.4	20.6	22.2	20.7	19.5	20.6
R8	39.0	32.7	25.1	38.7	30.8	23.5	36.7	30.2	20.2	36.5	28.2	20.2	34.8	26.3	18.7
R9	32.3	28.9	19.9	30.5	26.4	19.2	28.9	23.2	16.7	26.3	22.3	16.7	27.1	20.4	18.1
R10	22.6	35.8	21.5	21.5	34.0	20.3	20.2	31.4	18.1	18.9	30.3	18.1	18.6	28.1	17.1
Maximum	*103.2*	*102.7*	*101.0*	*94.9*	*101.0*	*91.7*	*88.4*	*98.7*	*87.9*	*84.7*	*92.6*	*75.8*	*76.3*	*88.8*	*70.1*

Table 5.3.10: Effect of Surface Roughness on Maximum 24-hour NO_2 Concentrations

Receptor	Surface Roughness = 0.9			Surface Roughness = 1.3		
	2003	2004	2005	2003	2004	2005
R1	21.0	20.6	16.1	21.2	20.6	19.6
R2	21.2	19.4	16.1	19.5	18.3	18.8
R3	33.4	20.4	21.2	34.5	19.2	20.4
R4	17.8	18.0	15.7	15.3	15.9	16.8
R5	16.9	15.1	14.7	14.3	15.8	18.1
R6	14.6	16.8	15.8	19.7	20.5	24.2
R7	14.0	19.0	17.2	27.5	23.8	27.5
R8	33.9	25.4	15.7	39.0	32.7	25.1
R9	27.9	20.4	20.6	32.3	28.9	19.9
R10	21.0	28.9	18.9	22.6	35.8	21.5
Maximum	95.6	87.7	*92.0*	*103.2*	*102.7*	*101.0*

Dispersion Modelling Results

The revised results of the dispersion modelling with emissions data for the power station burning natural gas are presented in Tables 5.3.11 to 5.3.13. The values in Tables 5.3.11 and 5.3.12 include the contribution from background concentrations of NO_2 and SO_2 respectively. In addition the spatial distribution of the contribution of the plant's emissions to annual mean concentrations of each pollutant are illustrated for oxides of nitrogen in Figures 5.3.2a-c, for sulphur dioxide in Figures 5.3.3a-c.and for fine particulate matter in Figures 5.3.4a-c.

Table 5.3.11: Dispersion Modelling Results, Natural Gas Fuel, NO_2 (revised)

Receptor	1-hour average (µg/m³)			24-hour average (µg/m³)			Annual average (µg/m³)		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
R1	355.5	346.9	327.6	21.2	20.6	19.6	5.5	6.2	5.9
R2	315.8	306.6	321.7	19.5	18.3	18.8	4.9	4.9	5.4
R3	352.7	326.0	342.6	34.5	19.2	20.4	6.1	4.6	6.2
R4	244.2	264.7	279.9	15.3	15.9	16.8	4.6	4.9	5.1
R5	232.4	263.7	264.3	14.3	15.8	18.1	5.0	5.9	5.7
R6	209.9	327.9	317.8	19.7	20.5	24.2	6.2	7.2	6.5
R7	257.6	327.8	333.1	27.5	23.8	27.5	8.2	8.6	7.3
R8	323.3	310.9	341.3	39.0	32.7	25.1	14.4	12.8	9.6
R9	332.7	355.4	330.2	32.3	28.9	19.9	6.5	5.2	6.4
R10	341.3	357.5	356.6	22.6	35.8	21.5	5.7	5.0	5.8
WB Standard (µg/m³)	**-**			**150**			**100**		
WHO Guideline (µg/m³)	200			-			40		

Table 5.3.12: Dispersion Modelling Results, Natural Gas Fuel, SO_2 (revised)

Receptor	10 minute average (μg/m³)*			24-hour average (μg/m³)			Annual average (μg/m³)		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
R1	18.1	17.3	16.6	2.2	2.2	2.2	1.7	1.7	1.7
R2	15.9	15.4	16.1	2.2	2.1	2.1	1.6	1.6	1.7
R3	17.9	16.3	17.2	2.7	2.1	2.2	1.7	1.6	1.7
R4	12.6	13.5	14.2	2.0	2.0	2.1	1.6	1.6	1.6
R5	12.1	13.5	13.5	2.0	2.0	2.1	1.6	1.7	1.7
R6	11.0	16.4	16.0	2.2	2.2	2.3	1.7	1.7	1.7
R7	13.2	16.4	16.6	2.4	2.3	2.4	1.8	1.8	1.7
R8	16.2	15.6	17.1	2.8	2.6	2.3	2.0	1.9	1.8
R9	16.8	19.3	16.5	2.6	2.5	2.2	1.7	1.6	1.7
R10	17.2	19.8	19.1	2.3	2.8	2.3	1.7	1.6	1.7
WB Standard (μg/m³)	-			**150**			**80**		
WHO Guideline (μg/m³)	500			125			50		

**Derived from 1-hour averages, correction factor of 1.3 applied.*

Table 5.3.13: Dispersion Modelling Results, PM_{10} (revised)

Receptor	24-hour average (µg/m³)			Annual average (µg/m³)		
	2003	2004	2005	2003	2004	2005
R1	0.5	0.5	0.5	0.1	0.1	0.1
R2	0.5	0.5	0.5	0.1	0.1	0.1
R3	0.9	0.5	0.5	0.1	0.1	0.1
R4	0.4	0.4	0.4	0.1	0.1	0.1
R5	0.3	0.4	0.4	0.1	0.1	0.1
R6	0.5	0.5	0.6	0.1	0.2	0.1
R7	0.7	0.6	0.7	0.2	0.2	0.2
R8	1.0	0.8	0.6	0.4	0.3	0.2
R9	0.8	0.8	0.5	0.1	0.1	0.1
R10	0.6	1.0	0.6	0.1	0.1	0.1
WB Standard (µg/m³)	**150**			**50**		
WHO Guideline (µg/m³)	-			-		

Predicted Impacts - Natural Gas Fuel

For each pollutant it is evident that the maximum impact occurs to the North East of the plant and that impacts to the west of the site are lower in magnitude. The largest emissions for a locally important pollutant are those of oxides of nitrogen and these disperse to raise annual mean concentrations of nitrogen dioxide at discrete receptors by between 3.6 and 13.4 µg/m³ above baseline levels. This represents a range of 4% - 13% of the World Bank criteria of 100 µg/m³ and 9% - 34% of the WHO Guideline value of 40 µg/m³. The predicted impact on levels of fine particulate matter and sulphur dioxide at discrete receptors achieve the respective threshold values by a very large margin.

Annual mean concentrations of NO_2 in excess of the World Bank Standard are predicted to occur at or in very close proximity to the site boundary. Such impacts are not representative of the level of exposure that would be experienced at air quality sensitive receptor sites.

The magnitude of short term impacts have also been predicted at selected receptors located close to the Plant. Maximum 24-hour impacts in the range of 13.3 to 38.0 µg/m³ for NO_2 were predicted. This represents between 9 % and 25% of the World Bank Standard for 24-hour NO_2 concentrations of 150 µg/m³. As with annual average NO_2 impacts, 24-hour concentrations in excess of the World Bank Standard are predicted to occur at or in very close proximity to the site boundary. Such impacts are therefore not representative of the level of exposure that would be experienced at air quality sensitive receptor sites.

Predicted short-term impacts on local ambient levels of SO_2 and PM_{10} would result in concentrations that are well within respective World Bank Standards and WHO Guideline values.

The WHO hourly standard value for NO_2 was not achieved at any of the selected receptors with the chosen stack height of 20 m. However, WHO ambient air quality guidelines are not mandatory.

Overall the impact of the plant emissions will be less than predicted as the values are based on an assumed operating condition of 9 engines (as oppose to 4 turbines originally proposed) running continuously at maximum load. In practice the emissions from the plant would be less than the value modelled and the impact on local air quality will be smaller than discussed above. This is also the case in terms of the predicted maximum 1-hour concentrations of NO_2, it is possible that the plant would not be operating at maximum load during the periods of adverse meteorological conditions when such impacts could occur.

Predicted Short-term Impacts – Diesel Backup Fuel

The maximum predicted short-term impacts associated with burning diesel as a back-up fuel are presented in Tables 5.3.14 to 5.3.16.

Table 5.3.14: Dispersion Modelling Results, Diesel, NO_2 (Revised)

Receptor	1-hour average (μg/m³)			24-hour average (μg/m³)		
	2003	2004	2005	2003	2004	2005
R1	441.8	432.5	433.1	41.6	32.0	34.7
R2	429.2	423.5	426.8	46.8	27.4	34.8
R3	431.8	431.4	435.4	51.0	26.5	30.5
R4	409.0	412.9	419.3	44.9	28.9	30.5
R5	405.3	411.6	415.2	42.7	34.0	42.4
R6	399.3	429.6	426.1	53.0	45.5	44.0
R7	416.0	430.0	431.0	63.3	48.1	45.0
R8	437.0	429.3	431.8	83.1	53.0	43.3
R9	432.5	442.0	433.6	51.1	46.3	36.8
R10	438.6	447.4	444.1	48.2	48.7	32.5
WB Standard (μg/m³)	-			**150**		
WHO Standard (μg/m³)	200			-		

Table 5.3.15: Dispersion Modelling Results, Diesel, SO_2 (Revised)						
Receptor	10-minute average (μg/m³)*			24-hour average (μg/m³)		
	2003	2004	2005	2003	2004	2005
R1	410.7	374.4	376.5	19.3	17.7	17.9
R2	361.2	339.0	352.0	17.5	16.2	16.5
R3	371.4	370.1	385.7	29.7	17.3	18.5
R4	282.0	297.6	322.7	14.1	14.4	15.5
R5	267.8	292.6	306.5	13.2	14.1	14.8
R6	244.4	362.7	349.2	15.4	17.8	18.6
R7	309.6	364.4	368.5	21.7	20.6	21.4
R8	392.0	361.7	371.4	33.8	26.9	20.0
R9	374.3	411.7	378.5	28.0	24.6	18.0
R10	398.2	432.6	419.7	19.8	32.3	19.6
WB Standard (μg/m³)	-			**150**		
WHO Standard (μg/m³)	500			125		

**Derived from 1-hour averages, correction factor of 1.3 applied.*

Table 5.3.16: Dispersion Modelling Results, Diesel, PM_{10} (revised)			
Receptor	24-hour average (μg/m³)		
	2003	2004	2005
R1	1.9	1.7	1.7
R2	1.7	1.6	1.6
R3	3.0	1.7	1.8
R4	1.3	1.4	1.5
R5	1.2	1.3	1.4
R6	1.5	1.7	1.8
R7	2.1	2.0	2.1
R8	3.4	2.7	2.0
R9	2.8	2.4	1.7
R10	1.9	3.3	1.9
WB Standard (μg/m³)	**150**		
WHO Guideline (μg/m³)	-		

The magnitude of short-term impacts in the area around selected receptors has been determined with the plant running on diesel fuel. The maximum predicted impacts do not exceed the World Bank limit criteria for concentrations of SO_2 or PM_{10} at any selected receptor. The World Bank PM_{10} standard is met by a very large margin.

Maximum 10-minute impact values for SO_2 were predicted to be between 243 $\mu g/m^3$ and 418 $\mu g/m^3$, or between 49% and 84% of the WHO guidance concentration. Maximum 24-hour concentrations are within the World Bank and WHO guidance values. The impact ranges by between 12 $\mu g/m^3$ and 32 $\mu g/m^3$, or between 8% and 21% of the World Bank standard.

Maximum 1-hour average impact values for NO_2 were predicted to be higher than the WHO guidance value at all selected receptors with the chosen stack height of 20 m, however the WHO guidance value is not mandatory. The predicted 24-hr average impact concentrations are between 26 $\mu g/m^3$ and 82 $\mu g/m^3$, or between 17% and 55% of the World Bank standard.

5.3.3 Mitigation Measures

Dust Generation

Fugitive emissions of dust during the construction phase would be minimised and controlled by the implementation of an Environmental Management Plan for the project (see Section 7). Mitigation measures to reduce construction dust emissions could include:

- Wherever possible materials arising from site earthworks will be stored and used within the redevelopment of the site. This will reduce the number of off-site vehicle movements required.

- Site roads and the site access route will be inspected, swept and sprayed with water as required to prevent dust causing a nuisance off site. An appropriate site speed limit will reduce dust generation from vehicles travelling over unmade surfaces.

- No mitigation measures will be required to control emissions from on site vehicles beyond accepted good practice. For example, maintaining vehicles in good working order, parking vehicles away from sensitive receptors and not running engines for longer than is necessary.

- All plant and stockpiles will be thoughtfully located, so as to minimise impacts on sensitive receptors. Where practicable to do so, storage areas should be located at least 50 m from sensitive receptors. Surplus excavation materials from the transmission line route will be moved if necessary to designated areas, away from sensitive receptors.

- The unnecessary handling of dusty materials will be avoided. During the processing of dusty materials, methods to mitigate the generation of dust emissions will be employed, such as minimising drop heights and dampening materials and surfaces with water.

- The area cleared for construction activities will be kept to a minimum, retaining ground cover where possible, including a screen of vegetation and mature trees between the power plant site and the main road and residential housing.

- Completed earthworks will be landscaped and vegetated or covered with hard standing as soon as practicable.

- A record will be kept of complaints received and actions taken.

Power Plant Emissions

No specific measures are employed to limit stack emissions.

5.3.4 Evaluation of Mitigated Impact

Dust Generation

Construction

The potential magnitude of dust impacts without mitigation is not considered within this assessment, as standard mitigation techniques for the control of dust emissions, including those identified in Section 5.3.3 above, will be included in the EMP for the project.

Construction dust can only have a significant impact on sensitive receptors if it is located in fairly close proximity to the activity. The potential for dust to be transferred off site, to affect PM_{10} levels or cause a perceptible increase in soiling rates, is likely to be limited to around 100 m from a construction process such as this, which involves considerable earthworks.

There is a distance of around 410 m between the nearest residential properties and the power plant boundary. As such, the impact of dust emissions due to construction activities occurring on the power plant site would be insignificant. Earthworks associated with the installation of the access road could potentially cause a perceptible increase in surface soiling rates and PM_{10} levels at residential housing close to the access road entrance. Such impacts would be short term and minor adverse in significance.

An area of approximately 3.5 ha, between the proposed power plant site and the main road, would be cleared and used as a construction compound. The storage of loose, dusty materials and the movement of construction vehicles within this area could result in emissions of fugitive dust across the site boundary affecting the closest residential properties. The impact of such emissions would be short term and minor adverse in significance

The incorporation of effective site management procedures and mitigation measures to control dust would ensure that the impact of construction works on nearby sensitive receptors would be minimised. Episodes of enhanced dust deposition should be restricted to periods of unusually dry and windy weather, during which background levels of dust would also become elevated.

The construction of the transmission line occurs over a short time period with each section taking two to three weeks to complete. Dust impacts at residential properties, where they occur, would be short term and minor adverse in significance.

A small proportion of the dust generated by construction activities will be PM_{10}. Under normal meteorological conditions, receptors located more than 50 m from the emission source are unlikely to experience a perceptible increase in PM_{10} concentrations. It is therefore unlikely that a measurable change in PM_{10} concentrations will be observed during the construction of the power plant. The impact of PM_{10} emissions on sensitive receptors during the construction of the site access road and the transmission line would be adverse short term in nature and minor in significance.

Power Plant Emissions

The principal control on operational emissions from the plant is in the form of stacks, of sufficient height to facilitate adequate dispersion of the exhaust plume before the pollutants reach ground level. The assessment has been based on the assumption that all nine stacks would be 20 m high and it has been confirmed that stacks of this height provide a level of protection at local air quality sensitive receptors sufficient to achieve World Bank criteria.

The sensitivity analysis also considered the impact associated with the use of higher stacks of 22.5 m, 25 m, 27.5 m and 30 m. The additional height resulted in a progressive improvement in the magnitude of impacts on ground level (z = 1 m) concentrations of NO_2. A shorter stack is not considered appropriate due to the height of the surrounding forest, as it would be likely to impair the dispersion of the emissions from the plant. An assessment of the height of the surrounding vegetation will however be undertaken to ensure the final stack height is above the upper forest canopy to ensure adequate dispersion.

Overall the impact from the operation of the plant on air quality would be adverse, long term, and minor in significance, with emissions discharged from an appropriate stack height.

5.3.5 Evaluation of Alternative Development Options

The zero (no project) option would remove the potentially negative impacts that may arise from the construction and operation of the project.

An alternative scenario has been considered within the main body of the original ESIA report. The alternative considered the impacts on air quality due to the use of gas turbines instead of the gas engines. This alternative would require four units in the place of the 9 units considered within this Addendum to provide the necessary output, and gas turbines produce lower NO_x emissions than engines. Impacts of this alternative are therefore predicted to be lower than for this case.

5.3.6 Conclusions

The overall conclusion from this Addendum assessment is that the construction and operation of the Kribi Power Plant will not result in impacts on the air quality of the project area with the potential to result in the exceedence of World Bank Air Quality Guideline Values.

During the construction phase dust generation, particularly at the construction site compound, has the potential to cause dust impacts at adjacent properties however simple and effective control measure for containing dust generation are available. In addition this will be a short-term impact.

During normal operation on natural gas fuel the engine emissions result in ground level pollutant concentrations below the guidelines values set by the World Bank.

During running on diesel, emissions will be higher however this operation is for very short-term period up to a maximum of approximately 8 days per year at 30% load. Short-term impacts from this temporary operation are still predicted to meet World Bank guideline criteria.

A summary of the impact evaluation is presented in Table 5.3.17.

Table 5.3.17: Summary of Impact Evaluation – Air Quality

Project Location	Phase[2]	Impact	Nature of Impact	Receptor	Nature[1]	Duration[1]	Significance[1]
Plant site	C	Dust nuisance / heath risk	Dust rise from on site activity	Local population	Adverse	Short-term	Minor
	O	Reduced local air quality	Emissions from power plant (gas)	Local population	Adverse	Long-term	Minor
	O	Reduced local air quality	Emissions from power plant (Diesel)	Local population	Adverse	Short-term	Minor
	C	Reduced local air quality	Vehicle exhaust emissions	Local population	Adverse	Short-term	Insignificant
	C	Dust nuisance / heath risk	Dust rise from on site activity	Local population	Adverse	Short-term	Minor
Transmission line	C	Reduced local air quality	Vehicle exhaust emissions	Local population	Adverse	short-term	Insignificant