Revised Monitoring Plan

Project Activity: **Lihir Geothermal Power Project**
Project Reference Number: **0279**
Date: **04/05/2010**

SECTION D. Application of a monitoring methodology and plan

D.1. Name and reference of approved monitoring methodology applied to the project activity:

Approved consolidated monitoring methodology ACM0002, *"Consolidated monitoring methodology for zero-emissions grid-connected electricity generation from renewable sources"* has been selected as the appropriate monitoring methodology for this project.

D.2. Justification of the choice of the methodology and why it is applicable to the project activity:

The LGPP meets the applicability criteria as outlined in the consolidated monitoring methodology ACM0002 (and which are in line with the applicability criteria of the consolidated baseline methodology ACM0002). Specifically, electricity generation from the LGPP will be monitored and data on the fugitive carbon dioxide and methane emissions from geothermal steam, and carbon dioxide emissions from the combustion of fossil fuels required to operate the LGPP will be calculated.

The project will monitor its net electricity production from the project activity using on site metering equipment at the substation (interconnection facility connecting the LGPP to the grid). The meter reading records will be made accessible to the auditors, and calibration tests records will be maintained.

As mentioned in Section B4, LGL (Lihir Gold Ltd) may have to drill additional holes to source additional steam for the LGPP. In that case the non-condensable gases in the steam coming from these additional wells will have to be counted as project emissions. For this reason LGPP will also monitor the amount of steam consumed by the LGPP, the drilling of new wells specifically for the LGPP, the amount of steam coming from these wells, and the quantity of greenhouse gases in the steam. Section D2.2 specifies how this monitoring will be conducted.

D.2. 1. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario

D.2.1.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment
1. Wi	Well	LGL	Number of wells	M	daily	100%	Electronic	Only condensable gases will be monitored from steam from wells specifically drilled for the LGPP (see note 3)
2. MS, y	Quantity of steam produced during year y	LGL	t	M	daily	100%	Electronic	See note 1
3. $w_{Main,CO2}$	Fraction of CO_2 in produced steam	LGL	tCO_2 / t steam	M	Every 4 months	100%	Electronic	See note 2
4. $w_{Main,CH4}$	Fraction of CH_4 in produced steam	LGL	tCH_4 / t steam	M	Every 4 months	100%	Electronic	See note 2
5. Ei,	24 hour average generation, turbine i	LGL	MW	M	Continuous	100%	Electronic	See note 1
6. MS i, y	Quantity of steam produced from well i during year	LGL	t	C	daily	100%	Electronic	See note 2,3

	y							
7. $w_{i,CO2}$	Fraction of CO_2 in produced steam from well i	LGL	tCO_2 / t steam	M	Every 4 months	100%	Electronic	See note 2, 3
8. $w_{i,CH4}$	Fraction of CH_4 in produced steam from well i	LGL	tCH_4 / t steam	M	Every 4 months	100%	Electronic	See note 2, 3
9. %Flow	Percentage of total flow (Ms,y) attributable to well i	LGL	%	C	Monthly	100%	Electronic	See note 3
10. $F_{i,y}$	Amount of fossil fuels used for the operation of the geothermal plant	LGL	Mass or volume	M	Monthly	100%	Electronic	
11. $COEF_i$	CO_2 emission coefficients of fossil fuel types I used for the operation of the geothermal plant	LGL	tCO_2 / mass or volume unit	M	As required	100%	Electronic	IPCC Default value used

The following specific notes apply to the table.

Note 1: Steam flow rate, power plant

The total steam flow to the LGPP will be measured with a venturi flow meter (or other equipment with at least the same accuracy). Measurement of temperature and pressure upstream of the venturi meter will define the steam properties. The calculation of steam quantities will be conducted on a continuous basis and based on international standards. The measurement results will be summarized transparently in regular production reports.

Emergency Procedures
In the event that the venturi flow meters fail, the metered power generation data (24hour average for each turbine), ejector steam flow and turbine performance curves are used to determine the total steam flow to the LGPP until the meters can be repaired or replaced. The performance curves are obtained from the turbine manufacturer and are based on turbine performance testing. Ejector steam flow is a constant value based on flow rates recorded during the full load performance testing, which is a conservative value representative of the maximum flow that would be seen through the ejectors.
The daily 24hour average generation in MW is obtained by summing the daily 24hour average generation of each turbine (Ei). In order to be conservative, the maximum daily 24 hour average generation for each suitable day in the month is selected as being the daily generation for each day in that month. The corresponding steam flow rate is obtained from the performance curve, and this value is used as the steam flow for each day in that month. Selecting the maximum generation for the month ensures that the steam consumption is conservative and results in an overestimation of the amount of steam consumed.

A suitable day is defined as a day where there is stable generation over the 24 hour period with the vent valves closed at the end of the 24 hour period (as indicated in the Power Station Daily Report) and wellhead valves in the same state as the previous day. Where one or more vent valves are open on the maximum generation day, additional steam (based on the maximum capacity of each vent valve and number of valves open) is added to the calculated turbine steam consumption and applied for the entire month. Where there are no stable 24 hour generation periods (minimum and maximum within 10% of the daily average) for the month, the total steam flow is based on the total capacity with all five vent valves fully open for the month. This ensures the most conservative approach is always taken based on reliable data.

The emergency procedures will only be utilized for a maximum period of 15 days following each individual venturi flow meter (or other equipment with at least the same accuracy) failure event. In the event that the venturi flow meters (or other equipment with at least the same accuracy) cannot be repaired within this 15 day period a deviation from the provisions of the registered monitoring plan will be prepared and submitted to the UNFCCC Secretariat.

The 15 day period will enable LGL to repair any minor issues associated with the venturi flow meter (or other equipment with at least the same accuracy) using onsite technical staff. In the event of total failure of the venturi flow meter (or other equipment with at least the same accuracy) requiring re-design and/or re-fabrication, this is likely to take longer than 15 days and a deviation from the provisions of the registered monitoring plan will be prepared and submitted to the UNFCCC Secretariat.

Note 2: Non-condensable gases in geothermal steam
Non-condensable gases (NCGs) in geothermal reservoirs usually consist mainly of CO_2 and H_2S. They also contain a small quantity of hydrocarbons, including predominantly CH_4. In geothermal power projects, NCGs flow with the steam into the power plant. A small proportion of the CO_2 is converted to carbonate / bicarbonate in the cooling water circuit. In addition, parts of the NCGs are reinjected into the geothermal reservoir (please note that this does not

occur at Lihir due to mining operational requirements). However, as a conservative approach, this methodology assumes that all NCGs entering the power plant are discharged to atmosphere via the cooling tower. NCG sampling will be carried out in production wells and at the sampling point immediately upstream of the venturi flow meter using ASTM Standard Practice E1675 for Sampling 2 - Phase Geothermal Fluid for Purposes of Chemical Analysis (as applicable to sampling single phase steam only). The CO_2 and CH_4 sampling and analysis procedure consists of collecting NCG samples from the main steam line with glass flasks, filled with sodium hydroxide solution and additional chemicals to prevent oxidation. Hydrogen sulphide (H_2S) and carbon dioxide (CO_2) dissolve in the solvent while the residual compounds remain in their gaseous phase. The gas portion will then be analyzed using gas chromatography to determine the content of the residuals including CH_4. All alkanes concentrations will be reported in terms of methane. The NCG sampling and analysis will be performed at least every three months and more frequently, if determined necessary. Accuracy of data monitoring and collection will be in line with the ASTM Standard Practice E1675.

Note 3: Quantity of steam produced from individual wellheads

$MS_{i,y}$ is the quantity of steam produced from wellhead i. In order to calculate this parameter it is necessary to apportion the total steam consumed by the LGPP to individual wellheads. $MS_{i,y}$ is used in the calculation of project emissions, as only the emissions from steam from wellheads drilled specifically for the purpose of power generation are included.

In order to apportion the steam, the results of the Tracer Flow Tests (TFT) undertaken on individual wellheads are used to determine the percentage contribution to total flow of each of the individual well heads. The TFT results provide a steam flow rate in tonnes/hour for each well head, and this is divided by the sum of all of the well head's flow rates to give a percentage. This percentage is then multiplied by the total steam flow rate ($MS_{,y}$), to determine a flow rate for each well[1].

Testing is undertaken by independent, suitably qualified personnel, in accordance with standard ASTM E1675 – Sampling Two Phase Geothermal Fluid for Purpose of Chemical Analysis. This is the testing standard also used for determining non condensable gases (NCG) in the steam. Samples are analysed offsite by an accredited laboratory and the tests conducted are performed in accordance with its terms of accreditation.

All archived data will be kept until two years after the last issuance of CERs for this project. The electricity generated by the LGPP will be measured with energy meters with an accuracy of within 1%. The Utilities Superintendent of LGL will be responsible for the monitoring and storing of this data. Data will be archived in LGL's existing information storage system on a monthly basis.

D.2.1.2. Description of formulae used to estimate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

[1] As geothermal wells discharge two phase fluid it is not practical to install continuous flow metering on individual lines.

Formulae used to estimate the project emissions for the project activity are as outlined in Section B2 of the PDD.

In addition, the following formulas will be applied to determine the quantity of steam produced from individual well heads that are included in the calculation of project emissions:

$M_{S,y\ (project\ emissions)} = \sum M_{S,y,\ i}$

Where $M_{S,y,i} = \%flow_{,i} \times M_{S,y}$

and

$M_{S,y}$ is the total quantity of steam produced during the year *y*

$M_{S,y\ (project\ emissions)}$ is the quantity of steam counted towards project emissions during the year y

$M_{S,y,\ i}$ is the quantity of steam produced from well i during the year y

$\%flow_{,i}$ is the percentage of total flow (Ms,y) attributable to well i

$w_{i,CO2}$ and $w_{i,CH4}$ for each well head steam are obtained from the sampling done at the respective well heads (see Note 2).

Note 4:

If during future monitoring periods the steam for the LGPP will be supplied only by wells drilled specifically for power generation there will be no requirement to apportion the steam. In this circumstance:

$M_{S,y\ (project\ emissions)} = M_{S,y}$

$w_{i,CO2}$ and $w_{i,CH4}$ are also not required, and $w_{Main,CO2}$ and $w_{Main,CH4}$ are taken from the sampling point immediately upstream of the venturi flow meter (see Note 2).

D.2.1.3. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHGs within the project boundary and how such data will be collected and archived :

ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment
12. EGy, power plant	Electricity supplied to the grid by the project	LGL	MWh	M	Continuous	100%	Electronic	Results can be cross checked with sales receipts of power consumption data

The baseline emission factor (EF) remains fixed for the entire single, fixed crediting period of 10 years. As such, the only data variable related to the baseline emission that requires monitoring is the quantity of electricity supplied to the grid by the project.

D.2.1.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

Formulae used to estimate the baseline emissions for the project activity is as below:

BEy = .EGy * EF

Where:
BEy : Baseline emissions (tCO_2e)
EGy : Electricity supplied to the grid by the project (MWh)
EF : Baseline emission factor (tCO_2e/MWh)

Baselines emission factor was fixed ex-ante as 0.678 tCO_2e/MWh and will remain fixed for the entire crediting period

D. 2.2. Option 2: Direct monitoring of emission reductions from the project activity (values should be consistent with those in section E).

Not applicable

D.2.2.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:								
ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

D.2.1.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

D.2.2.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

D.2.3. Treatment of leakage in the monitoring plan D.2.3.1. If applicable, please describe the data and information that will be collected in order to monitor leakage effects of the project activity								
ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

Not applicable, since leakage is determined as negligible, and does not have to be considered, according to ACM0002

D.2.3.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

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D.2.4. Description of formulae used to estimate emission reductions for the project activity (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

Formulae used to estimate the emission reductions for the project activity are as outlined in section B.2 of the PDD.

D.3. Quality control (QC) and quality assurance (QA) procedures are being undertaken for data monitored		
Data *(Indicate table and ID number e.g. 3.-1.; 3.2.)*	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
Table D.2.1.3: 10	Low	QA/QC procedures are planned for these data as these data will be directly used for calculation of emission reductions. Sales record to the grid and other records are used to ensure the consistency.
Others	Low	QA/QC procedures are planned for these data as these data as default data (for emission factors) are used to check the local data.

D.4 Please describe the operational and management structure that the project operator will implement in order to monitor emission reductions and any leakage effects, generated by the project activity

LGL propose to appoint a CDM Monitoring Officer within the External Affairs and Sustainability Development department to monitor emission reductions. As identified previously no significant sources of leakage are expected.

D.5 Name of person/entity determining the monitoring methodology:

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Annex 4 – Monitoring Plan

This plan aims to monitor on a regular basis the GHG emissions of the Lihir Geothermal Power Project from non-condensable gases and the power displaced from the Lihir electricity grid. Five main activities are to be performed within the monitoring process:

1. Calibration and maintenance of monitoring of equipment and instruments
2. Gathering of data from steam wells and power generation
3. Calculation of GHG emission reductions
4. Management and storage of data
5. Supervision of the quality of the monitoring process
6. Issuance of reports for internal and external verification

LMC propose to appoint a CDM Monitoring Officer within its Department for External Affairs and Sustainability Development who will be responsible for monitoring emission reductions.

Annex 4. Monitoring Procedures								
	Activity		Sub-Activity	Responsible		Periodicity	Performance Indicator	Report
1	Calibration and maintenance of monitoring of equipment and instruments	A	Calibrate sampling equipment and instruments (including sampling equipment and instruments used in the tracer flow tests)	Manufacturer of equipment/ External Affairs and Sustainable Development department	Manufacturer of equipment/CDM Monitoring Officer	Every 12 months	Sampling will be conducted in accordance with ASTM E1675-83: Standard Practice for Sampling Two Phase Geothermal Fluid for the Purposes of Chemical Analysis at the frequency specified	LGP-CM-01
		B	Calibrate and maintain laboratory equipment and instruments (including laboratory equipment and instruments used in the tracer flow tests)	Manufacturer of equipment/ External Affairs and Sustainable Development department	Manufacturer of equipment/CDM Monitoring Officer	In accordance with guidelines specified by the National Association of Testing Authorities, Australia (NATA), or equivalent	Sampling will be conducted in accordance with AS ISO/IEC 17025-2005: General requirements for the competence of testing and calibration laboratories at the frequency specified	LGP-CM-01
		C	Calibration and Maintenance of electricity meter	Manufacturer of equipment/ External Affairs and Sustainable Development department	Manufacturer of equipment/CDM Monitoring Officer	In accordance with the manufacturers recommendations	LMC will ensure that a manufacturer's test certificate accompanies all purchased meters. Meters will be recalibrated in accordance with IEC standards	Manufacturers test certificates
2	Gathering of data from steam wells and power generation	A	Sampling steam from wells used by the project activity	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every three months	Sampling will be conducted in accordance with ASTM E1675-83: Standard Practice for Sampling Two Phase Geothermal Fluid for the Purposes of Chemical Analysis at the frequency specified	LGP -GD-01
		B	Analyse CO2 content of the steam	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every three months	Sampling will be conducted in accordance with ASTM E947-83: Standard Specification for Sampling Single Phase Geothermal Liquid or Steam for Purposes of Chemical Analysis at the frequency specified	

		C	Analyse CH4 content of the steam	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every three months	Sampling will be conducted in accordance with ASTM E947-83: Standard Specification for Sampling Single Phase Geothermal Liquid or Steam for Purposes of Chemical Analysis at the frequency specified	
		D	Report the findings of the chemical analysis	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months	Table D.2.1.1. on PDD	
		E	Read electricity generation data from meter	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Table D.2.1.1. on PDD	LGP -GD-02
		F	Measure the steam flow	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Table D.2.1.1. on PDD	
		G	Report the data from the readings and measure	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Table D.2.1.1. on PDD	
3	Calculation of GHG emission reductions	A	Calculate the project activity emissions from CO2 and CH4 emissions from NCG discharged to the atmosphere due to the project activity	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Sections D.2.1.2 and B.2 on PDD	-
		B	Calculate the CO2 and CH4 emissions offset from the grid	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Section D.2.4	-
		C	Calculate the CO2 and CH4 emission reductions	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Section D.2.4	

4	Management and storage of data	A	Archive data from steam wells	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months	Table D.2.1.1 and section D.4 on PDD	-
		B	Archive data from steam wells and power generation	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Table D.2.1.1 and section D.4 on PDD	-
		C	Manage the data and information	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	Sections D.2.1 and D.4 on PDD	-
		D	Storage the data and information	External Affairs and Sustainable Development department	CDM Monitoring Officer	daily	The data and information should be storage two years after the crediting period has finished	-
5	Supervision of the quality of the monitoring process	A	Review all reports are being performed as mentioned in this plan	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months	Monitoring plan and Section D.3 on PDD	LGP -SMP-01
		B	Interview the monitoring personnel	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months		
		C	Performance evaluation of monitoring personnel	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months	Monitoring plan procedures and reports	
		D	Issue a evaluation report of the monitoring process	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months	Send the report on time to all clients	

		E	Assure the periodical training of personnel within the External Affairs and Sustainability Development department	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every six months	All personnel involved in the monitoring process is capable or performing their appointed tasks according with the "performance indicators" mentioned in this plan	LGP -SMP-02
6	Issuance of reports for internal and external verification	A	Produce a Monitoring Management report summarising the reports mentioned above	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every six months	Send the report on time to all clients	LGP -MM-01
		B	Produce a report of the GHG emission reductions	External Affairs and Sustainable Development department	CDM Monitoring Officer	Every four months	Send the report on time to all clients and according with section D on the PDD	LGP -GHG-01

Annex 4. List of Monitoring Reports				
Code	Name	Content	Issuer	Receiver
LGP -CM-01	Instruments and Equipments Calibration and Maintenance Report	List of equipments and instruments used in the sampling and laboratory chemical analysis which have been calibrated and maintained, mentioning the applicable international standards	CDM Monitoring Officer	General Manager Operations
LGP -GD-01	Non Condensable Gases (NCG) Sampling and Data Analysis Report	Description of sampling and data analysis process, including any problem faced an its solution.	CDM Monitoring Officer	General Manager Operations
		Present the result of the analysis in terms of the proportion of NCG found in the samples	CDM Monitoring Officer	General Manager Operations
LGP -GD-02	Power Generation Report	Electricity supplied to the grid (MWh) and daily power output (MW)	Technical Services Manager	General Manager Operations
LGP -SMP-01	Monitoring Auditing Report	Describe every anomaly found and the way the External Affairs and Sustainability Development department have proceeded to fix them.	Technical Services Manager	General Manager Operations
LGP -SMP-02	Trained Monitoring Personnel Report	Description of the training courses delivered to personnel from the Monitoring Department in the External Affairs and Sustainability Development including who attended and briefly describing the content of the course.	Technical Services Manager	General Manager Operations
		Letter certifying the sampling and laboratory staff has proper capacity to perform the samplings and analysis (the letter must be issued every year)	CDM Monitoring Officer	General Manager Operations
LGP -MM-01	Monitoring Management Report	Summarise all other reports	Technical Services Manager	General Manager Operations

LGP -GHG-01	GHG Report	Describe the GHG emissions of the project activity as well as the GHG emission reduction from the electricity displaced from the grid	Technical Services Manager	General Manager Operations